A Layout Control System for Model Railroads

Helmut Fieres December 10, 2024

Contents

CONTENTS

A   Listings test

A.1   CDC Lib

APPENDIX A. LISTINGS TEST

```
1    //------------------------------------------------------------------------------------------------------------
2    //
3    // LCS - Controller Dependent Code - Include file
4    //
5    //------------------------------------------------------------------------------------------------------------
6    // The controller dependent code layer concentrates all processor dependent code into one library. The idea
7    // is twofold. First, there needs to be a way to isolate the controller specific hardware from the LCS runtime
8    // Library as well as the extension module firmware. The Raspberry PI Pico offers a C++ SDK with a set of
9    // libraries to invoke the desired function rather than access to registers.The Pico also offers a great
10   // flexibility of pin assignment for the hardware IO functions. Second, within the hardware IO boundaries of
11   // the controller family the individual hardware pin assignment used may vary from board to board design.
12   // Nevertheless, the Extension Connector layout and basic functions available should be the same for all
13   // controllers used. For the upper software layers, the CDC library offers a structured way to describe
14   // the possible pins assignments.
15   //
16   // Note that this layer is not a generic HW abstraction. The layer is very specific to the LCS controller
17   // boards described in the book. Nevertheless, some pins can vary, depending on the board version. Currently,
18   // only the Raspberry PI Pico Board is supported.
19   //
20   //------------------------------------------------------------------------------------------------------------
21   //
22   // LCS - Controller Dependent Code - Include file
23   // Copyright (C) 2022 - 2024  Helmut Fieres
24   //
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34   // http://www.gnu.org/licenses
35   //
36   //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
37   //
38   //------------------------------------------------------------------------------------------------------------
39   #ifndef LcsCdcLib_h
40   #define LcsCdcLib_h
41
42   //------------------------------------------------------------------------------------------------------------
43   // Include files.
44   //
45   //------------------------------------------------------------------------------------------------------------
46   #include <stdio.h>
47   #include <stdint.h>
48   #include <cstring>
49
50   //------------------------------------------------------------------------------------------------------------
51   // All definitions and functions are in the CDC name space.
52   //
53   //------------------------------------------------------------------------------------------------------------
54   namespace CDC {
55
56   //------------------------------------------------------------------------------------------------------------
57   // Error status codes. The errors are used when setting up the Hal library. During operation, all routines
58   // validate the input for correctness. If they are not correct, the call is simply not performed and an
59   // error is returned.
60   //
61   // ??? clean up a little ... what is really needed ?
62   //------------------------------------------------------------------------------------------------------------
63   enum CdcStatus : uint8_t {
64
65       NO_ERR             = 0,
66       INIT_PENDING       = 1,
67       NOT_SUPPORTED      = 2,
68       NOT_IMPLEMENTED    = 3,
69
70       MEM_SIZE_ERR       = 10,
71
72       READY_LED_PIN_ERR  = 12,
73       ACTIVE_LED_PIN_ERR = 13,
74       BUTTON_PIN_ERR     = 14,
75       PFAIL_PIN_ERR      = 15,
76       EXT_INT_PIN_ERR    = 16,
77       DIO_PIN_ERR        = 17,
78       ADC_PIN_ERR        = 18,
79       PWM_PIN_ERR        = 19,
80
81       UART_PORT_ERR      = 20,
82       UART_CONFIG_ERR    = 21,
83       UART_WRITE_ERR     = 22,
84       UAT_READ_ERR       = 23,
85
86       SPI_PORT_ERR       = 25,
87       SPI_CONFIG_ERR     = 26,
88       SPI_WRITE_ERR      = 27,
89       SPI_READ_ERR       = 28,
90
91       I2C_PORT_ERR       = 30,
92       I2C_CONFIG_ERR     = 31,
93       I2C_WRITE_ERR      = 32,
94       I2C_READ_ERR       = 33
95
96   };
97
98   //------------------------------------------------------------------------------------------------------------
```

APPENDIX A. LISTINGS TEST

```cpp
 99   // Controller pin related definitions. A pin can be valid, undefined or illegal. An undefined pin for a pin
100   // field in the configuration structure indicates that  the pin has not been used by the firmware
101   // implementation but is a pin that the particular controller would support. An illegal pin means that the
102   // pin is not offered by this controller and cannot be assigned at all.
103   //
104   //-----------------------------------------------------------------------------------------------------------
105   const uint8_t UNDEFINED_PIN   = 255;
106   const uint8_t ILLEGAL_PIN     = 254;
107
108   //-----------------------------------------------------------------------------------------------------------
109   // The controller families. Currently, there is only the Raspberry PI Pico models.
110   //
111   //-----------------------------------------------------------------------------------------------------------
112   enum ControllerFamily : uint8_t {
113
114       CF_UNDEFINED    = 0,
115       CF_RP_PICO      = 1
116   };
117
118   //-----------------------------------------------------------------------------------------------------------
119   // DIO pin related definitions. A digital pin can be an input pin, with or without pull-up, or an output
120   // pin. DIO pins can also be associated with an interrupt handler. The handler itself is mapped to an edge
121   // or level event.
122   //
123   //-----------------------------------------------------------------------------------------------------------
124   enum dioMode : uint8_t {
125
126       IN            = 0,
127       OUT           = 1,
128       IN_PULLUP     = 2
129   };
130
131   //-----------------------------------------------------------------------------------------------------------
132   // GPIO interrupts are detected as level change or edge changes.
133   //
134   //-----------------------------------------------------------------------------------------------------------
135   enum intEventTyp : uint8_t {
136
137       EVT_NONE    = 0,
138       EVT_LOW     = 1,
139       EVT_HIGH    = 2,
140       EVT_FALL    = 3,
141       EVT_RISE    = 4,
142       EVT_CHANGE  = 5
143   };
144
145   //-----------------------------------------------------------------------------------------------------------
146   // The UART modes. There are two implementations. The PICO offers two hardware UARTS. We use them with 8
147   // bits with a parity bit. The second type UART is a software implementation based on the PICO PIO blocks.
148   //
149   //-----------------------------------------------------------------------------------------------------------
150   enum UartMode : uint8_t {
151
152       UART_MODE_UNDEFINED = 0,
153       UART_MODE_8N1       = 1,
154       UART_MODE_8N1_PIO   = 2
155   };
156
157   //-----------------------------------------------------------------------------------------------------------
158   // Callback functions signatures.
159   //
160   //-----------------------------------------------------------------------------------------------------------
161   extern "C" {
162
163       typedef void ( *TimerCallback ) ( uint32_t timerVal );
164       typedef void ( *GpioCallback ) ( uint8_t pin, uint8_t event );
165   }
166
167   //-----------------------------------------------------------------------------------------------------------
168   // CDC features a data structure that records all HW specific pins and flags. The values are set by the
169   // initialization code in a project and are validated. All modules in a project will then just use the
170   // data structure fields using the data for calls to the Hal layer. For example, an application that
171   // uses DIO_PIN_0 and DIO_PIN_1 will set the HW pin numbers of the controller / board combination used
172   // in a config data structure "cfg". A call to write a value to the DIO pin, will then just use
173   // "cfg.DIO_PIN_1" as argument in the "writeDio" call. The "writeDio" call itself will not check the
174   // value of the configured DIO pin, all it will do is to ensure that it is not UNDEFINED. Note that the
175   // structure has more pins defined that a potential controller may have. If so, these fields are set to
176   // UNDEFINED. The structure is the superset of all possible HW items to configure.
177   //
178   // In a later runtime version, we may put this structure as constant data into the non-volatile chip on
179   // the board. It will then just be read from there.
180   //
181   //-----------------------------------------------------------------------------------------------------------
182   struct CdcConfigDesc {
183
184       uint8_t   CFG_STATUS;
185
186       uint8_t   PFAIL_PIN;
187       uint8_t   EXT_INT_PIN;
188       uint8_t   READY_LED_PIN;
189       uint8_t   ACTIVE_LED_PIN;
190
191       uint8_t   DIO_PIN_0;
192       uint8_t   DIO_PIN_1;
193       uint8_t   DIO_PIN_2;
194       uint8_t   DIO_PIN_3;
195       uint8_t   DIO_PIN_4;
196       uint8_t   DIO_PIN_5;
197       uint8_t   DIO_PIN_6;
```

```
198        uint8_t    DIO_PIN_7;
199        uint8_t    DIO_PIN_8;
200        uint8_t    DIO_PIN_9;
201        uint8_t    DIO_PIN_10;
202        uint8_t    DIO_PIN_11;
203        uint8_t    DIO_PIN_12;
204        uint8_t    DIO_PIN_13;
205        uint8_t    DIO_PIN_14;
206        uint8_t    DIO_PIN_15;
207
208        uint8_t    ADC_PIN_0;
209        uint8_t    ADC_PIN_1;
210        uint8_t    ADC_PIN_2;
211        uint8_t    ADC_PIN_3;
212
213        uint8_t    PWM_PIN_0;
214        uint8_t    PWM_PIN_1;
215        uint8_t    PWM_PIN_2;
216        uint8_t    PWM_PIN_3;
217
218        // ??? do we need more for quad controller ?
219
220        uint8_t    UART_RX_PIN_0;
221        uint8_t    UART_TX_PIN_0;
222
223        uint8_t    UART_RX_PIN_1;
224        uint8_t    UART_TX_PIN_1;
225
226        uint8_t    UART_RX_PIN_2;
227        uint8_t    UART_TX_PIN_2;
228
229        uint8_t    UART_RX_PIN_3;
230        uint8_t    UART_TX_PIN_3;
231
232        uint8_t    SPI_MOSI_PIN_0;
233        uint8_t    SPI_MISO_PIN_0;
234        uint8_t    SPI_SCLK_PIN_0;
235
236        uint8_t    SPI_MOSI_PIN_1;
237        uint8_t    SPI_MISO_PIN_1;
238        uint8_t    SPI_SCLK_PIN_1;
239
240        uint8_t    NVM_I2C_SCL_PIN;
241        uint8_t    NVM_I2C_SDA_PIN;
242        uint8_t    NVM_I2C_ADR_ROOT;
243
244        uint8_t    EXT_I2C_SCL_PIN;
245        uint8_t    EXT_I2C_SDA_PIN;
246        uint8_t    EXT_I2C_ADR_ROOT;
247
248        uint32_t   NODE_NVM_SIZE;
249        uint32_t   EXT_NVM_SIZE;
250
251        uint8_t    CAN_BUS_CTRL_MODE;
252        uint8_t    CAN_BUS_RX_PIN;
253        uint8_t    CAN_BUS_TX_PIN;
254        uint32_t   CAN_BUS_DEF_ID;
255 };
256
257 //-------------------------------------------------------------------------------------------------------------
258 // The routines that make up the hardware abstraction layer. The routines expect hardware pin numbers.
259 // To recap, the CDC layer offers a set of reserved resource names, such as "DIO_PIN_0", which describes
260 // the resource containing the hardware pin and some flags. The configuration routines in this layer will use
261 // these pins and other data stored to configure the hardware. Under the defined resource name name all
262 // upper layers refer to the hardware using the to the configured IO capabilities.
263 //
264 // Complex resources, such as the UART or SPI interface, have more than one HW pin they will use. In this
265 // case one of the HW pins, see the function documentation, will serve as the handle to the resource.
266 //
267 //-------------------------------------------------------------------------------------------------------------
268
269 //-------------------------------------------------------------------------------------------------------------
270 // The console IO functions. We will provide a serial IO via the USB connector of the PICO. The files
271 // need to be linked with the "tinyUSB" library and the cmake file needs to set the option. Then we can
272 // use scanf and printf and so on. In addition, we need  function  that just attempts to read a character
273 // and returns immediately when there is none.
274 //
275 //-------------------------------------------------------------------------------------------------------------
276 uint8_t         configureConsoleIO( );
277 bool            isConsoleConnected( );
278 char            getConsoleChar( uint32_t timeoutVal = 0 );
279
280 //-------------------------------------------------------------------------------------------------------------
281 // CDC setup and configuration routines. The idea is to help the library write with a default configuration
282 // structure. All pins HW that are fixed in their location will be set. A library programmer will just get
283 // that default structure and set the values necessary for the particular case.
284 //
285 //-------------------------------------------------------------------------------------------------------------
286 CdcConfigDesc   getConfigDefault( );
287 CdcConfigDesc   *getConfigActual( );
288 void            printConfigInfo( CdcConfigDesc *ci );
289 void            setDebugLevel( uint8_t level = 0 );
290
291 uint8_t         init( CdcConfigDesc *ci );
292 void            fatalError( uint8_t n );
293 void            fatalErrorMsg( char *str, uint8_t n, uint8_t rStat );
294
295 //-------------------------------------------------------------------------------------------------------------
296 // General controller routines.
```

```
297    //
298    //-------------------------------------------------------------------------------------------------
299    uint16_t        getFamily( );
300    uint32_t        getVersion( );
301    uint32_t        getChipMemSize( );
302    uint32_t        getChipNvmSize( );
303    uint32_t        getCpuFrequency( );
304    uint32_t        getMillis( );
305    uint32_t        getMicros( );
306    void            sleepMillis( uint32_t val );
307    void            sleepMicros( uint32_t val );
308
309    //-------------------------------------------------------------------------------------------------
310    // The LCS runtime needs to build a unique ID for the node.
311    //
312    //-------------------------------------------------------------------------------------------------
313    uint32_t        createUid( );
314
315    //-------------------------------------------------------------------------------------------------
316    // Timer management routines.
317    //
318    //-------------------------------------------------------------------------------------------------
319    void            onTimerEvent( TimerCallback functionId );
320    void            startRepeatingTimer( uint32_t val );
321    void            setRepeatingTimerLimit( uint32_t val );
322    uint32_t        getRepeatingTimerLimit( );
323    void            stopRepeatingTimer( );
324
325    //-------------------------------------------------------------------------------------------------
326    // Analog input routines.
327    //
328    //-------------------------------------------------------------------------------------------------
329    uint8_t         configureAdc( uint8_t adcPin );
330    uint16_t        getAdcRefVoltage( );
331    uint16_t        getAdcDigitRange( );
332    uint16_t        readAdc( uint8_t adcPin );
333
334    //-------------------------------------------------------------------------------------------------
335    // Digital Input/Output routines.
336    //
337    //-------------------------------------------------------------------------------------------------
338    uint8_t         configureDio( uint8_t dioPin, uint8_t Mode = IN );
339    void            registerDioCallback( uint8_t dioPin, uint8_t event, CDC::GpioCallback func );
340    void            unregisterDioCallback( uint8_t dioPin );
341    bool            readDio( uint8_t dioPin );
342    uint8_t         writeDio( uint8_t dioPin, bool val );
343    uint8_t         toggleDio( uint8_t dioPin );
344    uint32_t        readDioMask( uint32_t dioMask );
345    uint8_t         writeDioMask( uint32_t dioMask, uint32_t dioVal );
346    uint8_t         writeDioPair( uint8_t dioPin1, bool val1, uint8_t dioPin2, bool val2 );
347
348    //-------------------------------------------------------------------------------------------------
349    // PWM output routines.
350    //
351    //-------------------------------------------------------------------------------------------------
352    uint8_t         configurePwm( uint8_t   pwmPin,
353                                  uint32_t  pwmFreqency,
354                                  bool      phaseCorrect  = true,
355                                  bool      inverted      = false
356                                );
357
358    uint8_t         writePwm( uint8_t pwmPin, uint8_t dutyCycle );
359
360    //-------------------------------------------------------------------------------------------------
361    // Serial IO routines.
362    //
363    //-------------------------------------------------------------------------------------------------
364    uint8_t         configureUart( uint8_t rxPin, uint8_t txPin, uint32_t baudRate, UartMode mode );
365    uint8_t         startUartRead( uint8_t rxPin );
366    uint8_t         stopUartRead( uint8_t rxPin );
367    uint8_t         getUartBuffer( uint8_t rxPin, uint8_t *buf, uint8_t bufLen );
368
369    //-------------------------------------------------------------------------------------------------
370    // I2C management routines.
371    //
372    //-------------------------------------------------------------------------------------------------
373    uint8_t         configureI2C( uint8_t sclPin, uint8_t sdaPin, uint32_t baudRate = 100 * 1000 );
374    uint8_t         i2cWrite( uint8_t sclPin, uint8_t i2cAdr, uint8_t *buf, uint16_t len, bool stopBit = false );
375    uint8_t         i2cRead( uint8_t sclPin, uint8_t i2cAdr, uint8_t *buf, uint16_t len, bool stopBit = false );
376
377    //-------------------------------------------------------------------------------------------------
378    // SPI management routines.
379    //
380    //-------------------------------------------------------------------------------------------------
381    uint8_t         configureSPI( uint8_t sclkPin, uint8_t mosiPin, uint8_t misoPin, uint32_t baudRate = 10 * 1000 * 1000 );
382    uint8_t         spiBeginTransaction( uint8_t sclkPin, uint8_t csPin );
383    uint8_t         spiEndTransaction( uint8_t sclkPin, uint8_t csPin );
384    uint8_t         spiRead( uint8_t sclkPin, uint8_t *buf, uint32_t len );
385    uint8_t         spiWrite( uint8_t sclkPin, uint8_t *buf, uint32_t len );
386
387    };
388
389    #endif
```

APPENDIX A. LISTINGS TEST

```
1   //------------------------------------------------------------------------------------------------------------
2   //
3   // LCS - Controller dependent code Layer - Raspberry PI Pico Implementation
4   //
5   //------------------------------------------------------------------------------------------------------------
6   // This source file contains the the RP2040 controller family hardware library code. The idea of this library
7   // is to shield the actual hardware of processor and board implementation from the upper layers but still keep
8   // the flexibility and performance of the underlying hardware. The library works with the concept of HW pins,
9   // which are identifiers for an HW entity. This is easy for a GPIO pin, where the mapping is directly one to
10  // one. For more complex HW entries such as the I2C or UART hardware, one pin is selected as the identifier to
11  // that entity. For each complex entity an instance variable is maintained where all the relevant data is kept.
12  //
13  // A historic note. The original LCS code was written for Atmega and Pico. With the complete shift to PICO,
14  // the CDC library just serves as a simple interface to the PICO functions. One day, we may see more different
15  // controllers and controller families. The idea is that the LCS runtime is shielded from them.
16  //
17  //------------------------------------------------------------------------------------------------------------
18  //
19  // LCS - Controller Dependent Code - Raspberry PI Pico Implementation
20  // Copyright (C) 2022 - 2024 Helmut Fieres
21  //
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31  // http://www.gnu.org/licenses
32  //
33  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
34  //
35  //------------------------------------------------------------------------------------------------------------
36  #include <stdio.h>
37  #include <stdint.h>
38  #include <inttypes.h>
39
40  #include "pico/stdlib.h"
41  #include "pico/stdio.h"
42  #include "tusb_config.h"
43  #include "hardware/regs/usb.h"
44  #include "hardware/regs/rosc.h"
45  #include "hardware/regs/addressmap.h"
46  #include "hardware/clocks.h"
47  #include "hardware/gpio.h"
48  #include "hardware/adc.h"
49  #include "hardware/pwm.h"
50  #include "hardware/uart.h"
51  #include "hardware/i2c.h"
52  #include "hardware/spi.h"
53
54  #include "LcsCdcLib.h"
55
56  //------------------------------------------------------------------------------------------------------------
57  // Local name space. This file has two sections. The first is this local name space with all internal
58  // variables and routines local to the file. The second part contains the exported routines to be called by
59  // the core library and the firmware designers that need access to the underlying HW portion managed by this
60  // lowest layer.
61  //
62  //------------------------------------------------------------------------------------------------------------
63  namespace {
64
65  using namespace CDC;
66
67  //------------------------------------------------------------------------------------------------------------
68  // "CDC_DEBUG" is the local define for printing debug information. In contrast to the rest of the debugging
69  // and tracing of LCS libraries and programs, this library will have to be recompiled to enable debugging.
70  //
71  //------------------------------------------------------------------------------------------------------------
72  #define CDC_DEBUG 1
73
74  //------------------------------------------------------------------------------------------------------------
75  // Debug and Trace support. Instead of conditional compilation, we will print debug messages based on the
76  // setting of the debug level.
77  //------------------------------------------------------------------------------------------------------------
78  uint8_t debugLevel = 0;
79
80  //------------------------------------------------------------------------------------------------------------
81  // The CDC Library version data.
82  //
83  //------------------------------------------------------------------------------------------------------------
84  const uint8_t CDC_LIB_MAJOR_VERSION = 1;
85  const uint8_t CDC_LIB_MINOR_VERSION = 0;
86
87  //------------------------------------------------------------------------------------------------------------
88  // Valid pin mapping for the Raspberry PI Pico board. We construct a set of bitmask for the pin numbers.
89  // Pin Numbers range from 0 to 28. The bitmasks specify wether a pin can be assigned to the hardware type
90  // purpose. During configuration of a CDC function, the pins are checked against these bitmasks. All pins
91  // can be used as GPIO pins or PWM pins. All other hardware functions are bound to dedicated pins. Note
92  // that we do not check for assigning a pin to several different hardware functions. All we check is that
93  // the pin can be used for the desired purpose. A check performed by the CDC library routines is simply
94  // done through:
95  //
96  //    if (( 1 <<  pin ) & VALID_xxx )
97  //
98  //------------------------------------------------------------------------------------------------------------
```

```
 99   const uint8_t  MAX_PIN_NUM          = 28;
100
101   const uint32_t VALID_GPIO_PINS       = 0x1FFFFFFF;
102   const uint32_t VALID_PWM_PINS        = 0x1FFFFFFF;
103   const uint32_t VALID_ADC_PINS        = ( 1 << 26 ) | ( 1 << 27 ) | ( 1 << 28 );
104
105   const uint32_t VALID_I2C_0_SDA_PINS = ( 1 << 0  ) | ( 1 << 4  ) | ( 1 << 8  ) |
106                                         ( 1 << 12 ) | ( 1 << 16 ) | ( 1 << 20 );
107   const uint32_t VALID_I2C_0_SCL_PINS = ( 1 << 1  ) | ( 1 << 5  ) | ( 1 << 9  ) |
108                                         ( 1 << 13 ) | ( 1 << 17 ) | ( 1 << 21 );
109
110   const uint32_t VALID_I2C_1_SDA_PINS = ( 1 << 2  ) | ( 1 << 6  ) | ( 1 << 10 ) |
111                                         ( 1 << 14 ) | ( 1 << 18 ) | ( 1 << 26 );
112   const uint32_t VALID_I2C_1_SCL_PINS = ( 1 << 3  ) | ( 1 << 7  ) | ( 1 << 11 ) |
113                                         ( 1 << 15 ) | ( 1 << 19 ) | ( 1 << 27 );
114
115   const uint32_t VALID_UART_0_TX_PINS = ( 1 << 0  ) | ( 1 << 12 ) | ( 1 << 16 );
116   const uint32_t VALID_UART_0_RX_PINS = ( 1 << 1  ) | ( 1 << 13 ) | ( 1 << 17 );
117
118   const uint32_t VALID_UART_1_TX_PINS = ( 1 << 4  ) | ( 1 << 8  );
119   const uint32_t VALID_UART_1_RX_PINS = ( 1 << 5  ) | ( 1 << 9  );
120
121   const uint32_t VALID_SPI_0_SCK_PINS = ( 1 << 2  ) | ( 1 << 6  ) | ( 1 << 18 );
122   const uint32_t VALID_SPI_0_TX_PINS  = ( 1 << 3  ) | ( 1 << 7  ) | ( 1 << 19 );
123   const uint32_t VALID_SPI_0_RX_PINS  = ( 1 << 0  ) | ( 1 << 4  ) | ( 1 << 16 );
124
125   const uint32_t VALID_SPI_1_SCK_PINS = ( 1 << 10 ) | ( 1 << 14 );
126   const uint32_t VALID_SPI_1_TX_PINS  = ( 1 << 11 ) | ( 1 << 15 );
127   const uint32_t VALID_SPI_1_RX_PINS  = ( 1 << 8  ) | ( 1 << 12 );
128
129   const uint32_t VALID_I2C_0_PINS      = VALID_I2C_0_SDA_PINS | VALID_I2C_0_SCL_PINS;
130   const uint32_t VALID_I2C_1_PINS      = VALID_I2C_1_SDA_PINS | VALID_I2C_1_SCL_PINS;
131
132   const uint32_t VALID_UART_0_PINS     = VALID_UART_0_TX_PINS | VALID_UART_0_RX_PINS;
133   const uint32_t VALID_UART_1_PINS     = VALID_UART_1_TX_PINS | VALID_UART_1_RX_PINS;
134
135   const uint32_t VALID_SPI_0_PINS      = VALID_SPI_0_SCK_PINS | VALID_SPI_0_TX_PINS | VALID_SPI_0_RX_PINS;
136   const uint32_t VALID_SPI_1_PINS      = VALID_SPI_1_SCK_PINS | VALID_SPI_1_TX_PINS | VALID_SPI_1_RX_PINS;
137
138   //------------------------------------------------------------------------------------------------------
139   // Characteristics of the Raspberry Pi Pico and some key constants for the CDC library.
140   //
141   //------------------------------------------------------------------------------------------------------
142   const uint16_t CONTROLLER_FAMILY         = CDC::CF_RP_PICO;
143   const uint32_t CHIP_MEM_SIZE             = 264 * 1024;
144   const uint32_t CHIP_NVM_SIZE             = 0;
145
146   const uint16_t ADC_DIGIT_RANGE           = 1024;
147   const uint16_t ADC_REF_VOLTAGE_MILLI_VOLT = 3300;
148
149   const uint8_t  MAX_UART_BUF_SIZE         = 8;
150
151   const uint32_t I2C_FREQUENCY             = 100 * 1000;
152   const uint32_t I2C_TIME_OUT_IN_MS        = 250;
153
154   const uint32_t SPI_FREQUENCY             = 10000000L;
155
156   const uint16_t  MAX_CPU_CORE             = 2;
157   const uint16_t  MAX_INT_PIN              = 24;
158
159   //------------------------------------------------------------------------------------------------------
160   // A timer instance. We currently support inly one HW timer.
161   //
162   //------------------------------------------------------------------------------------------------------
163   struct TimerInst {
164
165       bool              configured  = false;
166       repeating_timer_t   timerData;
167
168   };
169
170   //------------------------------------------------------------------------------------------------------
171   // An ADC instance. The PICO supports up to three ADC inputs. When we use such an input, the corresponding
172   // instance data is kept in this structure. We also keep the PICO ADC number, so we can select the correct
173   // instance.
174   //
175   //------------------------------------------------------------------------------------------------------
176   struct AdcInst {
177
178       bool      configured  = false;
179       uint8_t   adcPin      = CDC::UNDEFINED_PIN;
180       uint8_t   adcNum      = 0;
181   };
182
183   //------------------------------------------------------------------------------------------------------
184   // A PWM output instance. GPIO pins can also be used as PWM output pins. The PWM output related data is
185   // kept in this instance.
186   //
187   //------------------------------------------------------------------------------------------------------
188   struct PwmInst {
189
190       bool      configured  = false;
191       uint8_t   pwmPin      = CDC::UNDEFINED_PIN;
192       uint32_t  wrap        = 0;
193
194       // ??? what else to keep around ?
195   };
196
197   //------------------------------------------------------------------------------------------------------
```

```cpp
198    // A UART instance. UARTS are used to read in a serial stream from the RailCom detectors. There can be two
199    // hardware based UART instances, or up to four software defined instances. The instance also keeps a small
200    // buffer where the data is read into. We also keep the PICO UART HW instance used.
201    //
202    //-------------------------------------------------------------------------------------------------------------------
203    struct UartInst {
204
205        bool               configured    = false;
206        uint8_t            rxPin         = CDC::UNDEFINED_PIN;
207        uint8_t            txPin         = CDC::UNDEFINED_PIN;
208        uint16_t           baudSetting   = 0;
209        uint8_t            dataBits      = 8;
210        uart_parity_t      parityMode    = UART_PARITY_NONE;
211        uint8_t            stopBits      = 1;
212        int                uartIrq       = 0;
213        uint8_t            uartMode      = 0;
214
215        volatile uint8_t   rxBufIndex    = 0;
216        volatile uint8_t   rxDataBuf[ MAX_UART_BUF_SIZE ] = { 0 };
217
218        uart_inst_t        *uartHw       = nullptr;
219    };
220
221    //-------------------------------------------------------------------------------------------------------------------
222    // The I2C instance. The PICO features two HW instances of an I2C port. The instance data contains the
223    // assigned GPIO pins, the baud rate and a timeout. We also keep the I2C HW instance used.
224    //
225    //-------------------------------------------------------------------------------------------------------------------
226    struct I2CInst {
227
228        bool        configured   = false;
229        uint8_t     sclPin       = CDC::UNDEFINED_PIN;
230        uint8_t     sdaPin       = CDC::UNDEFINED_PIN;
231        uint32_t    baudRate     = I2C_FREQUENCY;
232        uint32_t    timeoutValMs = I2C_TIME_OUT_IN_MS;
233
234        i2c_inst_t  *i2cHw       = nullptr;
235    };
236
237    //-------------------------------------------------------------------------------------------------------------------
238    // The SPI instance. The PICO features two SPI HW instances. We keep the assigned GPIO pins for the SPI
239    // interface as well as the PICO HW instance. Since the SPI protocol explicitly sets the selected HW select
240    // pin, we remember that we are in a transaction with perhaps more than one call to the SPI routines.
241    //
242    //-------------------------------------------------------------------------------------------------------------------
243    struct SPIInst {
244
245        bool        configured  = false;
246        bool        active      = false;
247        uint8_t     selectPin   = CDC::UNDEFINED_PIN;
248        uint8_t     mosiPin     = CDC::UNDEFINED_PIN;
249        uint8_t     misoPin     = CDC::UNDEFINED_PIN;
250        uint8_t     sclkPin     = CDC::UNDEFINED_PIN;
251        uint32_t    frequency   = SPI_FREQUENCY;
252
253        spi_inst_t  *spiHw       = nullptr;
254    };
255
256    //-------------------------------------------------------------------------------------------------------------------
257    // The interrupt table for the GPIO pin interrupts. The PICO can have only one interrupt handler. We will
258    // allocate a table where a handler can be set for each pin. When an interrupt comes in and there is a
259    // handler configured, it will be called.
260    //
261    //-------------------------------------------------------------------------------------------------------------------
262    struct GpioIsrTable {
263
264        uint16_t               numOfHandlers = 0;
265        CDC::GpioCallback      gpioIsrTable[ MAX_CPU_CORE ][ MAX_INT_PIN + 1 ];
266    };
267
268    //-------------------------------------------------------------------------------------------------------------------
269    // Local variables. We maintain an instance variable for each of the possible HW entities, such as an I2C
270    // interface or a UART. Note that not all are used at the same time. The instance variables map from the
271    // simple pin numbers to the PICO structures and whatever else we need to remember for this entity.
272    //
273    //-------------------------------------------------------------------------------------------------------------------
274    CDC::CdcConfigDesc         cfg;
275    CDC::TimerCallback         timerCallback = nullptr;
276    GpioIsrTable               cdcIntHandlers;
277    repeating_timer_t          timerData;
278    AdcInst                    CdcAdc0;
279    AdcInst                    CdcAdc1;
280    AdcInst                    CdcAdc2;
281    AdcInst                    CdcAdc3;
282    I2CInst                    CdcI2C0;
283    I2CInst                    CdcI2C1;
284    SPIInst                    CdcSPI0;
285    SPIInst                    CdcSPI1;
286    UartInst                   CdcUart0;
287    UartInst                   CdcUart1;
288    UartInst                   CdcUart2;
289    UartInst                   CdcUart3;
290    PwmInst                    CdcPwm0;
291    PwmInst                    CdcPwm1;
292    PwmInst                    CdcPwm2;
293    PwmInst                    CdcPwm3;
294
295    //-------------------------------------------------------------------------------------------------------------------
296    // "validPin" is called to check that a pin is in the correct number range, defined and matches the bitmask
```

```
297   // for the desired purpose. For example, configuring an I2C port will check that the two GPIO pins are
298   // indeed routable to the I2C HW block in the PICO.
299   //
300   //-------------------------------------------------------------------------------------------------------------
301   bool validPin( uint8_t pin, uint32_t mask ) {
302
303       if ( pin == CDC::UNDEFINED_PIN )  return ( true );
304       if ( pin > MAX_PIN_NUM )          return ( false );
305       return (( 1 << pin ) & mask );
306   }
307
308   //-------------------------------------------------------------------------------------------------------------
309   // When no interrupt is configured for a GPIO pin, we set the table entry to a dummy handler. This way
310   // we do not have to check for a valid procedure label when we handle an interrupt.
311   //
312   //-------------------------------------------------------------------------------------------------------------
313   void dummyIsrHandler ( uint8_t pin, uint8_t event ) { }
314
315   //-------------------------------------------------------------------------------------------------------------
316   // Setup the ISR table. The PICO can have only one interrupt handler. When you want a handler per GPIO pin,
317   // the solution is to have a table when you keep the handler on a per pin base.
318   //
319   //-------------------------------------------------------------------------------------------------------------
320   void initIsrTable( ) {
321
322       for ( uint16_t i = 0; i < MAX_CPU_CORE; i++ ) {
323
324           for ( uint16_t j = 0; j < MAX_INT_PIN; j++ ) {
325
326               cdcIntHandlers.gpioIsrTable[ i ][ j ] = dummyIsrHandler;
327           }
328       }
329   }
330
331   //-------------------------------------------------------------------------------------------------------------
332   // The PICO uses a set of constants to describe the interrupt type. We map our interrupt types to the PICO
333   // GPIO_IRQ_xxx types.
334   //
335   //-------------------------------------------------------------------------------------------------------------
336   uint32_t mapGpioIntEvent( uint8_t event ) {
337
338       switch ( event ) {
339
340           case CDC::EVT_LOW:     return( GPIO_IRQ_LEVEL_LOW );
341           case CDC::EVT_HIGH:    return( GPIO_IRQ_LEVEL_HIGH );
342           case CDC::EVT_FALL:    return( GPIO_IRQ_EDGE_FALL );
343           case CDC::EVT_RISE:    return( GPIO_IRQ_EDGE_RISE );
344           case CDC::EVT_CHANGE:  return( GPIO_IRQ_EDGE_RISE | GPIO_IRQ_EDGE_FALL );
345           default:      return( 0 );
346       }
347   }
348
349   //-------------------------------------------------------------------------------------------------------------
350   // The PICO uses a set of constants to describe the interrupt type. We map them to our types.
351   //
352   //-------------------------------------------------------------------------------------------------------------
353   uint8_t mapPicoGpioEvent ( uint32_t event ) {
354
355       switch ( event ) {
356
357           case GPIO_IRQ_LEVEL_LOW:  return( CDC::EVT_LOW );
358           case GPIO_IRQ_LEVEL_HIGH: return( CDC::EVT_HIGH );
359           case GPIO_IRQ_EDGE_FALL:  return( CDC::EVT_FALL );
360           case GPIO_IRQ_EDGE_RISE:  return( CDC::EVT_RISE );
361           default:                  return( 0 );
362       }
363   }
364
365   //-------------------------------------------------------------------------------------------------------------
366   // Global Interrupt handlers. The hardware and low level library will call these handlers, which in turn
367   // will invoke the respective callback function if configured. The GPIO interrupt handler manages the
368   // handler for all possible IO pins. The PICO can only have one interrupt routine, so we feature an array
369   // of handlers where a handler for a GPIO pin can be registered. If there is a handler set, we just invoke
370   // it. The other handlers are for the timer and the UART hardware.
371   //
372   //-------------------------------------------------------------------------------------------------------------
373   void gpioCallback( uint gpioPin, uint32_t event ) {
374
375       cdcIntHandlers.gpioIsrTable[ get_core_num( )][ gpioPin] ( gpioPin, mapPicoGpioEvent( event ));
376   }
377
378   bool repeatingTimerAlarm ( repeating_timer_t *rt ) {
379
380       if ( timerCallback != nullptr ) timerCallback((uint32_t) ( - timerData.delay_us ));
381       return ( true );
382   }
383
384   void uartRxCallback0( ) {
385
386       while ( uart_is_readable( uart0 )) {
387
388           uint8_t ch = uart_getc( uart0 );
389           if ( CdcUart0.rxBufIndex < MAX_UART_BUF_SIZE ) CdcUart0.rxDataBuf[CdcUart0.rxBufIndex++ ] = ch;
390       }
391   }
392
393   void uartRxCallback1( ) {
394
395       while ( uart_is_readable( uart1 )) {
```

```
396
397              uint8_t ch = uart_getc( uart1 );
398              if ( CdcUart1.rxBufIndex < MAX_UART_BUF_SIZE ) CdcUart1.rxDataBuf[ CdcUart1.rxBufIndex++ ] = ch;
399          }
400  }
401
402  //-----------------------------------------------------------------------------------------------------------
403  // The default configuration descriptor. The Application program fills in such a structure, which can be
404  // seen as the HW pin assignments for the PICO controllers and the particular board on which the application
405  // will be deployed. The application will simply use the field names to address the particular PICO HW
406  // function. For example, a configuration has mapped DIO_PIN_5 to GPIO pin 12, because that is where the
407  // particular board has mapped DIO_PIN_5 to the hardware line. The application will just use the DIO_PIN_5
408  // field when talking to that GPIO pin. Whenever the board layout changes, there could be another PICO GPIO
409  // pin, but the name "DIO_PIN_5" for the application upper layers does not change.
410  //
411  // Note that there is a great flexibility what a PICO HW  pin can do and hence a lot of our fields are just
412  // "UNDEFINED" with no constraints. Nevertheless, there is a function which will do some plausibility checks
413  // for such a structure. Also, each configuration routine will do again a check that the GPIO pins used do
414  // indeed map to a PICO HW block for the desired purpose.
415  //
416  // The configuration structure does not replace the actual configuration calls to make to the CDC library.
417  // It is just a mapping of reserved names to actual GPIO pins.
418  //
419  //-----------------------------------------------------------------------------------------------------------
420  CDC::CdcConfigDesc getConfigDefaultRP2040( ) {
421
422      CDC::CdcConfigDesc tmp;
423
424      tmp.CFG_STATUS           = CDC::INIT_PENDING;
425
426      // ??? controller family ?
427      // ??? what other characteristics ? ( e.g. mem size ? )
428
429      tmp.READY_LED_PIN        = CDC::UNDEFINED_PIN;
430      tmp.ACTIVE_LED_PIN       = CDC::UNDEFINED_PIN;
431
432      tmp.EXT_INT_PIN          = CDC::UNDEFINED_PIN;
433      tmp.PFAIL_PIN            = CDC::UNDEFINED_PIN;
434
435      tmp.DIO_PIN_0            = CDC::UNDEFINED_PIN;
436      tmp.DIO_PIN_1            = CDC::UNDEFINED_PIN;
437      tmp.DIO_PIN_2            = CDC::UNDEFINED_PIN;
438      tmp.DIO_PIN_3            = CDC::UNDEFINED_PIN;
439      tmp.DIO_PIN_4            = CDC::UNDEFINED_PIN;
440      tmp.DIO_PIN_5            = CDC::UNDEFINED_PIN;
441      tmp.DIO_PIN_6            = CDC::UNDEFINED_PIN;
442      tmp.DIO_PIN_7            = CDC::UNDEFINED_PIN;
443      tmp.DIO_PIN_8            = CDC::UNDEFINED_PIN;
444      tmp.DIO_PIN_9            = CDC::UNDEFINED_PIN;
445      tmp.DIO_PIN_10           = CDC::UNDEFINED_PIN;
446      tmp.DIO_PIN_11           = CDC::UNDEFINED_PIN;
447      tmp.DIO_PIN_12           = CDC::UNDEFINED_PIN;
448      tmp.DIO_PIN_13           = CDC::UNDEFINED_PIN;
449      tmp.DIO_PIN_14           = CDC::UNDEFINED_PIN;
450      tmp.DIO_PIN_15           = CDC::UNDEFINED_PIN;
451
452      tmp.ADC_PIN_0            = CDC::UNDEFINED_PIN;
453      tmp.ADC_PIN_1            = CDC::UNDEFINED_PIN;
454      tmp.ADC_PIN_2            = CDC::UNDEFINED_PIN;
455      tmp.ADC_PIN_3            = CDC::ILLEGAL_PIN;
456
457      tmp.PWM_PIN_0            = CDC::UNDEFINED_PIN;
458      tmp.PWM_PIN_1            = CDC::UNDEFINED_PIN;
459      tmp.PWM_PIN_2            = CDC::UNDEFINED_PIN;
460      tmp.PWM_PIN_3            = CDC::UNDEFINED_PIN;
461
462      tmp.UART_RX_PIN_0        = CDC::UNDEFINED_PIN;
463      tmp.UART_TX_PIN_0        = CDC::UNDEFINED_PIN;
464
465      tmp.UART_RX_PIN_1        = CDC::UNDEFINED_PIN;
466      tmp.UART_TX_PIN_1        = CDC::UNDEFINED_PIN;
467
468      tmp.UART_RX_PIN_2        = CDC::UNDEFINED_PIN;
469      tmp.UART_TX_PIN_2        = CDC::UNDEFINED_PIN;
470
471      tmp.UART_RX_PIN_3        = CDC::UNDEFINED_PIN;
472      tmp.UART_TX_PIN_3        = CDC::UNDEFINED_PIN;
473
474      tmp.SPI_MOSI_PIN_0       = CDC::UNDEFINED_PIN;
475      tmp.SPI_MISO_PIN_0       = CDC::UNDEFINED_PIN;
476      tmp.SPI_SCLK_PIN_0       = CDC::UNDEFINED_PIN;
477
478      tmp.SPI_MOSI_PIN_1       = CDC::UNDEFINED_PIN;
479      tmp.SPI_MISO_PIN_1       = CDC::UNDEFINED_PIN;
480      tmp.SPI_SCLK_PIN_1       = CDC::UNDEFINED_PIN;
481
482      tmp.NVM_I2C_SCL_PIN      = CDC::UNDEFINED_PIN;
483      tmp.NVM_I2C_SDA_PIN      = CDC::UNDEFINED_PIN;
484
485      tmp.EXT_I2C_SCL_PIN      = 17;
486      tmp.EXT_I2C_SDA_PIN      = 16;
487
488      tmp.CAN_BUS_RX_PIN       = CDC::UNDEFINED_PIN;
489      tmp.CAN_BUS_TX_PIN       = CDC::UNDEFINED_PIN;
490
491      return ( tmp );
492  }
493
494  //-----------------------------------------------------------------------------------------------------------
```

```
495  // Validate a configuration structure. This routine will do basic checking of the pin configuration passed.
496  // The PICO is very flexible when it comes to what a pin can do. However, there are still some rules to
497  // follow. Also, we have dedicated settings for at least the I2C channels and the CAN bus IO pins.
498  //
499  //------------------------------------------------------------------------------------------------------------
500  uint8_t validateConfigRP20040( CDC::CdcConfigDesc *ci ) {
501
502      // ??? a ton of "validXXX" ?
503
504      return ( NO_ERR ); // for now....
505  }
506
507  }; // namespace
508
509
510  //------------------------------------------------------------------------------------------------------------
511  // Bane CDC. All routines and definitions exported are in this name space.
512  //
513  //------------------------------------------------------------------------------------------------------------
514  namespace CDC {
515
516  //------------------------------------------------------------------------------------------------------------
517  // For debugging purposes. Instead of conditional compilations, the debug level will enable the printing of
518  // debug and trace data.
519  //
520  //------------------------------------------------------------------------------------------------------------
521  void setDebugLevel( uint8_t level ) {
522
523      debugLevel = level;
524  }
525
526  //------------------------------------------------------------------------------------------------------------
527  // "getConfigDefault" initializes a configuration structure and sets the pre-assigned values. A typical
528  // sequence for an application start sequence would be to create an initial structure this way and then set
529  // the relevant pins and values according to the actual hardware configuration.
530  //
531  //------------------------------------------------------------------------------------------------------------
532  CdcConfigDesc getConfigDefault( ) {
533
534      return ( getConfigDefaultRP2040( ));
535  }
536
537  //------------------------------------------------------------------------------------------------------------
538  // "getConfigActual" will return a pointer to the copy we kept when calling the init routine with the config
539  // structure to use. There is no need for the upper layers to keep the structure used at initialization time.
540  //
541  //------------------------------------------------------------------------------------------------------------
542  CdcConfigDesc *getConfigActual( ) {
543
544      return ( &cfg );
545  }
546
547  //------------------------------------------------------------------------------------------------------------
548  // CDC library setup. The "init" routine will ready the CDC library. The main task is to validate the pins and
549  // values for the particular controller capabilities. The init routine can be called more than once without a
550  // problem.
551  //
552  //------------------------------------------------------------------------------------------------------------
553  uint8_t init( CdcConfigDesc *ci ) {
554
555      cfg = *ci;
556
557      initIsrTable( );
558      configureConsoleIO( );
559
560      return ( validateConfigRP20040( ci ));
561  }
562
563  //------------------------------------------------------------------------------------------------------------
564  // "fatalError" is the error communication method when we cannot get anything to work, except the onboard
565  // LED. The Raspberry Pi PICO has a small Led on the board. We will use this LED to "blink" an error code.
566  // There are up to eight codes. The sequence is as follows:
567  //
568  //     repeat forever:
569  //
570  //     - 1s ON, 0.5s OFF
571  //     - for ( int i = 0; i < n; i++ ) { 0.5s ON; 0.5s OFF; }
572  //
573  // The only way to get out of this loop is then to reset the board. Fatal errors are hopefully not many. One
574  // obvious one is when we cannot detect the NVM and thus know nothing about the board.
575  //
576  //------------------------------------------------------------------------------------------------------------
577  void fatalError( uint8_t n ) {
578
579      const uint8_t   ledPin      = 25;
580      const uint32_t  longPulse   = 1000;
581      const uint32_t  shortPulse  = 250;
582
583      n = n % 8;
584
585      gpio_init( ledPin );
586      gpio_set_dir( ledPin, GPIO_OUT );
587
588      while ( true ) {
589
590          sleep_ms( longPulse );
591
592          for ( int i = 0; i < n; i++ ) {
593
```

```
594                gpio_put( ledPin, true );
595                sleep_ms( shortPulse );
596                gpio_put( ledPin, false );
597                sleep_ms( shortPulse );
598            }
599        }
600 }
601
602 //-------------------------------------------------------------------------------------------------------------
603 // "fatalErrorMsg" will result in a fatal error, but we attempt to first write an error message to the
604 // console.
605 //
606 //-------------------------------------------------------------------------------------------------------------
607 void fatalErrorMsg( char *str, uint8_t n, uint8_t rStat ) {
608
609     if ( isConsoleConnected( )) printf( "Fatal Error: %d: %s, rStat: %d\n", n, str, rStat );
610     fatalError( n );
611 }
612
613 //-------------------------------------------------------------------------------------------------------------
614 // Processor general values required by the low level LCS core library functions.
615 //
616 //-------------------------------------------------------------------------------------------------------------
617 uint16_t getFamily( ) {
618
619     return ( CONTROLLER_FAMILY );
620 }
621
622 uint32_t getVersion( ) {
623
624     return ( CDC_LIB_MAJOR_VERSION << 8 | CDC_LIB_MINOR_VERSION );
625 }
626
627 uint32_t getChipMemSize( ) {
628
629     return ( CHIP_MEM_SIZE );
630 }
631
632 uint32_t getChipNvmSize( ) {
633
634     return ( CHIP_NVM_SIZE   );
635 }
636
637 uint32_t getCpuFrequency( ) {
638
639     return ( clock_get_hz( clk_sys ));
640 }
641
642 uint32_t getMillis( ) {
643
644     return ( to_ms_since_boot( get_absolute_time( )));
645 }
646
647 uint32_t getMicros( ) {
648
649     return ( to_us_since_boot( get_absolute_time( )));
650 }
651
652 void sleepMillis( uint32_t val ) {
653
654     sleep_ms( val );
655 }
656
657 void sleepMicros( uint32_t val ) {
658
659     sleep_us( val );
660 }
661
662 //-------------------------------------------------------------------------------------------------------------
663 // "createUid" is the routine that produces a unique ID for the node. The scheme is still based on a random
664 // number. This is the PICO version for creating a random number. Alternatively we could use the unique
665 // flash chip ID on the board. TBD ...
666 //
667 //-------------------------------------------------------------------------------------------------------------
668 uint32_t createUid( ) {
669
670     uint32_t rVal = 0;
671
672     volatile uint32_t *rnd_reg = (uint32_t *) ( ROSC_BASE + ROSC_RANDOMBIT_OFFSET );
673
674     for ( int k = 0; k < 32; k++ ) {
675
676         rVal = rVal << 1;
677         rVal = rVal + ( 0x00000001 & ( *rnd_reg ));
678     }
679
680     return ( rVal );
681 }
682
683 //-------------------------------------------------------------------------------------------------------------
684 // Console IO section. We set up the stdio via the USB connector. As part of the CDC init call, the configure
685 // call should be done rather early, so that we can print out debug messages. In normal LCS node operation
686 // there is no USB connected. Detecting a connection helps to decide whether we can report an error or need
687 // to resort to a fatal error call at startup.
688 //
689 // There are two basic ways to detect an USB connection. The first is to simply check if there is power on
690 // the USB port. The PICO features an internal GPIO pin for this purpose. Using this method still does not
691 // mean that we have someone connected to the USB, but just that there is a cable with power. Well, good
692 // enough for us. The second method truly detects that there is a USB host connected. This check is provided
```

```
693  // via the PICO libraries which in turn use the tinyUSB library. However, there could be a timing problem
694  // where the USB stack is not ready and we conclude wrongly that there is no USB connection. For now, let's
695  // rather go with the risk that there is just power on the USB connector.
696  //
697  // Finally, there is a routine to get a character for the command interfaces. Since the function just reads
698  // in a character, optionally with a timeout how long to wait for any inout.
699  //
700  // PS: The USB check way would be "return( stdio_usb_connected( ));" instead of the GPIO check.
701  //------------------------------------------------------------------------------------------------------------
702  uint8_t configureConsoleIO( ) {
703
704      stdio_init_all( );
705      return( NO_ERR );
706  }
707
708  bool isConsoleConnected( ) {
709
710      gpio_init( PICO_VBUS_PIN );
711      gpio_set_dir( PICO_VBUS_PIN, GPIO_IN );
712
713      return( gpio_get( PICO_VBUS_PIN ));
714  }
715
716  char getConsoleChar( uint32_t timeoutVal ) {
717
718      int ch = getchar_timeout_us( timeoutVal );
719      return(( ch == PICO_ERROR_TIMEOUT ) ? 0 : ch );
720  }
721
722  //------------------------------------------------------------------------------------------------------------
723  // Timer section. The CDC library features one generic repeating timer with a microsecond resolution. The
724  // routines start and stop the timer and allow to set a new limit. The PICO offers a high level function that
725  // schedules a repeating timer with the property of measuring the interval also from the start of the
726  // callback invocation. This is exactly what we need to implement the tick interrupt for the DCC signal state
727  // machine. The "setRepeatingTimerLimit" function will adjust the timer limit counter while the timer already
728  // is counting toward a limit. Note that the timer option that already start the next round while the timer
729  // interrupt handler executes is specified by using negative limit values. The timer functionality also
730  // offers two timestamp routines to get the number of milliseconds and number of microseconds since system
731  // start.
732  //
733  // ??? would we one day need more than one timer instance ?
734  //------------------------------------------------------------------------------------------------------------
735  void startRepeatingTimer( uint32_t val ) {
736
737      int64_t limit = val;
738      add_repeating_timer_us( - limit, repeatingTimerAlarm, nullptr, &timerData );
739  }
740
741  void stopRepeatingTimer( ) {
742
743      cancel_repeating_timer( &timerData );
744  }
745
746  uint32_t getRepeatingTimerLimit( ) {
747
748      return ((uint32_t) ( - timerData.delay_us ));
749  }
750
751  void setRepeatingTimerLimit( uint32_t val ) {
752
753      int64_t limit = val;
754      timerData.delay_us = ((int64_t) - limit );
755  }
756
757  void onTimerEvent( CDC::TimerCallback functionId ) {
758
759      timerCallback = functionId;
760  }
761
762  //------------------------------------------------------------------------------------------------------------
763  // DIO section. A digital pin is the bread and butter hardware resource and can be an input or output pin. For
764  // inputs, an internal pull-up resistor can be set.There are a couple of interfaces. First the single pin
765  // read, write and toggle. Next are read and write mask routines which work on all IO pins at once. Note that
766  // no cross checking is done if the pins are used by other CDC functions. Finally there is a convenience
767  // routine which write a pair of data. This is typically used for the H-Bridge control pins, which are set at
768  // the same time.
769  //
770  // A GPIO pin can also have an attached interrupt handler. When we register a handler for a pin, there are
771  // two different PICO lib routines to use. When there is no handler registered so far, we register the
772  // common callback and store the particular GPIO handler in the handler table. Otherwise, we just store the
773  // handler and enable the GPIO pin for interrupts.
774  //
775  //------------------------------------------------------------------------------------------------------------
776  uint8_t configureDio( uint8_t dioPin, uint8_t mode ) {
777
778      if ( ! validPin( dioPin, VALID_GPIO_PINS )) return ( DIO_PIN_ERR );
779
780      gpio_init( dioPin );
781
782      switch ( mode ) {
783
784          case IN:  gpio_set_dir( dioPin, false );  break;
785          case OUT: {
786
787              gpio_set_dir( dioPin, true );
788              gpio_set_drive_strength ( dioPin, GPIO_DRIVE_STRENGTH_12MA );
789
790          }  break;
791
```

```
792         case IN_PULLUP: {
793
794             gpio_set_dir( dioPin, false );
795             gpio_pull_up( dioPin );
796
797         } break;
798
799         default: gpio_set_dir( dioPin, false );
800     }
801
802   return ( NO_ERR );
803 }
804
805 void registerDioCallback( uint8_t dioPin, uint8_t event, CDC::GpioCallback func ) {
806
807     if ( dioPin <= MAX_INT_PIN ) {
808
809         if ( cdcIntHandlers.numOfHandlers == 0 )
810             gpio_set_irq_enabled_with_callback( dioPin, mapGpioIntEvent( event ), true, gpioCallback );
811         else
812             gpio_set_irq_enabled( dioPin, mapGpioIntEvent( event ), true);
813
814         cdcIntHandlers.gpioIsrTable[ get_core_num( ) ][ dioPin ] = func;
815         cdcIntHandlers.numOfHandlers ++;
816     }
817 }
818
819 void unregisterDioCallback( uint8_t dioPin ) {
820
821     if ( dioPin <= MAX_INT_PIN ) {
822
823         if ( cdcIntHandlers.gpioIsrTable[ get_core_num( ) ][ dioPin ] != nullptr ) {
824
825             gpio_set_irq_enabled( dioPin, 0, false );
826             cdcIntHandlers.gpioIsrTable[ get_core_num( ) ][ dioPin ] = dummyIsrHandler;
827             cdcIntHandlers.numOfHandlers --;
828         }
829     }
830 }
831
832 bool readDio( uint8_t dioPin ) {
833
834     return ( gpio_get( dioPin ));
835 }
836
837 uint8_t writeDio( uint8_t dioPin, bool val ) {
838
839     gpio_put( dioPin, val );
840     return ( NO_ERR );
841 }
842
843 uint8_t toggleDio( uint8_t dioPin ) {
844
845     writeDio( dioPin, ! readDio( dioPin ));
846     return ( NO_ERR );
847 }
848
849 uint8_t writeDioPair( uint8_t dioPin1, bool val1, uint8_t dioPin2, bool val2 ) {
850
851     uint32_t maskData = ( 1UL << dioPin1 ) | ( 1UL << dioPin2 );
852     uint32_t valData = (( val1 ) ? ( 1 << dioPin1 ) : 0 ) | (( val2 ) ? ( 1 << dioPin2 ) : 0 );
853
854     gpio_put_masked( maskData, valData );
855     return ( NO_ERR );
856 }
857
858 uint32_t readDioMask( uint32_t dioMask ) {
859
860     return ( gpio_get_all( ) & dioMask );
861 }
862
863 uint8_t writeDioMask( uint32_t dioMask, uint32_t dioVal ) {
864
865     gpio_put_masked( dioMask, dioVal );
866     return ( NO_ERR );
867 }
868
869 //-------------------------------------------------------------------------------------------------------------
870 // ADC section. The analog input channel represented by the pin is configured. At initialization, the ADC pin
871 // number is validated and the ADC subsystem initialized. The PICO does an analog read in about 2us. This is
872 // so fast, it does for our purpose make not much sense to implement an asynchronous option. Furthermore, the
873 // ADC value scaled down to a 10-bit resolution.
874 //
875 //-------------------------------------------------------------------------------------------------------------
876 uint8_t configureAdc( uint8_t adcPin ) {
877
878     if ( ! validPin( adcPin, VALID_ADC_PINS ))  return ( ADC_PIN_ERR );
879
880     AdcInst *tmp = nullptr;
881
882     if ( adcPin == cfg.ADC_PIN_0 ) {
883
884         tmp = &CdcAdc0;
885         tmp -> adcPin = adcPin;
886         tmp -> adcNum = 0;
887
888     }
889      else if ( adcPin == cfg.ADC_PIN_1 ) {
890
```

```
891          tmp = &CdcAdc1;
892          tmp -> adcPin = adcPin;
893          tmp -> adcNum = 1;
894      }
895      else if ( adcPin == cfg.ADC_PIN_2 ) {
896
897          tmp = &CdcAdc2;
898          tmp -> adcPin = adcPin;
899          tmp -> adcNum = 2;
900      }
901      else return ( ADC_PIN_ERR );
902
903      adc_init( );
904      adc_gpio_init( tmp -> adcPin );
905      tmp -> configured = true;
906
907      return ( NO_ERR );
908  }
909
910  uint16_t getAdcRefVoltage( ) {
911
912      return ( ADC_REF_VOLTAGE_MILLI_VOLT );
913  }
914
915  uint16_t getAdcDigitRange( ) {
916
917      return ( ADC_DIGIT_RANGE );
918  }
919
920  uint16_t readAdc( uint8_t adcPin ) {
921
922      AdcInst *tmp = nullptr;
923
924      if      ( adcPin == CdcAdc0.adcPin ) tmp = &CdcAdc0;
925      else if ( adcPin == CdcAdc1.adcPin ) tmp = &CdcAdc1;
926      else if ( adcPin == CdcAdc2.adcPin ) tmp = &CdcAdc2;
927      else return ( 0 );
928      adc_select_input( tmp -> adcNum );
929      return ( adc_read( ) >> 2 );
930  }
931
932  //-------------------------------------------------------------------------------------------------------
933  // UART section. The UART interface is primarily used for the RailCom Detector that sends a serial signal.
934  // So far, only the receiver portion is implemented because that is all what is needed for RailCom messages.
935  // There are two general categories. The first uses the PICO built-in UART hardware blocks. The second
936  // implements a software UART based on the PICO PIO blocks.
937  //
938  // There are three routines. The "startUartRead" will enable the UART and start reading bytes into the local
939  // buffer. The "stopUartRead" will then finish the byte collection and disable the UART again. Finally, the
940  // "getUartBuffer" routine will return the bytes received. Again, note that this is not a generic UART read
941  // interface.
942  //
943  // The work on the PIO based UART version has not started yet ... it will be needed for the quad block
944  // controller. Looking forward to it ...:-)
945  //
946  //-------------------------------------------------------------------------------------------------------
947  uint8_t configureUart( uint8_t rxPin, uint8_t txPin, uint32_t baudRate, UartMode mode ) {
948
949      UartInst *uart = nullptr;
950
951      if ( mode == UART_MODE_8N1 ) {
952
953          if (( validPin( rxPin, VALID_UART_0_RX_PINS )) && ( validPin( txPin, VALID_UART_0_TX_PINS ))) {
954
955              uart                = &CdcUart0;
956              uart -> uartMode    = mode;
957              uart -> rxPin       = rxPin;
958              uart -> txPin       = txPin;
959              uart -> dataBits    = 8;
960              uart -> stopBits    = 1;
961              uart -> parityMode  = UART_PARITY_NONE;
962              uart -> uartHw      = uart0;
963              uart -> uartIrq     = UART0_IRQ;
964          }
965          else if (( validPin( rxPin, VALID_UART_1_RX_PINS )) && ( validPin( txPin, VALID_UART_1_TX_PINS ))) {
966
967              uart                = &CdcUart1;
968              uart -> uartMode    = mode;
969              uart -> rxPin       = rxPin;
970              uart -> txPin       = txPin;
971              uart -> dataBits    = 8;
972              uart -> stopBits    = 1;
973              uart -> parityMode  = UART_PARITY_NONE;
974              uart -> uartHw      = uart1;
975              uart -> uartIrq     = UART1_IRQ;
976          }
977          else return ( UART_PORT_ERR );
978
979          uart_init( uart -> uartHw, baudRate );
980          gpio_set_function( rxPin, GPIO_FUNC_UART );
981          gpio_set_function( txPin, GPIO_FUNC_UART );
982          uart_set_hw_flow( uart -> uartHw, false, false );
983          uart_set_format( uart -> uartHw, uart -> dataBits, uart -> stopBits, uart -> parityMode );
984          uart_set_fifo_enabled( uart -> uartHw, false );
985
986          if      ( uart -> uartIrq == UART0_IRQ ) irq_set_exclusive_handler( uart -> uartIrq, uartRxCallback0 );
987          else if ( uart -> uartIrq == UART1_IRQ ) irq_set_exclusive_handler( uart -> uartIrq, uartRxCallback1 );
988
989          irq_set_enabled( uart -> uartIrq, true );
```

```
 990
 991            return ( NO_ERR );
 992       }
 993       else if ( mode == UART_MODE_8N1_PIO ) {
 994
 995            return ( NOT_SUPPORTED );
 996       }
 997       else return ( NOT_SUPPORTED );
 998  }
 999
1000  uint8_t startUartRead( uint8_t rxPin ) {
1001
1002       UartInst *uart = nullptr;
1003
1004       if      ( rxPin == CdcUart0.rxPin ) uart = &CdcUart0;
1005       else if ( rxPin == CdcUart1.rxPin ) uart = &CdcUart1;
1006       else if ( rxPin == CdcUart2.rxPin ) uart = &CdcUart2;
1007       else if ( rxPin == CdcUart3.rxPin ) uart = &CdcUart3;
1008       else                                return ( CDC::UART_PORT_ERR );
1009
1010       if (( uart != nullptr ) && ( uart -> uartMode == UART_MODE_8N1 )) {
1011
1012            uart_set_irq_enables( uart -> uartHw, true, false );
1013            uart -> rxBufIndex = 0;
1014            return ( NO_ERR );
1015       }
1016       else if (( uart != nullptr ) && ( uart -> uartMode == UART_MODE_8N1_PIO )) {
1017
1018            return ( NOT_SUPPORTED );
1019       }
1020       else return ( UART_PORT_ERR );
1021  }
1022
1023  uint8_t stopUartRead( uint8_t rxPin ) {
1024
1025       UartInst *uart = nullptr;
1026
1027       if      ( rxPin == CdcUart0.rxPin ) uart = &CdcUart0;
1028       else if ( rxPin == CdcUart1.rxPin ) uart = &CdcUart1;
1029       else if ( rxPin == CdcUart2.rxPin ) uart = &CdcUart2;
1030       else if ( rxPin == CdcUart3.rxPin ) uart = &CdcUart3;
1031
1032       if (( uart != nullptr ) && ( uart ->uartMode == UART_MODE_8N1 )) {
1033
1034            uart_set_irq_enables( uart -> uartHw, false, false );
1035            return ( NO_ERR );
1036       }
1037       else if (( uart != nullptr ) && ( uart -> uartMode == UART_MODE_8N1_PIO )) {
1038
1039            return ( NOT_SUPPORTED );
1040       }
1041       else return ( UART_PORT_ERR );
1042  }
1043
1044  uint8_t getUartBuffer( uint8_t rxPin, uint8_t *buf, uint8_t bufLen ) {
1045
1046       UartInst *uart = nullptr;
1047
1048       if      ( rxPin == CdcUart0.rxPin ) uart = &CdcUart0;
1049       else if ( rxPin == CdcUart1.rxPin ) uart = &CdcUart1;
1050       else if ( rxPin == CdcUart2.rxPin ) uart = &CdcUart2;
1051       else if ( rxPin == CdcUart3.rxPin ) uart = &CdcUart3;
1052       else                                return ( 0 );
1053
1054       if (( uart != nullptr ) && ( uart -> rxBufIndex > 0 ) && ( bufLen > 0 )) {
1055
1056            uint8_t i = 0;
1057            while (( i < uart -> rxBufIndex ) && ( i < bufLen )) {
1058
1059                 buf[ i ] = uart -> rxDataBuf[ i ];
1060                 i++;
1061            }
1062
1063            return ( i );
1064       }
1065       else return ( 0 );
1066  }
1067
1068  //----------------------------------------------------------------------------------------------------------
1069  // PWM section. The PICO is quite flexible when it comes to PWM signals. We implement a simple PWM capability.
1070  // There is the frequency which set during configuration and there is the write operation which set the duty
1071  // cycle. The calculations are best described in the PICO C++ SDK. We do the setting of phase, wrap count,
1072  // etc. once when we configure the PWM channel. All the "writePwm" function then will do is to manipulate the
1073  // duty cycle. In other words, when we change the frequency we need to configure again.
1074  //
1075  // There is one small issue left. Channel come in pairs. For some reason there is no call to individually
1076  // set the "inverted" option on a channel. When we set the inverted option for a pin, we currently also set
1077  //  the inverted option for the other channel since we just don't know better. To be correct, all possible
1078  // PWM pins and their "inverted" option would need to be stored somewhere.
1079  //
1080  // To do .... ( there is a way via the pwm_Config CSR field... )
1081  //
1082  // ??? should we have also a kind of PWM pair ? Is that even possible ?
1083  // ??? do we need more PWM pins ? The PICO is really flexible ?
1084  // ??? combine DIO and PWM somehow ?
1085  //----------------------------------------------------------------------------------------------------------
1086  uint8_t configurePwm( uint8_t pwmPin, uint32_t pwmFreqency, bool phaseCorrect, bool inverted ) {
1087
1088       PwmInst *pwm = nullptr;
```

```
1089
1090        if        ( pwmPin == cfg.PWM_PIN_0 ) pwm = &CdcPwm0;
1091        else if ( pwmPin == cfg.PWM_PIN_1 ) pwm = &CdcPwm1;
1092        else if ( pwmPin == cfg.PWM_PIN_2 ) pwm = &CdcPwm2;
1093        else if ( pwmPin == cfg.PWM_PIN_3 ) pwm = &CdcPwm3;
1094        else                              return ( PWM_PIN_ERR );
1095
1096        if ( phaseCorrect ) pwmFreqency = pwmFreqency * 2;
1097
1098        uint32_t sysClock = getCpuFrequency( );
1099        uint32_t clkDiv   = sysClock / pwmFreqency / 4096 + ( sysClock % ( pwmFreqency * 4096 ) != 0 );
1100
1101        if ( clkDiv / 16 == 0 ) clkDiv = 16;
1102
1103        pwm -> pwmPin  = pwmPin;
1104        pwm -> wrap    = sysClock * 16 / clkDiv / pwmFreqency - 1;
1105
1106        pwm_config pwmConfig = pwm_get_default_config( );
1107        gpio_set_function( pwm -> pwmPin, GPIO_FUNC_PWM );
1108        pwm_config_set_wrap( &pwmConfig, pwm -> wrap );
1109        pwm_config_set_phase_correct( &pwmConfig, phaseCorrect );
1110        pwm_config_set_output_polarity( &pwmConfig, inverted, inverted );
1111        pwm_init ( pwm_gpio_to_slice_num ( pwm -> pwmPin ), &pwmConfig, false );
1112        pwm_set_clkdiv_int_frac( pwm_gpio_to_slice_num( pwm -> pwmPin ), clkDiv / 16, clkDiv & 0xF );
1113
1114        #if CDC_DEBUG == 1
1115        printf( "PWM Pin: % d, fPwm: % d, phase: % d, inverted: % d, clkDiv: % d, wrap: % d \n",
1116                   pwm -> pwmPin, pwmFreqency,  phaseCorrect, inverted, clkDiv, pwm -> wrap );
1117        #endif
1118
1119        return ( NO_ERR );
1120    }
1121
1122    uint8_t writePwm( uint8_t pwmPin, uint8_t dutyCycle ) {
1123
1124        #if CDC_DEBUG == 1
1125        printf( "Write PWM: Pin: %d, duty: %d\n", pwmPin, dutyCycle );
1126        #endif
1127
1128        PwmInst *pwm = nullptr;
1129
1130        if        ( pwmPin == cfg.PWM_PIN_0 ) pwm = &CdcPwm0;
1131        else if ( pwmPin == cfg.PWM_PIN_1 ) pwm = &CdcPwm1;
1132        else if ( pwmPin == cfg.PWM_PIN_2 ) pwm = &CdcPwm2;
1133        else if ( pwmPin == cfg.PWM_PIN_3 ) pwm = &CdcPwm3;
1134        else                              return ( PWM_PIN_ERR );
1135
1136        uint sliceNum = pwm_gpio_to_slice_num( pwmPin );
1137        uint channel  = pwm_gpio_to_channel( pwmPin );
1138
1139        if ( dutyCycle == 0 ) {
1140
1141            pwm_set_enabled( sliceNum, false );
1142            gpio_put( pwmPin, false );
1143        }
1144        else if ( dutyCycle == 255 ) {
1145
1146            pwm_set_enabled( sliceNum, false );
1147
1148            #if CDC_DEBUG == 1
1149            printf( "Write GPIO true: Pin: %d\n", pwmPin );
1150            #endif
1151
1152            gpio_put( pwmPin, true );
1153        }
1154        else {
1155
1156            pwm_set_chan_level( sliceNum, channel, ( pwm -> wrap * dutyCycle / 256 ));
1157            pwm_set_enabled( sliceNum, true );
1158        }
1159
1160        return ( NO_ERR );
1161    }
1162
1163    //----------------------------------------------------------------------------------------------------------
1164    // I2C Section. The PICO has two HW blocks for I2C interfaces. The interface implements a simple read and
1165    // write access to an I2C element. There is a timeout to avoid waiting forever on an operation.
1166    //
1167    //----------------------------------------------------------------------------------------------------------
1168    uint8_t configureI2C( uint8_t sclPin, uint8_t sdaPin, uint32_t baudRate ) {
1169
1170        I2CInst *i2c = nullptr;
1171
1172        if ((( 1 << sclPin ) & VALID_I2C_0_SCL_PINS ) && (( 1 << sdaPin ) & VALID_I2C_0_SDA_PINS )) {
1173
1174            i2c = &CdcI2C0;
1175            i2c -> i2cHw = i2c0;
1176        }
1177        else if ((( 1 << sclPin ) & VALID_I2C_1_SCL_PINS ) && (( 1 << sdaPin ) & VALID_I2C_1_SDA_PINS )) {
1178
1179            i2c = &CdcI2C1;
1180            i2c -> i2cHw = i2c1;
1181        }
1182        else return ( CDC::I2C_PORT_ERR );
1183
1184        i2c -> sclPin       = sclPin;
1185        i2c -> sdaPin       = sdaPin;
1186        i2c -> baudRate     = baudRate;
1187        i2c -> timeoutValMs = I2C_TIME_OUT_IN_MS;
```

```
1188        i2c -> configured   = true;
1189
1190        i2c_init( i2c -> i2cHw, i2c -> baudRate );
1191        i2c_set_slave_mode( i2c -> i2cHw, false, 0 );
1192
1193        gpio_set_function( i2c -> sclPin, GPIO_FUNC_I2C );
1194        gpio_set_function( i2c -> sdaPin, GPIO_FUNC_I2C);
1195        gpio_pull_up( i2c -> sclPin );
1196        gpio_pull_up( i2c -> sdaPin );
1197
1198        return ( NO_ERR );
1199    }
1200
1201    uint8_t i2cRead( uint8_t sclPin, uint8_t i2cAdr, uint8_t *buf, uint16_t len, bool stopBit ) {
1202
1203        I2CInst *i2c = nullptr;
1204
1205        if      (( CdcI2C0.sclPin == sclPin ) && ( CdcI2C0.configured )) i2c = &CdcI2C0;
1206        else if (( CdcI2C1.sclPin == sclPin ) && ( CdcI2C1.configured )) i2c = &CdcI2C1;
1207        else return ( I2C_PORT_ERR );
1208
1209        auto ret = i2c_read_blocking_until( i2c -> i2cHw,
1210                                            i2cAdr,
1211                                            buf,
1212                                            len,
1213                                            stopBit,
1214                                            make_timeout_time_ms( i2c -> timeoutValMs ));
1215
1216        #if CDC_DEBUG == 1
1217        printf( "i2cRead: scl: %d, i2c: 0x%x, buf: %p, buf[0] %x, buf[1] %x, len: %d, stop: %d\n",
1218                   sclPin, i2cAdr, buf, buf[0], buf[1], len, stopBit );
1219        if ( ret == PICO_ERROR_GENERIC ) printf( "I2C read, PICO generic error\n" );
1220        if ( ret == PICO_ERROR_TIMEOUT ) printf( "I2C read, PICO timeout error\n" );
1221        #endif
1222
1223        if (( ret == PICO_ERROR_GENERIC ) || ( ret == PICO_ERROR_TIMEOUT )) return ( I2C_READ_ERR );
1224
1225        return ( NO_ERR );
1226    }
1227
1228    uint8_t i2cWrite( uint8_t sclPin, uint8_t i2cAdr, uint8_t *buf, uint16_t len, bool stopBit ) {
1229
1230        #if CDC_DEBUG == 1
1231        printf( "i2cWrite: scl: %d, i2c: 0x%x, buf: %p, buf[0] %x, buf[1] %x, len: %d, stop: %d\n",
1232                  sclPin, i2cAdr, buf, buf[0], buf[1], len, stopBit );
1233        #endif
1234
1235
1236        I2CInst *i2c = nullptr;
1237
1238        if      (( CdcI2C0.sclPin == sclPin ) && ( CdcI2C0.configured )) i2c = &CdcI2C0;
1239        else if (( CdcI2C1.sclPin == sclPin ) && ( CdcI2C1.configured )) i2c = &CdcI2C1;
1240        else return ( I2C_PORT_ERR );
1241
1242        auto ret = i2c_write_blocking_until( i2c -> i2cHw,
1243                                             i2cAdr,
1244                                             buf,
1245                                             len,
1246                                             stopBit,
1247                                             make_timeout_time_ms( i2c -> timeoutValMs ));
1248
1249        #if CDC_DEBUG == 1
1250        if ( ret == PICO_ERROR_GENERIC ) printf( "I2C write, PICO generic error\n" );
1251        if ( ret == PICO_ERROR_TIMEOUT ) printf( "I2C write, PICO timeout error\n" );
1252        #endif
1253
1254        if (( ret == PICO_ERROR_TIMEOUT) || ( ret == PICO_ERROR_GENERIC ) || ( ret != len )) return ( I2C_WRITE_ERR );
1255
1256        return ( NO_ERR );
1257    }
1258
1259    //----------------------------------------------------------------------------------------------------------
1260    // SPI interface section. The PICO features two SPI HW blocks. We implement a simple SPI interface with a
1261    // a fixed set of SPI options for frequency, bit order and mode. One day this may change. We do not take
1262    // care of the chip select stuff and expect that the caller manages the select pin.
1263    //
1264    //----------------------------------------------------------------------------------------------------------
1265    uint8_t configureSPI( uint8_t sclkPin, uint8_t mosiPin, uint8_t misoPin, uint32_t baudRate ) {
1266
1267        SPIInst *spi = nullptr;
1268
1269         if ((( 1 << sclkPin ) & VALID_SPI_0_SCK_PINS ) &&
1270             (( 1 << mosiPin ) & VALID_SPI_0_TX_PINS  ) &&
1271             (( 1 << misoPin ) & VALID_SPI_0_RX_PINS  )) {
1272
1273            spi = &CdcSPI0;
1274            spi -> spiHw = spi0;
1275        }
1276        else if ((( 1 << sclkPin ) & VALID_SPI_1_SCK_PINS ) &&
1277                 (( 1 << mosiPin ) & VALID_SPI_1_TX_PINS  ) &&
1278                 (( 1 << misoPin ) & VALID_SPI_1_RX_PINS  )) {
1279
1280            spi = &CdcSPI1;
1281            spi -> spiHw = spi1;
1282        }
1283        else return ( SPI_PORT_ERR );
1284
1285        spi -> mosiPin     = mosiPin;
1286        spi -> misoPin     = misoPin;
```

```
1287        spi -> sclkPin      = sclkPin;
1288        spi -> frequency    = SPI_FREQUENCY;
1289        spi -> configured   = true;
1290        spi -> active       = false;
1291
1292        spi_init( spi -> spiHw, SPI_FREQUENCY );
1293
1294        spi_set_format( spi -> spiHw,      // SPI instance
1295                        8,                 // Number of bits per transfer
1296                        SPI_CPOL_1,        // Polarity (CPOL)
1297                        SPI_CPHA_1,        // Phase (CPHA)
1298                        SPI_MSB_FIRST );
1299
1300        gpio_set_function( sclkPin, GPIO_FUNC_SPI );
1301        gpio_set_function( mosiPin, GPIO_FUNC_SPI );
1302        gpio_set_function( misoPin, GPIO_FUNC_SPI );
1303
1304        return ( NO_ERR );
1305    }
1306
1307    uint8_t  spiBeginTransaction( uint8_t sclkPin, uint8_t csPin ) {
1308
1309        SPIInst *spi = nullptr;
1310
1311        if      (( CdcSPI0.sclkPin == sclkPin ) && ( CdcSPI0.configured )) spi = &CdcSPI0;
1312        else if (( CdcSPI1.sclkPin == sclkPin ) && ( CdcSPI1.configured )) spi = &CdcSPI1;
1313        else return ( SPI_PORT_ERR );
1314
1315        if ( spi -> active ) {
1316
1317            // ??? should we check who is active and just ignore when the same ? else "error " ?
1318
1319            return ( NO_ERR );
1320
1321        } else {
1322
1323            spi -> active     = true;
1324            spi -> selectPin  = csPin;
1325
1326            CDC::writeDio( csPin, false );
1327            return ( NO_ERR );
1328        }
1329    }
1330
1331    uint8_t spiEndTransaction( uint8_t sclkPin, uint8_t csPin ) {
1332
1333        SPIInst *spi = nullptr;
1334
1335        if      (( CdcSPI0.sclkPin == sclkPin ) && ( CdcSPI0.configured )) spi = &CdcSPI0;
1336        else if (( CdcSPI1.sclkPin == sclkPin ) && ( CdcSPI1.configured )) spi = &CdcSPI1;
1337        else return ( SPI_PORT_ERR );
1338
1339        if ( spi -> active ) {
1340
1341            // ??? check that this is the correct pin ?
1342
1343            CDC::writeDio( csPin, true );
1344
1345            spi -> active     = false;
1346            spi -> selectPin  = UNDEFINED_PIN;
1347
1348            return ( NO_ERR );
1349
1350        }
1351        else return ( NO_ERR ); // ???  "error "  not active...
1352    }
1353
1354    uint8_t spiRead( uint8_t sclkPin, uint8_t *buf, uint32_t len ) {
1355
1356        SPIInst *spi = nullptr;
1357
1358        if      (( CdcSPI0.sclkPin == sclkPin ) && ( CdcSPI0.configured )) spi = &CdcSPI0;
1359        else if (( CdcSPI1.sclkPin == sclkPin ) && ( CdcSPI1.configured )) spi = &CdcSPI1;
1360        else return ( SPI_PORT_ERR );
1361
1362        if ( spi -> active ) {
1363
1364            int bytesRead = spi_read_blocking( spi -> spiHw, 0, buf, len );
1365            return ( NO_ERR );
1366
1367        } else return ( NO_ERR ); // ??? fix : not active ...
1368    }
1369
1370    uint8_t spiWrite( uint8_t sclkPin, uint8_t *buf, uint32_t len ) {
1371
1372        SPIInst *spi = nullptr;
1373
1374        if      (( CdcSPI0.sclkPin == sclkPin ) && ( CdcSPI0.configured )) spi = &CdcSPI0;
1375        else if (( CdcSPI1.sclkPin == sclkPin ) && ( CdcSPI1.configured )) spi = &CdcSPI1;
1376        else return ( SPI_PORT_ERR );
1377
1378        if ( spi -> active ) {
1379
1380            spi_write_blocking( spi -> spiHw, buf, len );
1381            return ( NO_ERR );
1382
1383        } else return ( NO_ERR ); // ??? fix : not active ...
1384    }
1385
```

```
1386   //-------------------------------------------------------------------------------------------------------------
1387   // Print out the Config Structure.
1388   //
1389   //-------------------------------------------------------------------------------------------------------------
1390   void printConfigInfo( CdcConfigDesc *ci ) {
1391
1392       printf( "CDC Pin Configuration Info ( status %d ): \n", ci -> CFG_STATUS );
1393
1394       printf( "Pfail pin: %2d, ExtInt pin: %2d \n", ci -> PFAIL_PIN, ci -> EXT_INT_PIN );
1395
1396       printf( "ReadyLed pin: %2d, ActiveLed pin: %2d \n", ci -> READY_LED_PIN, ci -> ACTIVE_LED_PIN );
1397
1398       printf( "DIO pins ( 0 .. 7 ): %2d %2d %2d %2d %2d %2d %2d %2d\n",
1399               ci -> DIO_PIN_0, ci -> DIO_PIN_1, ci -> DIO_PIN_2, ci -> DIO_PIN_3,
1400               ci -> DIO_PIN_4, ci -> DIO_PIN_5, ci -> DIO_PIN_6, ci -> DIO_PIN_7 );
1401
1402       printf( "DIO pins ( 8 .. 15 ): %2d %2d %2d %2d %2d %2d %2d %2d\n",
1403               ci -> DIO_PIN_8, ci -> DIO_PIN_9, ci -> DIO_PIN_10, ci -> DIO_PIN_11,
1404               ci -> DIO_PIN_12, ci -> DIO_PIN_13, ci -> DIO_PIN_14, ci -> DIO_PIN_15 );
1405
1406       printf( "ADC pins ( 0 .. 3 ): %2d %2d %2d %2d\n",
1407               ci -> ADC_PIN_0, ci -> ADC_PIN_1, ci -> ADC_PIN_2, ci -> ADC_PIN_3 );
1408
1409       printf( "PWM pins ( 0 .. 3 ): %2d %2d %2d %2d\n",
1410               ci -> PWM_PIN_0, ci -> PWM_PIN_1, ci -> PWM_PIN_2, ci -> PWM_PIN_3 );
1411
1412       printf( "UART RX pins ( 0 .. 3 ): %2d %2d %2d %2d\n",
1413               ci -> UART_RX_PIN_0, ci -> UART_RX_PIN_1, ci -> UART_RX_PIN_2, ci -> UART_RX_PIN_3 );
1414
1415       printf( "UART TX pins ( 0 .. 3 ): %2d %2d %2d %2d\n",
1416               ci -> UART_TX_PIN_0, ci -> UART_TX_PIN_1, ci -> UART_TX_PIN_2, ci -> UART_TX_PIN_3 );
1417
1418       printf( "SPI0 Pins: MOSI: %2d, MISO: %2d, SCLK: %2d \n",
1419               ci -> SPI_MOSI_PIN_0, ci -> SPI_MISO_PIN_0, ci -> SPI_SCLK_PIN_0 );
1420
1421       printf( "SPI1 Pins: MOSI: %2d, MISO: %2d, SCLK: %2d \n",
1422               ci -> SPI_MOSI_PIN_1, ci -> SPI_MISO_PIN_1, ci -> SPI_SCLK_PIN_1 );
1423
1424       printf( "NVM I2C Pins: SCL: %2d, SDA: %2d, I2C Root: 0x%x \n",
1425               ci -> NVM_I2C_SCL_PIN, ci -> NVM_I2C_SDA_PIN, ci -> NVM_I2C_ADR_ROOT );
1426
1427       printf( "EXT I2C Pins: SCL: %2d, SDA: %2d, I2C Root: 0x%x \n",
1428               ci -> EXT_I2C_SCL_PIN, ci -> EXT_I2C_SDA_PIN, ci -> EXT_I2C_ADR_ROOT );
1429
1430       printf( "\n" );
1431
1432   }
1433
1434   }; // namespace CDC
```

A.2   LCS Runtime Lib

APPENDIX A. LISTINGS TEST

```
1    //------------------------------------------------------------------------------------------------------------
2    //
3    // Layout Control System - Runtime Library include file
4    //
5    //------------------------------------------------------------------------------------------------------------
6    // At the heart of the layout control system, LCS, is the runtime library implementing the basic functions.
7    // Please refer to the document for information on concepts and implementation notes. This is the external
8    // include file for the firmware programmer. All external definitions of key constants and types are
9    // included here.
10   //
11   //------------------------------------------------------------------------------------------------------------
12   //
13   // LCS - Runtime Library
14   // Copyright (C) 2021 - 2024  Helmut Fieres
15   //
16   // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
17   // General Public License as published by the Free Software Foundation, either version 3 of the License,
18   // or any later version.
19   //
20   // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
21   // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
22   // License for more details. You should have received a copy of the GNU General Public License along with
23   // this program.  If not, see <http://www.gnu.org/licenses/>.
24   //
25   //------------------------------------------------------------------------------------------------------------
26   #ifndef LCS_RT_LIB_h
27   #define LCS_RT_LIB_h
28
29   //------------------------------------------------------------------------------------------------------------
30   // Include files.
31   //
32   //------------------------------------------------------------------------------------------------------------
33   #include <stdint.h>
34   #include <inttypes.h>
35   #include "LcsCdcLib.h"
36
37   //------------------------------------------------------------------------------------------------------------
38   // All LCS Library definitions are in a name space "LCS". You can prefix each constant, type or function
39   // with the "LCS::" prefix, or declare using the namespace in your code.
40   //
41   //------------------------------------------------------------------------------------------------------------
42   namespace LCS {
43
44   //------------------------------------------------------------.-----------------------------------------------
45   // A node is identified through the node number. Node numbers start with one. The nodeId of zero represents
46   // the NIL node Id. The node Id is a 12-bit number, so up to 4095 nodes can be addressed. The nodeId, a
47   // unique Id for the LCS nodes in a layout, is also used as the canId used for the CAN bus. Keep in mind
48   // that a CAN bus nevertheless can reasonably handle about 127 nodes at the same time.
49   //
50   //------------------------------------------------------------------------------------------------------------
51   enum LcsNodeId : uint16_t {
52
53       NIL_NODE_ID   = 0,
54       MIN_NODE_ID   = 1,
55       MAX_NODE_ID   = 4095
56   };
57
58   //------------------------------------------------------------------------------------------------------------
59   // A node type can be assigned to a node. NodeId types start with one. The nodeType of zero represents the
60   // NIL node type. A node type is arbitrarily defined by the firmware programmer.
61   //
62   //------------------------------------------------------------------------------------------------------------
63   enum LcsNodeTypeId : uint8_t {
64
65       NIL_NODE_TYPE     = 0,
66       MIN_NODE_TYPE_ID  = 1,
67       MAX_NODE_TYPE_ID  = 255
68   };
69
70   //------------------------------------------------------------------------------------------------------------
71   // The port Id identifies the port on a node. Port numbers start with one. The port number zero represents
72   // the NIL port number and usually refers to the node itself. A node can have up to 15 ports.
73   //
74   //------------------------------------------------------------------------------------------------------------
75   enum LcsPortId : uint8_t {
76
77       NIL_PORT_ID   = 0,
78       MIN_PORT_ID   = 1,
79       MAX_PORT_ID   = 15
80   };
81
82   //------------------------------------------------------------------------------------------------------------
83   // A port type can be assigned to a port. Port types start with one. The portType of zero represents the
84   // NIL port type. A port type is arbitrarily defied by the firmware programmer.
85   //
86   //------------------------------------------------------------------------------------------------------------
87     enum LcsPortTypeId : uint8_t {
88
89       NIL_PORT_TYPE     = 0,
90       MIN_PORT_TYPE_ID  = 1,
91       MAX_PORT_TYPE_ID  = 255
92   };
93
94   //------------------------------------------------------------------------------------------------------------
95   // Events are just numbers assigned to an event by a configuration tool. Event id numbers start with one.
96   // The  event number zero represents the NIL event number. The maximum event id number is 65535.
97   //
98   //------------------------------------------------------------------------------------------------------------
```

```
99   enum LcsEventId : uint16_t {
100
101      NIL_EVENT_ID  = 0,
102      MIN_EVENT_ID  = 1,
103      MAX_EVENT_ID  = 65535
104  };
105
106  //-------------------------------------------------------------------------------------------------------
107  // Each locomotive has a type. There are STEAM, DIESEL and ELECTRIC engines so far.
108  //
109  // ??? additional types ?
110  //-------------------------------------------------------------------------------------------------------
111  enum DccLocoType : uint8_t {
112
113      LOC_T_NIL       = 0,
114      LOC_T_STEAM     = 1,
115      LOC_T_DIESEL    = 2,
116      LOC_T_ELECTRIC  = 3
117  };
118
119  //-------------------------------------------------------------------------------------------------------
120  // The base station maintains the locomotive sessions. A session is assigned by the base station and commands
121  // for the locomotive use this session number. Session Ids start with 1, up to 255 simultaneous sessions are
122  //  supported.
123  //
124  //-------------------------------------------------------------------------------------------------------
125  enum DccSessionId : uint8_t {
126
127      NIL_LOCO_SESSION_ID  = 0,
128      MIN_LOCO_SESSION_ID  = 1,
129      MAX_LOCO_SESSION_ID  = 255
130  };
131
132  //-------------------------------------------------------------------------------------------------------
133  // The cabId is the locomotive number or address. For DCC type locomotives, there is a short and long address
134  // for a decoder. The short address ranges from 1 .. 127, the long address from 1 .. to 10239. However, most
135  // base stations support just up to 9999 locomotives IDs and so do we. Analog engines do not really have a
136  // cabId. When an analog engines is introduced to the system by telling the base station about the engine and
137  // lo cation, the base station assign a cabId. Refer to the book for the details.
138  //
139  //-------------------------------------------------------------------------------------------------------
140  enum DccCabId : uint16_t {
141
142      NIL_CAB_ID  = 0,
143      MIN_CAB_ID  = 1,
144      MAX_CAB_ID  = 9999
145  };
146
147  //-------------------------------------------------------------------------------------------------------
148  // A DCC decoder features configuration variables, called CVs. CVs are numbered starting with 1, the maximum
149  // number is 1024.
150  //
151  //-------------------------------------------------------------------------------------------------------
152  enum DccCvId : uint16_t {
153
154      NIL_DCC_CV_ID  = 0,
155      MIN_DCC_CV_ID  = 1,
156      MAX_DCC_CV_ID  = 1024
157  };
158
159  //-------------------------------------------------------------------------------------------------------
160  // A locomotive decoder features up to 69 functions Ids. They are numbered from 0 to 68.
161  //
162  //-------------------------------------------------------------------------------------------------------
163  enum DccFuncId : uint8_t {
164
165      NIL_DCC_FUNC_ID   = 255,
166      MIN_DCC_FUNC_ID   = 0,
167      MAX_DCC_FUNC_ID   = 68
168  };
169
170  //-------------------------------------------------------------------------------------------------------
171  // According to the DCC standard, DCC decoder functions are grouped in ten groups, labelled from 1 to 10 .
172  //
173  //-------------------------------------------------------------------------------------------------------
174  enum DccFuncGroupId : uint8_t {
175
176      MIN_DCC_FUNC_GROUP_ID   = 1,
177      MAX_DCC_FUNC_GROUP_ID   = 10
178  };
179
180  //-------------------------------------------------------------------------------------------------------
181  // DCC decoder function mapping Ids. The LCS system defines a set of functions used by the handhelds such
182  // as horn, lights and so on. These identifiers are standardized for our handhelds and mapped to the DCC
183  // function.
184  //
185  //-------------------------------------------------------------------------------------------------------
186  enum LcsDccFuncId : uint8_t {
187
188      NIL_LCS_DCC_FUNC_ID = 0,
189      MIN_LCS_DCC_FUNC_ID = 1,
190
191      // ??? function IDs go here...
192
193      MAX_LCS_DCC_FUNC_ID = 68
194  };
195
196  //-------------------------------------------------------------------------------------------------------
197  // "CvModeOptions" is used by the DCC CV variables access routines to specify the access mode. Only options
```

```
198    // 0 and 1 are supported. The others are there for historic reasons, the functionality was found in older
199    // decoders and should not be supported anymore.
200    //
201    //-------------------------------------------------------------------------------------------------------------
202    enum DccCvModeOptions : uint8_t {
203
204        CVM_BYTE        = 0,
205        CVM_BIT         = 1,
206        CVM_PAGE        = 2,
207        CVM_REGISTER    = 3,
208        CVM_ADR_ONLY    = 4
209    };
210
211    //-------------------------------------------------------------------------------------------------------------
212    // The DCC standard defines several speed step modes. Today, the 28 speed step option is the one used in all
213    // new decoders. The other speed steps are mapped to the 128 value range.
214    //
215    //-------------------------------------------------------------------------------------------------------------
216    enum DccSpeedSteps : uint8_t {
217
218        DCC_SPEED_STEPS_14     = 1,
219        DCC_SPEED_STEPS_28     = 2,
220        DCC_SPEED_STEPS_128    = 3
221    };
222
223    //-------------------------------------------------------------------------------------------------------------
224    // The locomotive decoder speed. The range is defined for a DCC 128 speed step decoder, from 0 to 127. The
225    // speed of 1 represents the emergency speed stop. In normal operations, speed stops would thus go from 2
226    // to 0 and back. For analog engines, we keep this scheme and map it to the respective power levels.
227    //
228    //-------------------------------------------------------------------------------------------------------------
229    enum LocSpeed : uint8_t {
230
231        MIN_LOCO_SPEED      = 0,
232        ESTOP_LOCO_SPEED    = 1,
233        MAX_LOCO_SPEED      = 127
234    };
235
236    //-------------------------------------------------------------------------------------------------------------
237    // Locomotive direction.
238    //
239    //-------------------------------------------------------------------------------------------------------------
240    enum LocoDirection : uint8_t {
241
242        LOCO_DIR_LOCO_NEUTRAL  = 0,
243        LOCO_DIR_LOCO_FORWARD  = 1,
244        LOCO_DIR_LOCO_REVERSE  = 2
245    };
246
247    //-------------------------------------------------------------------------------------------------------------
248    // "LocSessionModes" specify the options when creating a session for the loco. Besides creating a normal
249    // session an existing session can be taken over or even shared among multiple handhelds.
250    //
251    //-------------------------------------------------------------------------------------------------------------
252    enum LocoSessionModes : uint8_t {
253
254        LSM_NORMAL  = 1,
255        LSM_STEAL   = 2,
256        LSM_SHARED  = 3
257    };
258
259    //-------------------------------------------------------------------------------------------------------------
260    // The defined board types. When the runtime is initialized, the firmware will pass the type to specify what
261    // board it expects. This value is compared to what is actually stored in the NVM of the main controller
262    // board. If they don't match, it is considered an error and the NVM needs to be configured to support the
263    // firmware.
264    //
265    //-------------------------------------------------------------------------------------------------------------
266    enum LcsBoardType : uint16_t {
267
268        BT_NIL                 = 0,
269        BT_MAIN_CONTROLLER     = 1,
270        BT_BASE_STATION        = 2,
271        BT_BLOCK_CONTROLLER    = 3,
272        BT_CAB_HANDHELD        = 4,
273
274        BT_EXT_NIL             = 10,
275        BT_EXT_OCC_DETECT      = 11,
276        BT_EXT_SERVO           = 12,
277        BT_EXT_GPIO            = 13
278    };
279
280    //-------------------------------------------------------------------------------------------------------------
281    // The defined chip families. There are controller chip families such as the controller family RP2040, or
282    // chip families for the NVM chips used, and so on.
283    //
284    //-------------------------------------------------------------------------------------------------------------
285    enum LcsControllerFamilyType : uint16_t {
286
287        CF_FAM_NIL             = 0,
288        CF_FAM_RPICO           = 1,
289        CF_FAM_MICROCHIP       = 3,
290        CF_FAM_NXP             = 4
291    };
292
293    //-------------------------------------------------------------------------------------------------------------
294    // Extension board driver flags. The flag are set when a board is detected and also during board operation.
295    //
296    //-------------------------------------------------------------------------------------------------------------
```

```
297  enum LcsBoardFlags : uint16_t {
298
299      BF_NIL                  = 0,
300      BF_EXT_BOARD_PRESENT    = ( 1U << 0 ),
301      BF_EXT_BOARD_VALID      = ( 1U << 1 ),
302      BF_EXT_BOARD_READY      = ( 1U << 2 )
303  };
304
305  //-----------------------------------------------------------------------------------------------------
306  // The configuration descriptor and node map have an option field. The following constants define the
307  // options that can be set.
308  //
309  //  NOPT_SKIP_NODE_ID_CONFIG - during startup, skip the nodeId configuration protocol.
310  //  NOPT_SKIP_NODE_INIT_STEP - during startup, skip the node initialization step.
311  //  NOPT_SKIP_PORT_INIT_STEP - during startup, skip the port initialization step.
312  //  NOPT_DEBUG_DURING_SETUP  - during startup print debug info until we use the mask of nodeMap
313  //
314  //-----------------------------------------------------------------------------------------------------
315  enum LcsNodeOptions : uint16_t {
316
317      NOPT_NIL                  = 0,
318      NOPT_SKIP_NODE_ID_CONFIG  = ( 1 << 0 ),
319      NOPT_SKIP_NODE_INIT_STEP  = ( 1 << 1 ),
320      NOPT_DEBUG_DURING_SETUP   = ( 1 << 2 ),
321      NOPT_FORMAT_RUNTIME       = ( 1 << 3 )
322  };
323
324  //-----------------------------------------------------------------------------------------------------
325  // Node Flags. Flags are initialized at library startup and represent library state information.
326  //
327  //  NFLAGS_EXT_PRESENT         - extension boards are present.
328  //  NFLAGS_NVM_WRITE_ENABLED   - write to the protected NVM areas is enabled.
329  //
330  //
331  //-----------------------------------------------------------------------------------------------------
332  enum LcsNodeFlags : uint16_t {
333
334      NFLAGS_NIL                = 0,
335      NFLAGS_EXT_PRESENT        = ( 1 << 0 ),
336      NFLAGS_NVM_WRITE_ENABLED  = ( 1 << 1 )
337  };
338
339  //-----------------------------------------------------------------------------------------------------
340  // Nodes, ports and drivers are accessed with three main routines, GET, SET and REQ.
341  //
342  // GET - the get routine will use the item numbers to retrieve the data labelled by the item.
343  //
344  // SET - the set routine will use the item numbers to set the value. Note that not all items that can be
345  // read can also be written to. An attempt will result in an error return.
346  //
347  // REQ - the request call will transmit the request parameters to the node / port / driver where a registered
348  // callback or the driver entry point will be invoked. The result is returned via the parameters.
349  //
350  // One argument is the item. Items range from  0 ... 255 and are defined as follows:
351  //
352  //   0          -  NIL item, not used
353  //   1  ..  63  -  Node / port / driver reserved area items, global items for GET/SET/REQ requests.
354  //  64  .. 127  -  User defined items, specific meaning, accessed via the REQ routine.
355  // 128  .. 191  -  Node / port / driver data attributes returned from MEM for GET/SET.
356  // 192  .. 255  -  Node / port / driver data attributes copied from NVM to MEM for GET, copied from MEM to NVM
357  //                 for SET. The item range mirrors items 128 - 191. For example, 128 and 192 refer to the same
358  //                 attribute. Note that for a SET on a driver the HW needs to be enabled.
359  //
360  // The following declarations does just list the item numbers defined. The ranges are defined in the internal
361  // include file. The ranges as well as the reserved items defined here should not be tampered with.
362  //
363  // ??? to be sorted when more stable...
364  //-----------------------------------------------------------------------------------------------------
365  enum LcsItems : uint8_t {
366
367      ITEM_ID_OPTIONS               = 1,
368      ITEM_ID_FLAGS                 = 2,
369      ITEM_ID_DEBUG_MASK            = 3,
370      ITEM_ID_VERSION               = 4,
371      ITEM_ID_TYPE                  = 5,
372
373      ITEM_ID_BOARD_VERSION         = 6,
374      ITEM_ID_CONTROLLER_FAMILY     = 7,
375      ITEM_ID_NVM_CHIP_FAMILY       = 8,
376
377      ITEM_ID_NODE_ID               = 10,
378      ITEM_ID_NODE_UID              = 11,
379      ITEM_ID_RESTART_COUNT         = 12,
380
381      ITEM_ID_PORT_MAP_ENTRIES      = 13,
382      ITEM_ID_EVENT_MAP_ENTRIES     = 14,
383      ITEM_ID_ATTR_MAP_ENTRIES      = 15,
384
385      ITEM_ID_NAME_1                = 17,
386      ITEM_ID_NAME_2                = 18,
387      ITEM_ID_NAME_3                = 19,
388      ITEM_ID_NAME_4                = 20,
389
390      ITEM_ID_EVENT_DELAY_TICKS     = 21,
391
392      ITEM_ID_RESET                 = 22,
393      ITEM_ID_SYNC                  = 23,
394      ITEM_ID_FORMAT                = 24,
395
```

```
396        ITEM_ID_ADD_EVENT_MAP_ENTRY          = 25,
397        ITEM_ID_DEL_EVENT_MAP_ENTRY          = 26,
398        ITEM_ID_GET_EVENT_MAP_ENTRY          = 27,
399
400        ITEM_ID_SET_READY_LED                = 30,
401        ITEM_ID_SET_ACTIVITY_LED             = 31,
402        ITEM_ID_TOGGLE_READY_LED             = 32,
403        ITEM_ID_TOGGLE_ACTIVITY_LED          = 33,
404
405        ITEM_ID_NVM_PROTECTED_ACCESS         = 35,
406
407        ITEM_ID_ENABLE_EVENT_PROCESSING      = 40,
408
409        // ??? add stop and enable periodic processing ?
410   };
411
412   //-----------------------------------------------------------------------------------------------------
413   // The portMap entry has a flag field. The constants defined here indicate the bit positions and fields
414   // defined.
415   //
416   //   PF_PORT_ENABLED                  - the port is initialized and active
417   //   PF_PORT_EVENT_HANDLING_ENABLED   - the port has event handling enabled
418   //   PF_EVENT_PENDING                 - an event has been received for this port and is pending.
419   //
420   //-----------------------------------------------------------------------------------------------------
421   enum LcsPortFlags : uint16_t {
422
423        PF_NIL                          = 0,
424        PF_PORT_ENABLED                 = ( 1 << 15 ),
425        PF_PORT_EVENT_HANDLING_ENABLED  = ( 1 << 14 ),
426        PF_EVENT_PENDING                = ( 1 << 13 )
427   };
428
429   //-----------------------------------------------------------------------------------------------------
430   // The port event action. When an event is received, it will be of the type shown below. There is an
431   // optional port specific time delay configured between the actual receipt of an event message and the
432   // invocation of the event callback.
433   //
434   //   PEA_EVENT_IDLE               - the port is idle.
435   //   PEA_EVENT_ON                 - an "ON" event was received.
436   //   PEA_EVENT_OFF                - an "OFF" event was received.
437   //   PEA_EVENT_EVT                - an event with additional arguments was received.
438   //
439   //-----------------------------------------------------------------------------------------------------
440   enum LcsPortEventAction : uint8_t {
441
442        PEA_EVENT_IDLE    = 0,
443        PEA_EVENT_ON      = 1,
444        PEA_EVENT_OFF     = 2,
445        PEA_EVENT_EVT     = 3
446   };
447
448   //-----------------------------------------------------------------------------------------------------
449   // The debug mask. The library has a debug mask where each major part of the library has a flag. There could
450   // also be flags reserved for the firmware. There is an ITEM to read and set this mask. Wherever debugging is
451   // needed, the bit mask will be used to determine whether to print debugging data or not. From a performance
452   // perspective, the test will take just a few instructions. In other words we do not take out debugging code
453   // when going into production. Never liked this approach of conditional debug anyway.
454   //
455   // The usage of the debug mask is generally:
456   //
457   //       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_xxx )) ....
458   //
459   // The DBG_CONFIG bit allows for the entire debugging messages to be enabled or disabled. This feature will
460   // also be used when we test whether we even have a console or not. If there is no console, all the prints
461   // will not be executed.
462   //
463   //-----------------------------------------------------------------------------------------------------
464   enum DebugOtions : uint16_t {
465
466        DBG_CONFIG         = ( 1U << 15 ),
467        DBG_SETUP          = ( 1U << 0 ),
468        DBG_NVM_ACCESS     = ( 1U << 1 ),
469        DBG_CAN_BUS        = ( 1U << 2 ),
470        DBG_MSG_BUS        = ( 1U << 3 ),
471        DBG_ATTRIBUTES     = ( 1U << 4 ),
472        DBG_EVENTS         = ( 1U << 5 )
473   };
474
475   //-----------------------------------------------------------------------------------------------------
476   // The message operation code identifies the LCS bus message. It is always the first data byte of the
477   // message. We encode the number of payload data bytes in the first three bits of the opCode. For each
478   // message length there is a maximum of 32 opCode possible. The OPC  macro helps to define the opcodes.
479   // The first argument is the length of the data bytes, the second the opcodeId within the group.
480   //
481   // ??? note: this list is work in progress, please us always the names rather than the numbers.
482   //-----------------------------------------------------------------------------------------------------
483   #define OPC( len, id ) ((uint8_t) (( len << 5 ) + ( id & 0x1F )))
484
485   enum LcsMsgOpCodes : uint8_t {
486
487        LCS_OP_NO_MSG            = OPC( 0, 0 ),
488        LCS_OP_CFG               = OPC( 0, 1 ),
489        LCS_OP_OPS               = OPC( 0, 2 ),
490        LCS_OP_BON               = OPC( 0, 3 ),
491        LCS_OP_BOF               = OPC( 0, 4 ),
492
493        LCS_OP_REL_LOC           = OPC( 1, 1 ),
494        LCS_OP_QRY_LOC           = OPC( 1, 2 ),
```

```
495       LCS_OP_KEEP_LOC           = OPC( 1, 3 ),
496       LCS_OP_ESTP               = OPC( 1, 4 ),
497
498       LCS_OP_PING               = OPC( 2, 1 ),
499       LCS_OP_ACK                = OPC( 2, 2 ),
500       LCS_OP_DCC_ACK            = OPC( 2, 3 ),
501       LCS_OP_SET_LSPD           = OPC( 2, 4 ),
502       LCS_OP_SET_LMOD           = OPC( 2, 5 ),
503       LCS_OP_LOC_FON            = OPC( 2, 6 ),
504       LCS_OP_LOC_FOF            = OPC( 2, 7 ),
505       LCS_OP_BACC               = OPC( 2, 8 ),
506       LCS_OP_EACC               = OPC( 2, 9 ),
507       LCS_OP_TON                = OPC( 2, 10 ),
508       LCS_OP_TOF                = OPC( 2, 11 ),
509
510       LCS_OP_RESET              = OPC( 3, 1 ),
511       LCS_OP_REQ_LOC            = OPC( 3, 2 ),
512       LCS_OP_SET_LCON           = OPC( 3, 3 ),
513       LCS_OP_LOC_FGRP           = OPC( 3, 4 ),
514       LCS_OP_SEND_DCC3          = OPC( 3, 5 ),
515       LCS_OP_DCC_ERR            = OPC( 3, 6 ),
516       LCS_OP_REQ_CVS            = OPC( 3, 7 ),
517
518       LCS_OP_EVT_ON             = OPC( 4, 1 ),
519       LCS_OP_EVT_OFF            = OPC( 4, 2 ),
520       LCS_OP_SEND_DCC4          = OPC( 4, 3 ),
521       LCS_OP_REP_CVS            = OPC( 4, 4 ),
522       LCS_OP_SET_CVS            = OPC( 4, 5 ),
523       LCS_SYS_TIME              = OPC( 4, 6 ),
524
525       LCS_OP_ERR                = OPC( 5, 1 ),
526       LCS_OP_SET_CVM            = OPC( 5, 2 ),
527       LCS_OP_SEND_DCC5          = OPC( 5, 3 ),
528
529       LCS_OP_EVT                = OPC( 6, 1 ),
530       LCS_OP_SEND_DCC6          = OPC( 6, 2 ),
531       LCS_OP_NCOL               = OPC( 6, 6 ),
532
533       LCS_OP_REQ_NID            = OPC( 7, 1 ),
534       LCS_OP_REP_NID            = OPC( 7, 2 ),
535       LCS_OP_SET_NID            = OPC( 7, 3 ),
536       LCS_OP_NODE_GET           = OPC( 7, 4 ),
537       LCS_OP_NODE_PUT           = OPC( 7, 5 ),
538       LCS_OP_NODE_REQ           = OPC( 7, 6 ),
539       LCS_OP_NODE_REP           = OPC( 7, 7 ),
540       LCS_OP_REP_LOC            = OPC( 7, 8 ),
541       LCS_INFO                  = OPC( 7, 9 )
542   };
543
544   //-------------------------------------------------------------------------------------------------
545   // LCS Core Library Error codes. The status code is used as a return value from most of the library methods.
546   // The numbers are grouped in a LCS library portion and a user firmware portion. The LCS library portion
547   // ranges from 1 to 127, the user portion from 128 to 255. The value of zero is generally an "OK".
548   //
549   // ??? add NVM errors, also CDC errors ?
550   //-------------------------------------------------------------------------------------------------
551   enum LcsErrorCodes : uint8_t {
552
553       ALL_OK                         = 0,
554       ERR_NOT_IMPLEMENTED            = 1,
555       ERR_NOT_SUPPORTED              = 2,
556       ERR_LIB_NOT_INITIALIZED        = 3,
557
558       ERR_CDC_SETUP                  = 10,
559       ERR_NVM_SETUP                  = 11,
560       ERR_MEM_SETUP                  = 12,
561       ERR_CAN_SETUP                  = 13,
562
563       ERR_NVM_CHIP_SIZE_DETECT       = 14,
564       ERR_NVM_NODE_MAP_CORRUPT       = 15,
565       ERR_NVM_SIZE_EXCEEDED          = 16,
566       ERR_MEM_SIZE_EXCEEDED          = 17,
567       ERR_NVM_OP_FAILED              = 18,
568
569       ERR_NODE_NOT_OPS_STATE         = 20,
570       ERR_NODE_NOT_CONFIG_STATE      = 21,
571       ERR_NODE_OUTSTANDING_REQ_LIMIT = 22,
572       ERR_TASK_MAP_SIZE_EXCEEDED     = 23,
573
574       ERR_INVALID_NODE_ID            = 30,
575       ERR_INVALID_PORT_ID            = 31,
576       ERR_INVALID_ITEM_ID            = 32,
577       ERR_INVALID_EVENT_ID           = 33,
578       ERR_INVALID_BOARD_ID           = 34,
579       ERR_INVALID_DRV_ITEM           = 35,
580       ERR_INVALID_ATTR_ARG           = 36,
581
582       ERR_INVALID_EVENT_MAP_INDEX    = 51,
583       ERR_EVENT_MAP_FULL             = 52,
584       ERR_PENDING_REQ_MAP_FULL       = 53,
585       ERR_REQ_TIMEOUT                = 54,
586
587       ERR_INVALID_SESSION_ID         = 60,
588       ERR_INVALID_CAB_ID             = 61,
589       ERR_INVALID_LOCO_SPEED         = 62,
590       ERR_INVALID_FGROUP_ID          = 63,
591       ERR_INVALID_FUNC_ID            = 64,
592       ERR_INVALID_CV_ID              = 65,
593       ERR_INVALID_CV_MODE            = 66,
```

```
594         ERR_CV_OP_NO_ACK                    = 67,
595         ERR_INVALID_BIT_POS                 = 68,
596         ERR_INVALID_PACKET_LEN              = 69,
597         ERR_INVALID_REPEATS                 = 70,
598
599         ERR_DRV_FUNC_MAP_FULL               = 75,
600         ERR_DRV_PUT_ERR                     = 76,
601         ERR_DRV_GET_ERR                     = 77,
602
603         ERR_CAN_BUS_INIT                    = 81,
604         ERR_CAN_INVALID_MODE                = 82,
605         ERR_CAN_BUS_MSG_SIZE                = 83,
606         ERR_CAN_MSG_SEND                    = 84,
607         ERR_CAN_MSG_RECV                    = 85,
608         ERR_CAN_MSG_NO_MSG                  = 86,
609         ERR_CAN_ID_COLLISION                = 87,
610         ERR_CAN_ID_CHANGED                  = 88,
611
612         ERR_EXT_BOARD_NOT_VALID             = 254,
613
614         ERR_USER_SPECIFIC_BASE              = 128
615     };
616
617     //------------------------------------------------------------------------------------------------------
618     // The CAN bus mode. The PICO_PIO_xxx modes use the Raspberry Pi Pico "can2040" library, which is a software
619     // implementation of the CAN bus. The "can2040" library could run on the same or on the separate processor
620     // core. Technically, the PICO could also run the MCP2515 via the SPI interface, but so far we just use the
621     // software version and avoid the additional controller hardware.
622     //
623     //------------------------------------------------------------------------------------------------------
624     enum CanBusControllerMode : uint8_t {
625
626         CAN_BUS_LIB_PICO_PIO_125K               = 1,
627         CAN_BUS_LIB_PICO_PIO_250K               = 2,
628         CAN_BUS_LIB_PICO_PIO_500K               = 3,
629         CAN_BUS_LIB_PICO_PIO_1000K              = 4,
630
631         CAN_BUS_LIB_PICO_PIO_125K_M_CORE        = 11,
632         CAN_BUS_LIB_PICO_PIO_250K_M_CORE        = 12,
633         CAN_BUS_LIB_PICO_PIO_500K_M_CORE        = 13,
634         CAN_BUS_LIB_PICO_PIO_1000K_M_CORE       = 14,
635     };
636
637     //------------------------------------------------------------------------------------------------------
638     // "MsgPriority" defines the values for the message priority. It tracks the general definition found in the
639     // sendMsg routines of the LCS library. For the CAN bus, the priority is encoded in the CAN address field.
640     // A CAN Id consists of the CAN Id number and the priority. Messages start out with a hard coded priority and
641     // on message timeout are raised in their priority. This done transparently to the firmware programmer.
642     //
643     //------------------------------------------------------------------------------------------------------
644     enum MsgPriority : uint8_t {
645
646         MSG_PRI_VERY_HIGH   = 0,
647         MSG_PRI_HIGH        = 1,
648         MSG_PRI_NORMAL      = 2,
649         MSG_PRI_LOW         = 3
650     };
651
652     //------------------------------------------------------------------------------------------------------
653     // Core library callback function signatures. Callbacks are registered by the firmware at setup time and
654     // invoked as the communication back to the firmware layer.
655     //
656     //      LcsMsgCallback      -   is called with a LCS management message received.
657     //      LcsCmdCallback      -   when the command interpreter detects a non LCS command, the command line
658     //                              is passed on to the callback.
659     //      LcsTaskCallback     -   a callback for a previously registered task. The callback is invoked on
660     //                              the configured periodic basis.
661     //
662     //      LcsResetCallback    -   a callback invoked when a reset is performed. The npId is passed so that
663     //                              the callback can detect wether a port or node is the target.
664     //
665     //      LcsInitCallback     -   a callback called at initialization time, as part of "startRuntime". The
666     //                              npId is passed so that the callback can detect wether a port or node is
667     //                              the target.
668     //
669     //      LcsPfailCallback    -   a callback when a power fail situation is detected. The npId is passed
670     //                              so that the callback can detect wether a port or node is the target.
671     //
672     //      LcsReqCallback      -   a callback to invoke for a user request message. The callback is passed
673     //                              the item and a reference to the two input / output arguments.
674     //
675     //      LcsRepCallback      -   a callback to return the reply message for a previous LCS message sent. The
676     //                              reply can be a data reply, an ACK or NACK or a timeout error. The arguments
677     //                              are the item that was requested, the arguments and the return status of the
678     //                              operation.
679     //
680     //      LcsEventCallback    -   a callback for a received event. The arguments are the issuing npId, the
681     //                              event type and the optional arguments.
682     //
683     // All callback functions need to return a status, which is ALL_OK if the callback was successful.
684     //
685     //------------------------------------------------------------------------------------------------------
686     extern "C" {
687
688         typedef uint8_t ( *LcsMsgCallback ) ( uint8_t *msg );
689         typedef uint8_t ( *LcsCmdCallback ) ( char *cmdLine );
690         typedef uint8_t ( *LcsTaskCallback ) ( void );
691
692         typedef uint8_t ( *LcsResetCallback ) ( uint16_t npId );
```

```
693        typedef uint8_t ( *LcsInitCallback ) ( uint16_t npId );
694        typedef uint8_t ( *LcsPfailCallback ) ( uint16_t npId );
695
696        typedef uint8_t ( *LcsReqCallback ) ( uint8_t portId, uint8_t item, uint16_t *arg1, uint16_t *arg2 );
697        typedef uint8_t ( *LcsRepCallback ) ( uint8_t portId, uint8_t item, uint16_t arg1, uint16_t arg2, uint8_t ret );
698
699        typedef uint8_t ( *LcsEventCallback ) ( uint16_t npId, uint16_t eId, uint8_t eAction, uint16_t eData );
700 }
701
702 //-----------------------------------------------------------------------------------------------------------
703 // A  driver for an extension board is invoked through this routine signature. During setup, the correct
704 // driver label needs to be set in the driver map.
705 //
706 //-----------------------------------------------------------------------------------------------------------
707 extern "C" {
708
709        typedef uint8_t ( *LcsDrvReqFunc ) ( uint8_t boardId, uint8_t item, uint16_t *arg1, uint16_t *arg2 );
710 }
711
712 //-----------------------------------------------------------------------------------------------------------
713 // "LcsConfigDesc" is the data structure that contains initial data for setting up a node. There is the
714 // option field with bits.
715 //
716 // ??? also add the CAN bus mode ?
717 //-----------------------------------------------------------------------------------------------------------
718 struct LcsConfigDesc {
719
720     uint16_t options  = 0;
721
722 };
723
724 //-----------------------------------------------------------------------------------------------------------
725 // Library functions. The main function are the initialization and start of the LCS runtime. Between "init"
726 // and "start", the firmware should do its own setup and register the required callbacks. We will not return
727 // from the "start" routine. All call a plain C style library calls. Since we have only one instance of this
728 // library, there is not really a need to encapsulate the internal data and function pointers in a structure
729 // that is passed to each call. However, data structures are kept wherever possible local to the file and
730 // only structures that are references throughout the library file set are available externally. Perhaps
731 // one day, we encapsulate all data in a private structure for security reasons. To be determined.
732 //
733 //-----------------------------------------------------------------------------------------------------------
734 LcsConfigDesc       getConfigDefault( );
735 uint8_t             initRuntime( LcsConfigDesc *lcsConfig, CDC::CdcConfigDesc *cdcConfig );
736 void                startRuntime( );
737
738 //-----------------------------------------------------------------------------------------------------------
739 // Access the node local GET/SET/REQ items. Although we pass the node/port Id, only the port Id is actually
740 // used to identify whether we refer to a local port or the local node. Accessing a remote node / port is
741 // implemented with the LCS library message send calls.
742 //
743 //-----------------------------------------------------------------------------------------------------------
744 uint8_t             nodeGet( uint16_t npId, uint8_t item, uint16_t *arg1, uint16_t *arg2 = nullptr );
745 uint8_t             nodePut( uint16_t npId, uint8_t item, uint16_t arg1, uint16_t arg2 = 0 );
746 uint8_t             nodeReq( uint16_t npId, uint8_t item, uint16_t *arg1 = nullptr, uint16_t *arg2 = nullptr );
747
748 //-----------------------------------------------------------------------------------------------------------
749 // Function registration routines for callbacks, tasks, driver types, etc.
750 //
751 //-----------------------------------------------------------------------------------------------------------
752 void                registerLcsMsgCallback( LcsMsgCallback functionId );
753 void                registerDccMsgCallback( LcsMsgCallback functionId );
754 void                registerCmdCallback( LcsCmdCallback functionId );
755 void                registerInitCallback( LcsInitCallback handler );
756 void                registerResetCallback( LcsResetCallback handler );
757 void                registerPfailCallback( LcsPfailCallback handler );
758 void                registerEventCallback( LcsEventCallback functionId );
759 void                registerReqCallback( LcsReqCallback handler );
760 void                registerRepCallback( LcsRepCallback handler );
761 uint8_t             registerTaskCallback( LcsTaskCallback task, uint32_t interval = 0 );
762 uint8_t             registerDrvFunc( uint16_t drvType, LcsDrvReqFunc drvReqFunction );
763
764 //-----------------------------------------------------------------------------------------------------------
765 // A set of convenience functions to send an LCS message.
766 //
767 //-----------------------------------------------------------------------------------------------------------
768 uint8_t             sendCfg( uint16_t npId );
769 uint8_t             sendOps( uint16_t npId );
770 uint8_t             sendReset( uint16_t npId );
771 uint8_t             sendBusOn( );
772 uint8_t             sendBusOff( );
773 uint8_t             sendPing( uint16_t npId );
774 uint8_t             sendAck( uint16_t npId );
775 uint8_t             sendErr( uint16_t npId, uint8_t errCode, uint8_t arg1 = 0, uint8_t arg2 = 0 );
776
777 uint8_t             sendReqNodeId( uint16_t npId, uint32_t nodeUID, uint8_t flags );
778 uint8_t             sendRepNodeId( uint16_t npId, uint32_t nodeUID );
779 uint8_t             sendSetNodeId( uint16_t npId, uint32_t nodeUID );
780 uint8_t             sendNodeIdCollision( uint16_t npId, uint32_t nodeUID );
781
782 uint8_t             sendGetNode( uint16_t npId, uint8_t item, uint16_t arg1 = 0, uint16_t arg2 = 0 );
783 uint8_t             sendSetNode( uint16_t npId, uint8_t item, uint16_t arg1 = 0, uint16_t arg2 = 0 );
784 uint8_t             sendRepNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2  );
785 uint8_t             sendReqNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2  );
786
787 uint8_t             sendEventOn( uint16_t npId, uint16_t eventId );
788 uint8_t             sendEventOff( uint16_t npId, uint16_t eventId );
789 uint8_t             sendEvent( uint16_t npId, uint16_t eventId, uint16_t arg );
790
791 uint8_t             sendTrackOn( );
```

```
792   uint8_t              sendTrackOff( );
793   uint8_t              sendEstop( );
794
795   uint8_t              sendReqLoc( uint16_t locAdr, uint8_t flags  );
796   uint8_t              sendRelLoc( uint8_t sId  );
797   uint8_t              sendRepLoc( uint8_t sId, uint16_t locAdr, uint8_t spDir, uint8_t fn1 = 0, uint8_t fn2 = 0, uint8_t fn3 = 0 );
798   uint8_t              sendLocConsist( uint8_t sId, uint8_t consId, uint8_t flags );
799   uint8_t              sendQueryLoc( uint8_t sId   );
800   uint8_t              sendKeepLoc( uint8_t sId  );
801   uint8_t              sendSetLocSpDir( uint8_t sId, uint8_t spDir );
802   uint8_t              sendSetLocMode( uint8_t sId, uint8_t mode );
803   uint8_t              sendSetLocFuncOn( uint8_t sId, uint8_t fNum );
804   uint8_t              sendSetLocFuncOff( uint8_t sId, uint8_t fNum );
805   uint8_t              sendSetLocFgroup( uint8_t sId, uint8_t fGroup, uint8_t data );
806
807   uint8_t              sendSetLocCvMain( uint8_t sId, uint16_t cvId, uint8_t mode, uint8_t val );
808   uint8_t              sendSetLocCvProg( uint16_t cvId, uint8_t mode, uint8_t val );
809   uint8_t              sendReqLocCvProg( uint16_t cvId, uint8_t mode );
810   uint8_t              sendRepLocCvProg( uint16_t cvId, uint8_t val );
811
812   uint8_t              sendSetBacc( uint16_t accAdr, uint8_t flags  );
813   uint8_t              sendSetEacc( uint16_t accAdr, uint8_t val  );
814
815   uint8_t              sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3 );
816   uint8_t              sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4 );
817   uint8_t              sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4, uint8_t arg5 );
818   uint8_t              sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4, uint8_t arg5, uint8_t arg6 );
819
820   uint8_t              sendDccAck( );
821   uint8_t              sendDccErr( uint8_t errCode, uint8_t arg1 = 0, uint8_t arg2 = 0 );
822
823   uint8_t              sendRawMsg( uint8_t *msgBuf );
824
825   void                 printLcsMs( uint8_t *msgBuf );
826
827   //-------------------------------------------------------------------------------------------------------------
828   // The driver interface. The firmware communicated with an extension board by making calls to the driver
829   // for the board. Just like for the node / port items, there are routines to GET/SET/REQ driver data and
830   // functions. The init function is only called by the library at setup time.
831   //
832   //-------------------------------------------------------------------------------------------------------------
833   uint8_t              drvInit( uint8_t boardId );
834   uint8_t              drvGet( uint8_t boardId, uint8_t item, uint16_t *arg );
835   uint8_t              drvPut(uint8_t boardId, uint8_t item, uint16_t arg );
836   uint8_t              drvReq( uint8_t boardId, uint8_t item, uint16_t *arg1 = nullptr, uint16_t *arg2 = nullptr );
837
838   //-------------------------------------------------------------------------------------------------------------
839   // The User Map interface. The LCS library offers a set of routines for the firmware to access the user
840   // NVM area. The size is dependent on what the actual chip on the board offers. The meaning of this data
841   // area is entirely firmware specific. Note that there are also routines for accessing the runtime data
842   // area as well as the individual extension board areas. They are declared in the internal include file.
843   //
844   //-------------------------------------------------------------------------------------------------------------
845   uint8_t              usrNvmPutWord( uint32_t ofs, uint16_t word );
846   uint8_t              usrNvmGetWord( uint32_t ofs, uint16_t *word );
847   uint8_t              usrNvmPutBytes( uint32_t ofs, uint8_t *buf, uint32_t len );
848   uint8_t              usrNvmGetBytes( uint32_t ofs, uint8_t *buf, uint32_t len );
849   uint8_t              usrNvmInitArea( uint32_t ofs, uint32_t len, uint8_t val);
850   uint32_t             usrNvmGetSize( );
851
852   }; // LCS NameSpace
853
854   #endif
```

```
1    //------------------------------------------------------------------------------------------------------
2    //
3    // Layout Control System - Runtime Library internals include file
4    //
5    //------------------------------------------------------------------------------------------------------
6    // The LCS library internal definitions are all grouped in this include file. A firmware write needs to only
7    // include the external include file. There is nothing in here that is needed outside.
8    //
9    //------------------------------------------------------------------------------------------------------
10   //
11   // LCS - Core Library
12   // Copyright (C) 2021 - 2024  Helmut Fieres
13   //
14   // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
15   // General Public License as published by the Free Software Foundation, either version 3 of the License,
16   // or any later version.
17   //
18   // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
19   // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
20   // License for more details. You should have received a copy of the GNU General Public License along with
21   // this program.  If not, see <http://www.gnu.org/licenses/>.
22   //
23   //------------------------------------------------------------------------------------------------------
24   #ifndef LCS_RT_LIB_INT_h
25   #define LCS_RT_LIB_INT_h
26
27   //------------------------------------------------------------------------------------------------------
28   // Include files. Besides the standard C libraries, there is the external LCS runtime include file, and the
29   // dependent code library include file.
30   //
31   //------------------------------------------------------------------------------------------------------
32   #include <stdint.h>
33   #include <ctype.h>
34   #include "LcsCdcLib.h"
35   #include "LcsRuntimeLib.h"
36
37   namespace LCS {
38
39   //------------------------------------------------------------------------------------------------------
40   // The LCS Runtime needs to maintain a couple of internal data structures. As a general concept, most of the
41   // data areas are stored in the NVM and shadowed by a memory copy. Upon reset or power up the memory areas
42   // are initialized from their NVM counter parts. Data that needs to be changed permanently is flushed from
43   // memory to NVM so that it is the initial value on the next restart. All data is stored in controller native
44   // endianness. Only the messages exchanged via the LcsMsgBus are transmitted in big endian order.
45   //
46   // The NVM layout is a fixed one. We have the nodeMap starting at offset zero, The CDC map starting at offset
47   // 0x200, the portMap starting at offset 0x400, the attributeMap starting at offset 0x800 and the eventMap
48   // at offset 0x1000. The system area is in total 8 Kbytes. The optional user map occupies all the remaining
49   // bytes in the NVM and starts at 0x2000. A firmware programmer can access the system as well as the user
50   // data areas. However, note that dangerous things can be done when modifying the system area directly.
51   //
52   //          0x0000    :-------------------------------------------:
53   //                    :                                           :
54   //                    :          Node Map                         :
55   //                    :                                           :
56   //          0x0200    :-------------------------------------------:
57   //                    :                                           :
58   //                    :          CDC Map                          :
59   //                    :                                           :
60   //          0x0400    :-------------------------------------------:
61   //                    :                                           :
62   //                    :          Port Map                         :
63   //                    :                                           :
64   //          0x0800    :-------------------------------------------:
65   //                    :                                           :
66   //                    :          Attribute Map                    :
67   //                    :                                           :
68   //          0x1000    :-------------------------------------------:
69   //                    :                                           :
70   //                    :          Event Map                        :
71   //                    :                                           :
72   //          0x2000    :-------------------------------------------:
73   //                    :                                           :
74   //                    :                                           :
75   //                    :                                           :
76   //                    :          Optional User Map                :
77   //                    :                                           :
78   //                    :                                           :
79   //                    :                                           :
80   //          0xNNNN    :-------------------------------------------:
81   //
82   // The node map and port map do not fill the entire area allocated for them. Yet. For future developments,
83   // each area has some spare room. The attribute map contains the variables for the node and ports. Each
84   // entity has 64 attributes max, the attribute map is 1Kbyte in total. By putting all attributes in one
85   // area, access to an attribute value is easy to calculate and quick.
86   //
87   // The event map is an area with 4-byte entries. A node can keep track of up to 1024 event/port pairs.
88   // The event map is a sorted map, lookup is done via a binary search. Finally, the optional user map
89   // data area is just a set of bytes with a structure only know to the firmware designer.
90   //
91   // In general each of the runtime areas could have also been designed in a way that they are dynamically
92   // configurable in size. For example, a port map could be up to 15 ports but also less. The attributes of
93   // a node or port could be up to 64 attributes or less. Considering the size and price of NVM chips as well
94   // as the memory size of the supported controller platforms, the current implementation uses fixed sizes
95   // for each area, avoiding configuration complexity.
96   //
97   //------------------------------------------------------------------------------------------------------
98   const uint16_t  MAX_NODE_DATA_BLOCKS          = 16;
```

```cpp
 99   const uint16_t  MAX_ATTR_MAP_ENTRIES           = 64;
100   const uint16_t  MAX_PORT_MAP_ENTRIES           = 15;
101   const uint16_t  MAX_EVENT_MAP_ENTRIES          = 1024;
102   const uint16_t  MAX_TASK_MAP_ENTRIES           = 16;
103
104   const uint16_t  MAX_LCS_MSG_SIZE               = 8;
105   const uint16_t  MAX_NODE_NAME_SIZE             = 16;
106   const uint16_t  MAX_PORT_NAME_SIZE             = 16;
107   const uint16_t  MAX_BOARD_NAME_SIZE            = 16;
108   const uint16_t  MAX_COMMAND_LINE_SIZE          = 256;
109
110   const uint16_t  MAX_EXT_BOARD_MAP_ENTRIES      = 4;
111   const uint16_t  MAX_PENDING_REQ_MAP_ENTRIES    = 8;
112   const uint16_t  EVENT_DELAY_TICK_MILLIS        = 32;
113
114   const uint8_t   MAX_DRV_TYPES                  = 8;
115   const uint8_t   MAX_EXT_BOARDS                 = 4;
116   const uint8_t   MAX_DRV_DATA_SIZE              = 64;
117
118   const uint16_t  NVM_NODE_MAP_START             = 0;
119   const uint16_t  NVM_CDC_MAP_START              = 0x200;
120   const uint16_t  NVM_PORT_MAP_START             = 0x400;
121   const uint16_t  NVM_NODE_DATA_START            = 0x800;
122   const uint16_t  NVM_EVENT_MAP_START            = 0x1000;
123   const uint16_t  NVM_USER_MAP_START             = 0x2000;
124   const uint16_t  NVM_RUNTIME_AREA_SIZE          = 0x2000;
125
126   //-------------------------------------------------------------------------------------------------------
127   // The nodeMap on NVM has two locations with a "magic" word. We simply read in a nodeMap and check these
128   // two locations for the magic words. If found, the area was configured before. It would be quite unlikely
129   // that a random NVM content has these two words at the right spot. In a similar way, we have two magic
130   // words for the NVM in an extension board. Same idea, same logic. But even if the area was configured
131   // before, it does not automatically mean that all the data is correct. Further checking will be done
132   // during startup.
133   //
134   //-------------------------------------------------------------------------------------------------------
135   const uint16_t NVM_MWORD_1 = (uint16_t) ( 'L' << 8 ) + 'C';
136   const uint16_t NVM_MWORD_2 = (uint16_t) ( 'S' << 8 ) + 'O';
137
138   //-------------------------------------------------------------------------------------------------------
139   // The node states. The node starts in the INIT state and once all is initialized and registered ends up in
140   // the OPS or CFG mode.
141   //
142   //   NS_NIL          -
143   //   NS_FAIL         -   The node startup failed.
144   //   NS_PFAIL        -   The node startup detected that we come up after a power fail.
145   //   NS_INIT         -   The node entered the startup state.
146   //   NS_REGISTER     -   The node entered the node register state, awaiting a nodeId.
147   //   NS_COLLISION    -   The node detected a nodeId collision on the LCS bus.
148   //   NS_HALTED       -   The node was halted.
149   //   NS_CONFIG       -   The node is in configuration mode.
150   //   NS_OPERATE      -   The node is on operations mode.
151   //
152   //-------------------------------------------------------------------------------------------------------
153   enum LcsNodeState : uint16_t {
154
155       NS_NIL             = 0,
156       NS_FAIL            = 1,
157       NS_PFAIL           = 2,
158       NS_INIT            = 3,
159       NS_REGISTER        = 4,
160       NS_COLLISION       = 5,
161       NS_HALTED          = 6,
162       NS_CONFIG          = 7,
163       NS_OPERATE         = 8
164   };
165
166   //-------------------------------------------------------------------------------------------------------
167   // Nodes, ports and drivers are accessed with three main routines, GET, SET and REQ.
168   //
169   // GET - the get routine will use the item numbers to retrieve the data labelled by the item.
170   //
171   // SET - the set routine will use the item numbers to set the value. Note that not all items that can be
172   // read can also be written to. An attempt will result in an error return.
173   //
174   // REQ - the request call will transmit the request parameters to the node / port / driver where a registered
175   // callback or the driver entry point will be invoked. The result is returned via the parameters.
176   //
177   // One argument is the item. Items range from  0 ... 255 and are defined as follows:
178   //
179   //    0         -   NIL item, not used
180   //    1  ..  63 -   Node / port / driver reserved area items, global items for GET/SET/REQ requests.
181   //   64  .. 127 -   User defined items, specific meaning, accessed via the REQ routine.
182   //  128  .. 191 -   Node / port / driver data attributes returned from MEM for GET/SET.
183   //  192  .. 255 -   Node / port / driver data attributes copied from NVM to MEM for GET, copied from MEM to NVM
184   //                  for SET. The item range mirrors items 128 - 191. For example, 128 and 192 refer to the same
185   //                  attribute. Note that for a SET on a driver the HW needs to be enabled.
186   //
187   // The items are defined in the external include file. This part here defined the boundaries for internal
188   // checking.
189   //
190   //-------------------------------------------------------------------------------------------------------
191   enum ItemRanges : uint8_t {
192
193       IR_NIL                   = 0,
194
195       IR_LIB_MAP_RANGE_START   = 1,
196       IR_LIB_MAP_RANGE_END     = 63,
197
```

```
198        IR_USER_RANGE_START          = 64,
199        IR_USER_RANGE_END            = 127,
200
201        IR_ATTR_MEM_RANGE_START      = 128,
202        IR_ATTR_MEM_RANGE_END        = 191,
203
204        IR_ATTR_NVM_RANGE_START      = 192,
205        IR_ATTR_NVM_RANGE_END        = 255,
206
207        IR_MAX_ITEMS                 = 255
208  };
209
210  //----------------------------------------------------------------------------------------------------------------
211  // "LcsMsgBusCAN" is the CAN bus interface. The two key routines are the send and receive routines. For
212  // debugging purposes a debug level can be set so that diagnostic messages are displayed to the console.
213  //
214  //----------------------------------------------------------------------------------------------------------------
215  struct LcsMsgBusCAN {
216
217      public:
218
219      uint8_t      init( uint16_t canId, uint8_t pinRx, uint8_t pinTx, uint8_t fMode = CAN_BUS_LIB_PICO_PIO_125K );
220
221      uint8_t      sendLcsMsg ( uint8_t *msgBuf, uint8_t msgPri = MSG_PRI_NORMAL );
222      uint8_t      receiveLcsMsg( uint8_t *msg );
223      void         setDebugLevel( uint8_t level );
224
225      private:
226
227      uint16_t   canId = 0;
228  };
229
230
231  //----------------------------------------------------------------------------------------------------------------
232  // Each NVM memory, ie the NVM on the controller board or an extension board, starts with the header data
233  // structure. This structure contains information to detect that the NVM was formatted, as well as some
234  // hardware specific data to identify the board and relevant chips on it. The data in this header must be
235  // "programmed" during a board setup. This is easily accomplished trough console commands and needs of
236  // course only be done once per board. The data structure size is 32 bytes.
237  //
238  //----------------------------------------------------------------------------------------------------------------
239  struct LcsNvmHeader {
240
241      uint16_t    magicWord1                    = NVM_MWORD_1;
242      uint16_t    boardType                     = BT_NIL;
243      uint16_t    boardVersion                  = 0;
244      uint16_t    controllerFamily              = CF_FAM_RPICO;
245      uint16_t    nvmChipFamily                 = CF_FAM_MICROCHIP;
246      uint16_t    reservedArea[ 10 ]            = { 0 };
247      uint16_t    magicWord2                    = NVM_MWORD_2;
248  };
249
250  //----------------------------------------------------------------------------------------------------------------
251  // Every LCS board uses the CDC layer to access the controller hardware. The CDC descriptor contains the
252  // pin configuration data. Currently, the CDC config data is set directly by the application. We copy this
253  // data to the "cfg" structure. One day, we may store this data in the descriptor. So far, this is more of
254  // a place holder.
255  //----------------------------------------------------------------------------------------------------------------
256  struct LcsCdcMap {
257
258      CDC::CdcConfigDesc cfg;
259  };
260
261  //----------------------------------------------------------------------------------------------------------------
262  // An LCS node and the ports on the node each have an area of variables that are in memory as well as in
263  // the node NVM. Typical usage examples are configuration items such as a limit value. Upon power up or
264  // reset, the node data from the NVM area is copied to the MEM counterpart. Although the node and port
265  // attributes are logically part of the portMap and nodeMap, they are kept in this separate structure,
266  // which then is a nice 2 Kbyte block of 16 areas of 64 words each and thus are very easy to access.
267  //
268  //----------------------------------------------------------------------------------------------------------------
269  struct LcsNodeData {
270
271      uint16_t map[ MAX_PORT_MAP_ENTRIES + 1 ][ MAX_ATTR_MAP_ENTRIES ] = { 0 };
272  };
273
274  //----------------------------------------------------------------------------------------------------------------
275  // The port map contains an array of ports, each described by a port map entry. The portMap entry contains
276  // the fields that deal with the actual event received. There are fields for the sending node, the event
277  // and its action. An event can also be invoked with a delay time. The are fifteen entries in the port map.
278  // The portMap starts fixed at NVM offset 0x1000. Each port also has an area of attributes, which are
279  // stored in the data block area.
280  //
281  //----------------------------------------------------------------------------------------------------------------
282  struct LcsPortMapEntry {
283
284      uint16_t   options                      = 0;
285      uint16_t   flags                        = 0;
286      uint16_t   type                         = 0;
287
288      uint16_t   eventNodeId                  = NIL_NODE_ID;
289      uint16_t   eventId                      = NIL_EVENT_ID;
290      uint16_t   eventValue                   = 0;
291      uint16_t   eventAction                  = PEA_EVENT_IDLE;
292      uint16_t   eventDelayTime               = 0;
293      uint32_t   eventTimeStamp               = 0L;
294
295      char       name[ MAX_PORT_NAME_SIZE ]   = { 0 };
296  };
```

```
297
298   struct LcsPortMap {
299
300       LcsPortMapEntry map[ MAX_PORT_MAP_ENTRIES ];
301   };
302
303   //------------------------------------------------------------------------------------------------------------
304   // The event map entry contains the mapping from eventId to portId. Every port interested in a certain event
305   // will have an entry in the event map. It is a sorted table of event and port pairs. A port id of zero
306   // refers to all ports with the event Id. This table is searched for an incoming event to find the ports
307   // that are interested in the event.
308   //
309   //------------------------------------------------------------------------------------------------------------
310   struct LcsEventMapEntry {
311
312       uint16_t eventId  = NIL_EVENT_ID;
313       uint16_t portId   = NIL_PORT_ID;
314   };
315
316   struct LcsEventMap {
317
318       LcsEventMapEntry    map[ MAX_EVENT_MAP_ENTRIES ];
319   };
320
321   //------------------------------------------------------------------------------------------------------------
322   // The first locations of the NVM area on the controller board NVM chip represent the nodeMap. It is the
323   // heart of all data on the node. When bringing up a node, we read in the node map from the NVM. The first
324   // check is whether the nodeMap read is a valid nodeMap.
325   //
326   //------------------------------------------------------------------------------------------------------------
327   struct LcsNodeMap {
328
329       //--------------------------------------------------------------------------------------------------------
330       // NMV header. We read this in first an check for validity.
331       //--------------------------------------------------------------------------------------------------------
332       LcsNvmHeader    head;
333
334       //--------------------------------------------------------------------------------------------------------
335       // Node data.
336       //
337       //--------------------------------------------------------------------------------------------------------
338       uint16_t        nodeState                    = NS_NIL;
339       uint16_t        nodeOptions                  = 0;
340       uint16_t        nodeFlags                    = 0;
341       uint16_t        nodeId                       = NIL_NODE_ID;
342       uint32_t        nodeUID                      = 0L;
343       uint16_t        nodeType                     = NIL_NODE_TYPE;
344       uint16_t        nodeSwVersion                = 0;
345       uint16_t        nodeSwPatchLevel             = 0;
346       uint16_t        nodeRestartCnt               = 0;
347       uint32_t        nodeSystemTime               = 0;
348       uint16_t        nodeMapSize                  = sizeof( LcsNodeMap );
349       char            name[ MAX_NODE_NAME_SIZE ]   = { 0 };
350
351       //--------------------------------------------------------------------------------------------------------
352       // Runtime area offsets in the NVM. We also keep track of the data structure sizes and check when we
353       // read in the maps that they match a give library version.
354       //
355       //--------------------------------------------------------------------------------------------------------
356       uint16_t        nvmNodeMapOfs                = NVM_NODE_MAP_START;
357       uint16_t        nvmNodeMapSize               = sizeof( LcsNodeMap );
358
359       uint16_t        nvmCdcMapOfs                 = NVM_CDC_MAP_START;
360       uint16_t        nvmCdcMapSize                = sizeof( LcsCdcMap );
361
362       uint16_t        nvmPortMapOfs                = NVM_PORT_MAP_START;
363       int16_t         nvmPortMapSize               = sizeof( LcsPortMap );
364
365       uint16_t        nvmNodeDataOfs               = NVM_NODE_DATA_START;
366       uint16_t        nvmNodeDataSize              = sizeof( LcsNodeData );
367
368       uint16_t        nvmEventMapOfs               = NVM_EVENT_MAP_START;
369       uint16_t        nvmEventMapSize              = sizeof( LcsEventMap );
370
371       uint16_t        nvmUserMapOfs                = NVM_USER_MAP_START;
372       uint16_t        nvmUserMapSize               = 0;
373
374       uint32_t        nvmMemSize                   = NVM_RUNTIME_AREA_SIZE;
375
376       //--------------------------------------------------------------------------------------------------------
377       // The number of entries in the core areas and a high water mark.
378       //
379       //--------------------------------------------------------------------------------------------------------
380       uint16_t        portMapEntries               = MAX_PORT_MAP_ENTRIES;
381       uint16_t        portMapHwm                   = 0;
382
383       uint16_t        eventMapEntries              = MAX_EVENT_MAP_ENTRIES;
384       uint16_t        eventMapHwm                  = 0;
385
386       uint16_t        taskMapEntries               = MAX_TASK_MAP_ENTRIES;
387       uint16_t        taskMapHwm                   = 0;
388
389       uint16_t        pendingMapEntries            = MAX_PENDING_REQ_MAP_ENTRIES;
390       uint16_t        pendingMapHwm                = 0;
391
392       uint16_t        drvFuncMapEntries            = MAX_DRV_TYPES;
393       uint16_t        drvFuncMapHwm                = 0;
394
395       uint16_t        drvMapEntries                = MAX_EXT_BOARD_MAP_ENTRIES;
```

```
396        uint16_t          drvMapHwm                        = 0;
397    };
398
399    //------------------------------------------------------------------------------------------------------
400    // The LCS runtime communicates back to the firmware via callbacks. There are global callbacks for message
401    // receipt and events as well as callbacks for the node and ports that can be registered.
402    //
403    //------------------------------------------------------------------------------------------------------
404    struct LcsCallbackMap {
405
406        LcsMsgCallback         lcsMsgCallback          = nullptr;
407        LcsMsgCallback         dccMsgCallback          = nullptr;
408        LcsCmdCallback         cmdLineCallback         = nullptr;
409        LcsEventCallback       eventCallback           = nullptr;
410
411        LcsInitCallback        initCallback            = nullptr;
412        LcsResetCallback       resetCallback           = nullptr;
413        LcsPfailCallback       pfailCallback           = nullptr;
414
415        LcsReqCallback         reqCallback             = nullptr;
416        LcsRepCallback         repCallback             = nullptr;
417    };
418
419    //------------------------------------------------------------------------------------------------------
420    // The core library maintains an array of periodic task items. To balance the needs of other core library
421    // internal periodic tasks, such as checking for incoming messages, the periodic tasks are run one at a
422    // time, round robin, with the other internal tasks interleaving. The structure maintains the task procedure
423    // label, the time it ran the last time, and the interval between invocations. Note that the timing is not
424    // very accurate, but it is guaranteed that a task will eventually run when the interval is reached.
425    //
426    //------------------------------------------------------------------------------------------------------
427    struct LcsPTaskMapEntry {
428
429        LcsTaskCallback     task          = nullptr;
430        uint32_t            timeStamp     = 0;
431        uint32_t            interval      = 0;
432    };
433
434    struct LcsTaskMap {
435
436        LcsPTaskMapEntry    map[ MAX_TASK_MAP_ENTRIES ];
437    };
438
439    //------------------------------------------------------------------------------------------------------
440    // The pending request map keeps track of outstanding requests to another node. We add an entry when our
441    // node sends a "REQ" type packet and clear the entry when the reply comes in. The idea is that we only
442    // invoke the callback when we expect a reply. Additionally, there is a timeout value, so that we can
443    // can invoke the reply callback with a timeout message if requested.
444    //
445    //------------------------------------------------------------------------------------------------------
446    struct LcsPendingReqEntry {
447
448        uint16_t  npId;
449        int32_t   reqTimeoutTs;
450    };
451
452    struct LcsPendingReqMap {
453
454        LcsPendingReqEntry map[ MAX_PENDING_REQ_MAP_ENTRIES ];
455    };
456
457    //------------------------------------------------------------------------------------------------------
458    // Each extension board will have a NVM to store the board configuration data. Similar to the node map of
459    // the controller board, this extension board will have a data structure that is read at initialization time.
460    // The structure of this data is rather simple. We have the common 8-word header which describes the board in
461    // general an area which contains driver relevant information. The board type will tell the setup routines
462    // what driver to load for the extension board. The driver data area is entirely driver specific and the
463    // meaning is only know to the driver software. At startup time, all we have to do then is locate the board
464    // type, load the  respective driver and let the driver code do whatever needs to be done according to the
465    // data area content.
466    //
467    // Note that the extension board NVM data is "read only". To write to it, a jumper is set on the board. The
468    // data area is configured and then the jumper should be removed. This does however not mean that that data
469    // once it is loaded during setup cannot be changed during operations. For example, the driver area is the
470    // "working area" for the driver to keep temporary values. At node restart, all data is set back to the NVM
471    //  data configured on the extension board chip.
472    //
473    //------------------------------------------------------------------------------------------------------
474    struct LcsDrvBoardDesc {
475
476        LcsNvmHeader     head;
477        uint16_t         driverData[ MAX_DRV_DATA_SIZE ]  = { 0 };
478    };
479
480    //------------------------------------------------------------------------------------------------------
481    // An extension board is accessed via a dedicated driver. The firmware is required to register the available
482    // drivers with the runtime. The type and function label are kept in the driver label map. This data is
483    // used when a board os detected to select the correct driver.
484    //
485    //------------------------------------------------------------------------------------------------------
486    struct LcsDrvFuncEntry {
487
488        uint16_t         drvType = BT_NIL;
489        LcsDrvReqFunc    drvFunc = nullptr;
490    };
491
492    struct LcsDrvFuncMap {
493
494        LcsDrvFuncEntry map[ MAX_DRV_TYPES ] = { 0 };
```

```
495  };
496
497  //----------------------------------------------------------------------------------------------------------
498  // The runtime library maintains a driver table, which has for each of the extension boards an entry. The
499  // first board has an index of zero.  While the drivers are set regardless of the order of the extension
500  // boards, the boardId would change with the order of extension boards connected. A firmware either needs
501  // to insist on the correct order or map the extension boards regardless of order.
502  //
503  // The entry contains a set of flags about the driver, the procedure label for the driver code and the
504  // extension board descriptor, which is read in from the extension board NVM area. During startup all
505  // extension boards will be located, if there are any. For each board the correct driver procedure label
506  // will be stored in the driver map entry.
507  //
508  // If the extension board descriptor is invalid, the driver map entry is marked as failed. We can however
509  // still access the data area from configuration tools, when the jumper to enable writing to the board is
510  // set.
511  //
512  //----------------------------------------------------------------------------------------------------------
513  struct LcsDrvEntry {
514
515      uint16_t            flags       = 0;
516      uint16_t            lastErr     = 0;
517      LcsDrvReqFunc       drvFunc     = nullptr;
518
519      LcsDrvBoardDesc     extBoard;
520  };
521
522  struct LcsDrvMap {
523
524      LcsDrvEntry     map[ MAX_EXT_BOARDS ];
525  };
526
527  //----------------------------------------------------------------------------------------------------------
528  // The LCS runtime routine signatures of routines used across the different source files.
529  //
530  // ??? keep this list short... maybe keep local to each file....
531  //----------------------------------------------------------------------------------------------------------
532  uint8_t     configNvm( CDC::CdcConfigDesc *ci );
533
534  uint8_t     rtNvmPutWord( uint32_t ofs, uint16_t word );
535  uint8_t     rtNvmGetWord( uint32_t ofs, uint16_t *word );
536  uint8_t     rtNvmPutBytes( uint32_t ofs, uint8_t *buf, uint32_t len );
537  uint8_t     rtNvmGetBytes( uint32_t ofs, uint8_t *buf, uint32_t len );
538  uint8_t     rtNvmClearArea( uint32_t ofs, uint32_t len, uint8_t val = 0 );
539  uint32_t    rtNvmGetSize( );
540
541  uint8_t     extNvmPutWord( uint8_t boardId, uint32_t ofs, uint16_t word );
542  uint8_t     extNvmGetWord( uint8_t boardId, uint32_t ofs, uint16_t *word );
543  uint8_t     extNvmPutBytes( uint8_t boardId, uint32_t ofs, uint8_t *buf, uint32_t len );
544  uint8_t     extNvmGetBytes( uint8_t boardId, uint32_t ofs, uint8_t *buf, uint32_t len );
545  uint8_t     extNvmClearArea( uint8_t boardId, uint32_t ofs, uint32_t len, uint8_t val = 0 );
546  uint32_t    extNvmGetSize( );
547
548  uint8_t     resetNode( uint16_t npId );
549
550  uint8_t     syncEventMap( );
551  uint8_t     addEvent( uint16_t eventId, uint16_t portId = NIL_PORT_ID );
552  uint8_t     removeEvent( uint16_t eventId, uint16_t portId = NIL_PORT_ID );
553  int         searchEvent( uint16_t eventId, uint16_t portId = NIL_PORT_ID );
554  uint8_t     getMemEmapEntry( uint16_t index, uint16_t *evId, uint16_t *pId );
555
556  void        handleMsgLcsMgt( uint8_t *msg );
557  void        handleMsgEvent( uint8_t *msg );
558
559  uint8_t     setupSerialCommand( );
560  uint8_t     handleSerialCommand( );
561
562  void        handleNodeState( );
563
564  } // namespace LCS
565
566  #endif
```

APPENDIX A. LISTINGS TEST

```
1   //------------------------------------------------------------------------------------------------------------
2   //
3   // "LcsMsgBusCAN" - CAN Bus Interface for Raspberry PI Pico
4   //
5   //------------------------------------------------------------------------------------------------------------
6   // The "LcsMsgBusCAN" object implements the LCS message bus as a CAN bus. The CAN bus is a widely established
7   // bus, which is quite robust. We use the standard CAN bus with a maximum CAN Id of 29 bits. In our case the
8   // 16 bit node / port ID along with a 2 bit priority field is used as the CAN address.
9   //
10  // On the PICO, there is a library, "can2040", available that implements the CAN bus protocol in software,
11  // using the PICO PIO state machines. This saves us an external controller. In addition, we allow for the
12  // option to run the CAN bus state machine on a separate core. This is highly recommend as the LCS Runtime
13  // has a lot of other things to do. Using a queue from the PICO C++ SDK, the core running the CAN state
14  // machine will just queue the received message to be picked up by the other core when ready.
15  //
16  //------------------------------------------------------------------------------------------------------------
17  //
18  // LCS - Can Bus Interface Library
19  // Copyright (C) 2022 - 2024,  Helmut Fieres
20  //
21  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
22  // General Public License as published by the Free Software Foundation, either version 3 of the License,
23  // or any later version.
24  //
25  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
26  // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
27  // License for more details. You should have received a copy of the GNU General Public License along with
28  // this program.  If not, see <http://www.gnu.org/licenses/>.
29  //
30  //------------------------------------------------------------------------------------------------------------
31  #include <stdio.h>
32  #include "pico/stdlib.h"
33  #include "pico/stdio.h"
34  #include "pico/util/queue.h"
35  #include "pico/multicore.h"
36
37  #include "LcsRuntimeLib.h"
38  #include "LcsRtLibInt.h"
39
40  //------------------------------------------------------------------------------------------------------------
41  // The can2040 is a C library. Make it extern C, otherwise the linker gets confused.
42  //
43  //------------------------------------------------------------------------------------------------------------
44  extern "C" {
45
46      #include "./Can2040Lib/can2040.h"
47  }
48
49  //------------------------------------------------------------------------------------------------------------
50  // The debug mask. See the internal include file for details.
51  //
52  //------------------------------------------------------------------------------------------------------------
53  namespace LCS {
54
55      extern uint16_t debugMask;
56  };
57
58  //------------------------------------------------------------------------------------------------------------
59  // The name space for file local declarations.
60  //
61  //------------------------------------------------------------------------------------------------------------
62  namespace {
63
64  using namespace LCS;
65
66  //------------------------------------------------------------------------------------------------------------
67  // The maximum message length of a CAN bus ( and LCS ) message. The LCS library still uses the "classic"
68  // CAN bus message size. Finally, the CAN bus library for the RP2040 needs a static opaque structure. We also
69  // need a receiver queue for storing the received messages when they come in.
70  //
71  //------------------------------------------------------------------------------------------------------------
72  const uint8_t   MAX_CAN_MSG_SIZE  = 8;
73  const uint8_t   RX_QUEUE_SIZE     = 4;
74  const uint8_t   TX_RETRY_TIMEOUT  = 5;
75
76  //------------------------------------------------------------------------------------------------------------
77  // The setup and start of the CAN Bus can run on ether core 0 or core 1, depending whether a multi-core
78  // implementation is desired. The "Can2040ConfigDesc" structure holds all the necessary configuration data
79  // for the initialization routine to use.
80  //
81  //------------------------------------------------------------------------------------------------------------
82  struct Can2040ConfigDesc {
83
84      uint32_t        mcPioNum;
85      uint32_t        mcSysClock;
86      uint32_t        mcBitRate;
87      uint32_t        mcRxPin;
88      uint32_t        mcTxPin;
89      can2040_rx_cb   mcRxCallback;
90      uint32_t        mcRxQueueSize;
91      bool            mcRunOnCore1;
92      bool            mcSetupOK;
93  };
94
95  //------------------------------------------------------------------------------------------------------------
96  // File local variables and constants.
97  //
98  //------------------------------------------------------------------------------------------------------------
```

```
 99   Can2040ConfigDesc        cfg;
100   struct can2040           cBus;
101   queue_t                  rxQueue;
102
103   //--------------------------------------------------------------------------------------------------
104   // The "buildCanBusMsgHeader" constructs the canId header for the message. It encodes the canId itself and
105   // flags such as EXT or RTR.
106   //
107   //--------------------------------------------------------------------------------------------------
108   inline uint32_t buildCanBusMsgHeader( uint16_t canId, uint8_t msgPri, bool RTR = false ) {
109
110       uint32_t header = canId | ((uint32_t)( msgPri & 0x3 ) << 16 ) | 0x80000000;
111
112       if ( RTR ) header |=  0x40000000;
113
114       return ( header );
115   }
116
117   //--------------------------------------------------------------------------------------------------
118   // The interrupt signature to register with the RP2040 for PIO interrupts. The interrupt handler itself is
119   // provided by the can2040 library.
120   //
121   //--------------------------------------------------------------------------------------------------
122   void CanBusPIOIrqHandler( ) {
123
124       can2040_pio_irq_handler( &cBus );
125   }
126
127   //--------------------------------------------------------------------------------------------------
128   // For each messages transmitted or received this callback is invoked from within the interrupt handler, so
129   // all we can do is a quick non-blocking action. The callback allows to react to a message sent, a message
130   // received and an internal buffer overflow error.
131   //
132   // The callback could be used to filter messages directly at this stage. Only messages that concern this
133   // node should be processed. Easy said, but perhaps no so easy to do. We can basically to filtering at the
134   // higher message bus level or at the lower layers. The benefit for doing it here is that when we run at the
135   // other core, the main core is relieved even further. To think about one day.
136   //
137   //--------------------------------------------------------------------------------------------------
138   void canBusEventCallback( struct can2040 *cd, uint32_t notify, struct can2040_msg *msg ) {
139
140       if ( notify == CAN2040_NOTIFY_RX ) {
141
142           if ( ! queue_try_add( &rxQueue, msg )) {
143
144               // ??? we could not add ... what to do ?
145           }
146       }
147       else if ( notify == CAN2040_NOTIFY_TX ) {
148
149           // ??? transmit completed successfully
150       }
151       else if ( notify == CAN2040_NOTIFY_ERROR ) {
152
153           // ??? internal buffer overflow ... what to do ?
154       }
155   }
156
157   //--------------------------------------------------------------------------------------------------
158   // "canBusCore" is the routine that encapsulates the can2040 setup and launch work. For the multi-core
159   // version it needs to be a routine that can be called from the current core or be launched on the other
160   // core. The routine communicates the successful setup with a boolean flag in the configuration descriptor.
161   // Note that the setup routine must be a void procedure with no parameters. This is expected by the launch
162   // routine in the PICO C++ SDK.
163   //
164   //--------------------------------------------------------------------------------------------------
165   void canBusCore( ) {
166
167       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_CAN_BUS )) {
168
169           printf( "canBusSetup -> pio: %d, clk: %d, bitRate: %d, rxPin: %d, txPin: %d, cb: %u, rxQS: %d, MC: %d\n",
170                   cfg.mcPioNum, cfg.mcSysClock, cfg.mcBitRate,
171                   cfg.mcRxPin, cfg.mcTxPin, cfg.mcRxCallback,
172                   cfg.mcRxQueueSize, cfg.mcRunOnCore1 );
173       }
174
175       queue_init( &rxQueue, sizeof( can2040_msg ), cfg.mcRxQueueSize );
176
177       can2040_setup( &cBus, cfg.mcPioNum );
178       can2040_callback_config( &cBus, cfg.mcRxCallback );
179
180       if ( cfg.mcPioNum == 0 ) {
181
182           irq_set_exclusive_handler( PIO0_IRQ_0, CanBusPIOIrqHandler );
183           irq_set_priority( PIO0_IRQ_0, 1 );
184           irq_set_enabled( PIO0_IRQ_0, true );
185       }
186       else if ( cfg.mcPioNum == 1 ) {
187
188           irq_set_exclusive_handler( PIO1_IRQ_0, CanBusPIOIrqHandler );
189           irq_set_priority( PIO1_IRQ_0, 1 );
190           irq_set_enabled( PIO1_IRQ_0, true );
191       }
192
193       can2040_start( &cBus, cfg.mcSysClock, cfg.mcBitRate, cfg.mcRxPin, cfg.mcTxPin );
194
195       cfg.mcSetupOK = true;
196
197     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_CAN_BUS )) {
```

```
198
199              printf( "CAN Bus Initialized, runs on Core: %d\n", get_core_num( ));
200      }
201
202      if ( cfg.mcRunOnCore1 ) {
203
204              while ( true ) tight_loop_contents( );
205      }
206 }
207
208 }; // namespace
209
210
211 //-------------------------------------------------------------------------------------------------------------
212 // The LCS name space CanBus Object methods declared in this file.
213 //
214 //-------------------------------------------------------------------------------------------------------------
215 namespace LCS {
216
217 //-------------------------------------------------------------------------------------------------------------
218 // "init" is called to setup the CAN bus interface. We will first check the parameters and setup the CAN bus.
219 // Next set up the interrupt handler and start the CAN bus processing. This is also the time to set the
220 // initial canId.
221 //
222 //-------------------------------------------------------------------------------------------------------------
223 uint8_t LcsMsgBusCAN::init( uint16_t canId, uint8_t rxPin, uint8_t txPin, uint8_t fMode ) {
224
225      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_CAN_BUS )) {
226
227              printf( "Init Can Bus -> Node: %d, Rx: %d, Tx: %d, Mode: %d\n", canId, rxPin, txPin, fMode );
228      }
229
230      if (( rxPin == CDC::UNDEFINED_PIN ) || ( txPin == CDC::UNDEFINED_PIN )) return ( ERR_CAN_BUS_INIT );
231
232      this -> canId = canId;
233
234      cfg.mcSetupOK       = true;
235      cfg.mcRxPin         = rxPin;
236      cfg.mcTxPin         = txPin;
237      cfg.mcRxCallback    = canBusEventCallback;
238      cfg.mcSysClock      = CDC::getCpuFrequency( );
239      cfg.mcPioNum        = 0;
240      cfg.mcRxQueueSize   = RX_QUEUE_SIZE;
241
242      cfg.mcRunOnCore1    =  (( fMode == CAN_BUS_LIB_PICO_PIO_125K_M_CORE ) ||
243                              ( fMode == CAN_BUS_LIB_PICO_PIO_250K_M_CORE ) ||
244                              ( fMode == CAN_BUS_LIB_PICO_PIO_500K_M_CORE ) ||
245                              ( fMode == CAN_BUS_LIB_PICO_PIO_1000K_M_CORE ));
246
247      switch ( fMode ) {
248
249          case CAN_BUS_LIB_PICO_PIO_125K:
250          case CAN_BUS_LIB_PICO_PIO_125K_M_CORE:   cfg.mcBitRate = 125000; break;
251
252          case CAN_BUS_LIB_PICO_PIO_250K:
253          case CAN_BUS_LIB_PICO_PIO_250K_M_CORE:   cfg.mcBitRate = 250000; break;
254
255          case CAN_BUS_LIB_PICO_PIO_500K:
256          case CAN_BUS_LIB_PICO_PIO_500K_M_CORE:   cfg.mcBitRate = 500000; break;
257
258          case CAN_BUS_LIB_PICO_PIO_1000K:
259          case CAN_BUS_LIB_PICO_PIO_1000K_M_CORE:  cfg.mcBitRate = 1000000; break;
260
261          default: cfg.mcSetupOK = false;
262      }
263
264      if ( cfg.mcSetupOK ) {
265
266              if ( cfg.mcRunOnCore1 ) multicore_launch_core1( canBusCore );
267              else canBusCore( );
268      }
269
270      return (( cfg.mcSetupOK ) ? ALL_OK : ERR_CAN_BUS_INIT );
271 }
272
273 //-------------------------------------------------------------------------------------------------------------
274 // "sendLcsMsg" will send a data packet. We are passed the message buffer and the message priority. The
275 // message length is encoded in the first message byte, which represents the LCS message opCode as well as
276 // the length of the message. The message has a certain initial priority. When we cannot send the message
277 // right away, the priority is raised. When we cannot send at the highest priority, the message send
278 // failed.
279 //
280 //-------------------------------------------------------------------------------------------------------------
281 uint8_t LcsMsgBusCAN::sendLcsMsg ( uint8_t *msgBuf, uint8_t msgPri ) {
282
283      can2040_msg msg;
284
285      msg.id  = buildCanBusMsgHeader( canId, msgPri );
286      msg.dlc = ( msgBuf[ 0 ] >> 5 ) + 1;
287
288      for ( uint32_t i = 0; i < msg.dlc; i++ ) msg.data[ i ] = msgBuf[ i ];
289
290      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_CAN_BUS )) {
291
292              printf( "CAN Send (TS: 0x%x)(Id: 0x%x, Pri: %d)(Data: ", CDC::getMillis( ), canId, msgPri );
293              for ( int i = 0; i < msg.dlc; i++ ) printf( " 0x%x", msgBuf[ i ] );
294              printf( ")\n" );
295      }
296
```

```
297        if ( can2040_transmit( &cBus, &msg ) != 0 ) {
298
299            CDC::sleepMillis( TX_RETRY_TIMEOUT );
300
301            if ( msgPri > MSG_PRI_VERY_HIGH ) return ( sendLcsMsg( msgBuf, msgPri - 1 ));
302            else                              return ( ERR_CAN_MSG_SEND );
303
304        } else return ( ALL_OK );
305  }
306
307  //-------------------------------------------------------------------------------------------------------
308  // "receiveLcsMsg" will check for a CAN Bus message and if one is available fill the passed message buffer.
309  // With the "can2040" library CAN bus messages are received via a callback function, which will store the
310  // each received message in the local receiver queue.
311  //
312  // Besides receiving a message, there is the handling of CAN Id collisions. When we detect a non-zero length
313  // message with a Can Id that is our own, we have a collision and report an error. This could happen for
314  // example when a node hardware is connected to another layout. Both nodes will then stop and wait for
315  // manual resolution.
316  //
317  // In addition to message processing, we also need to react to RTR messages. We answer such a request with
318  // sending a zero length message response. Replying to such a message from other nodes results in a status
319  // return of "ERR_CAN_MSG_NO_MSG" on this call as no LCS message was actually received. This is also the
320  // case when the message queue is empty.
321  //
322  //-------------------------------------------------------------------------------------------------------
323  uint8_t LcsMsgBusCAN::receiveLcsMsg( uint8_t *msgBuf ) {
324
325      can2040_msg msg;
326
327      if ( queue_try_remove( &rxQueue, &msg )) {
328
329          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_CAN_BUS )) {
330
331              printf( "CAN Recv (TS: 0x%x)(Id: 0x%x, len: %d)(Data: ", CDC::getMillis( ), msg.id, msg.dlc );
332              for ( uint32_t i = 0; i < msg.dlc; i++ ) printf( " 0x%x", msg.data[ i ] );
333              printf( ")\n" );
334          }
335
336          bool      rtrFlag    = ( msg.id & 0x40000000 );
337          bool      extFlag    = ( msg.id & 0x80000000 );
338          uint16_t  remoteCanId = (( extFlag ) ? ( msg.id & 0x3FFF ) : ( msg.id & 0x7F ));
339
340          if (( remoteCanId == canId ) && ( msg.dlc > 0 )) {
341
342              return ( ERR_CAN_ID_COLLISION );
343          }
344          else if ( rtrFlag ) {
345
346              msg.id        = canId;
347              msg.dlc       = 0;
348              msg.data32[ 0 ] = 0;
349              msg.data32[ 1 ] = 0;
350
351              can2040_transmit( &cBus, &msg );
352              return ( ERR_CAN_MSG_NO_MSG );
353          }
354          else {
355
356              memcpy( msgBuf, msg.data, msg.dlc );
357              return ( ALL_OK );
358          }
359      }
360      else return ( ERR_CAN_MSG_NO_MSG );
361  }
362
363  }; // namespace LCS
```

40

APPENDIX A. LISTINGS TEST

```cpp
//--------------------------------------------------------------------------------------------------------------
//
// LCS Runtime library - Non volatile storage based on the M24LCxxx chip family
//
//--------------------------------------------------------------------------------------------------------------
// This file implements the LCS runtime library non-volatile memory. The hardware is the AA24xxx chip family,
// which offers an I2C protocol based chip with various capacities. They all share the same pin layout and
// command structure.
//
// In addition we also support the M24C04 chip, which is used on the extension boards as a configuration
// storage. This chip will however be replaced by 24AA32, a 4K chip of the same chip family as the other
// chips on the controller board.
//
//--------------------------------------------------------------------------------------------------------------
//
// LCS Core library - Non volatile storage based on the M24LCxxx chip family
// Copyright (C) 2021 - 2024  Helmut Fieres
//
// This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
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// option) any later version.
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// http://www.gnu.org/licenses
//
//  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
//
//--------------------------------------------------------------------------------------------------------------

//--------------------------------------------------------------------------------------------------------------
// Include files.
//
//--------------------------------------------------------------------------------------------------------------
#include "LcsRuntimeLib.h"
#include "LcsRtLibInt.h"

//--------------------------------------------------------------------------------------------------------------
// Externals.
//
//--------------------------------------------------------------------------------------------------------------
namespace LCS {

    extern uint16_t debugMask;
};

//--------------------------------------------------------------------------------------------------------------
// Local file declarations.
//
//--------------------------------------------------------------------------------------------------------------
namespace {

using namespace LCS;

//--------------------------------------------------------------------------------------------------------------
// Definitions for the M24LCxxx chips page size and total size. The chips have a pageSize which is the unit
// updated in case of a write. A write cannot across a page boundary and must be split into several writes
// if necessary. Reads do not have this problem. Al chips have the same I2C address root which is "1010".
// There are three address lines A2, A1 and A0, which are used to select a chips. Up to eight chips can be
// addressed on a single I2C bus.
//
// The pageSizes on the chip are a multiple of 32bytes. For now, we use this size as the common denominator.
// Block handling and chipSize page handling are nicely taken care of this way. The downside is however that
// a write will update the chip page up to four times for a pageSize of 128. However, since the chips have
// more than a million write cycles and we rarely write large chunks of data, this will hopefully not be an
// issue in the near future.
//
// ??? the M24C04 is to be phased out ... we do not use that chip anymore...
//--------------------------------------------------------------------------------------------------------------
const uint16_t  BUFFER_BLOCK_SIZE          = 16; // ??? until we remove the M24C04 chip.

const uint16_t  M24LC32_PAGE_SIZE          = 32;
const uint32_t  M24LC32_MAX_SIZE           = 4096;

const uint16_t  M24LC64_PAGE_SIZE          = 32;
const uint32_t  M24LC64_MAX_SIZE           = 8192;

const uint16_t  M24LC128_PAGE_SIZE         = 64;
const uint32_t  M24LC128_MAX_SIZE          = 16384;

const uint16_t  M24LC256_PAGE_SIZE         = 64;
const uint32_t  M24LC256_MAX_SIZE          = 32768;

const uint16_t  M24LC512_PAGE_SIZE         = 128;
const uint32_t  M24LC512_MAX_SIZE          = 65536;

const uint16_t  M24C04_PAGE_SIZE           = 16;
const uint32_t  M24C04_MAX_SIZE            = 512;

const uint8_t   NVM_I2C_ADR_ROOT           = 0b1010000;
const uint8_t   EXT_I2C_ADR_ROOT           = 0b1010000;

const uint8_t   NVM_WRITE_DELAY            = 0x05;

//--------------------------------------------------------------------------------------------------------------
```

```
99   // Runtime NVM sizes. The runtime map has a maximum of 8Kb. The maximum size of a NVM chip is 64Kb. The
100  // maximum size for an extension board NVM chip is 4Kb.
101  //
102  //-------------------------------------------------------------------------------------------------------------
103  const uint32_t  NVM_RUNTIME_MAP_SIZE      = 0x2000;
104  const uint32_t  NVM_MAX_NVM_SIZE          = 0x10000;
105  const uint32_t  NVM_MAX_EXT_SIZE          = 0x1000;
106
107  //-------------------------------------------------------------------------------------------------------------
108  // Module global data. A LCS node board has two NVM channels. The "NVM" channel refers to the NVM chip on
109  // main controller board. The "EXT" channel is the I2C bus that reaches out the the extension boards. On
110  // each extension board there is again a small NVM chip with configuration data. Besides the hardware pins
111  // there are the sizes of the chips.
112  //
113  // There is no easy way to determine the size of the actual chip. By convention, the extension board NVM
114  // chip has a fixed 4 Kbytes. The NVM chip on the main controller board is at least 8Kbytes, which is the
115  // architected runtime data structures size. The maximum size is 64 Kbytes. All the chips are from a hardware
116  // perspective identical. When we start a node, the nodeMap structure, i.e. the first few hundred bytes,
117  // contains a field that holds the actual size configured for the chip on the particular board. The difference
118  // between the runtime map size and the particular NVM chip maximum is considered "user NVM space" which the
119  // firmware can use as needed.
120  //
121  //-------------------------------------------------------------------------------------------------------------
122  uint32_t    nodeNvmSize                   = 0;
123  uint32_t    extNvmSize                    = 0;
124
125  uint8_t     nvmSclPin                     = CDC::UNDEFINED_PIN;
126  uint8_t     nvmSdaPin                     = CDC::UNDEFINED_PIN;
127
128  uint8_t     extSclPin                     = CDC::UNDEFINED_PIN;
129  uint8_t     extSdaPin                     = CDC::UNDEFINED_PIN;
130
131  //-------------------------------------------------------------------------------------------------------------
132  // "testNvmChipMemorySize" will check the NVM chip for its size. Since the chip itself has no way of telling
133  // its memory capacity, we need to go a rather cumbersome way. For each possible size, read the last byte,
134  // store a new value there, read it again. If the values match, it is a valid memory location. Don't forget
135  // to restore the previous value. If we are not successful, try the next smaller size. Currently, the LCS
136  // hardware uses The chip family M24LCxxx with sizes of 4, 8, 16, 32 and 64Kbytes.
137  //
138  // ??? not tested yet ...
139  //-------------------------------------------------------------------------------------------------------------
140  uint32_t testNvmChipMemorySize( uint8_t sclPin, uint8_t i2cAdr ) {
141
142      uint32_t    nvmSize        = M24LC512_MAX_SIZE;
143      uint32_t    testAdr        = nvmSize - 1;
144      uint8_t     originalValue  = 0;
145      uint8_t     testValue      = 0xab;
146      uint8_t     tmpValue       = 0;
147      uint8_t     tmpBuf[ 3 ]    = { 0 };
148      uint8_t     rStat          = ALL_OK;
149
150      while ( nvmSize >= M24LC32_MAX_SIZE ) {
151
152          tmpBuf[ 0 ] = testAdr >> 8 & 0xFF;
153          tmpBuf[ 1 ] = testAdr &0xFF;
154
155          rStat = CDC::i2cWrite( sclPin, i2cAdr, tmpBuf, 2, true );
156          if ( rStat == ALL_OK ) rStat = CDC::i2cRead( sclPin, i2cAdr, &originalValue, 1 );
157          if ( rStat != ALL_OK ) return( ERR_NVM_CHIP_SIZE_DETECT );
158
159          tmpBuf[ 2 ] = testValue;
160
161          rStat = CDC::i2cWrite( sclPin, i2cAdr, tmpBuf, sizeof( tmpBuf ));
162          if ( rStat == ALL_OK ) {
163
164              CDC::sleepMillis( NVM_WRITE_DELAY );
165
166              rStat = CDC::i2cWrite( sclPin, i2cAdr, tmpBuf, 2, true );
167              if ( rStat == ALL_OK ) rStat = CDC::i2cRead( sclPin, i2cAdr, &tmpValue, 1 );
168              if ( rStat == ALL_OK ) {
169
170                  if ( tmpValue == testValue ) {
171
172                      rStat = CDC::i2cWrite( sclPin, i2cAdr, tmpBuf, sizeof( tmpBuf ));
173                      CDC::sleepMillis( NVM_WRITE_DELAY );
174                      return( nvmSize );
175                  }
176                  else {
177
178                      nvmSize = nvmSize / 2;
179                      testAdr = nvmSize - 1;
180                  }
181              }
182          }
183          else return( ERR_NVM_CHIP_SIZE_DETECT );
184      }
185
186      return( nvmSize );
187  }
188
189  //-------------------------------------------------------------------------------------------------------------
190  // Each NVM chip has certain size. This function will round the size to the next lower chip memory size.
191  // We expect however that the programmer used the correct size, so this is done just in case. The lowest
192  // value is the 4Kb chip.
193  //
194  //-------------------------------------------------------------------------------------------------------------
195  uint32_t roundNvmMaxSize( uint16_t chipSize ) {
196
197      if      ( chipSize <= M24C04_MAX_SIZE )   return ( M24C04_MAX_SIZE );
```

```
198        else if ( chipSize <= M24LC32_MAX_SIZE )  return ( M24LC32_MAX_SIZE );
199        else if ( chipSize <= M24LC64_MAX_SIZE )  return ( M24LC64_MAX_SIZE );
200        else if ( chipSize <= M24LC128_MAX_SIZE ) return ( M24LC128_MAX_SIZE );
201        else if ( chipSize <= M24LC256_MAX_SIZE ) return ( M24LC256_MAX_SIZE );
202        else if ( chipSize <= M24LC512_MAX_SIZE ) return ( M24LC512_MAX_SIZE );
203        else                                      return ( M24LC32_MAX_SIZE );
204 }
205
206 //-------------------------------------------------------------------------------------------------------
207 // The nvmSize in buffer size blocks.
208 //
209 //-------------------------------------------------------------------------------------------------------
210 uint16_t nvmSizeInBlocks( uint32_t nvmSize ) {
211
212     return( nvmSize / BUFFER_BLOCK_SIZE );
213 }
214
215 //-------------------------------------------------------------------------------------------------------
216 // "nvmGetBytesFromPage" transmits a set of data bytes only within the page boundary. Although a read can
217 // cross a page boundary, we follow the same principle as we do for writes when it comes to page boundaries.
218 // The read is send ing the address with retaining the bus. The PICO library will then use the restart
219 // condition. Just like we did in the write buffer counterpart, we need to send the address as one buffer.
220 //
221 //-------------------------------------------------------------------------------------------------------
222 uint8_t nvmGetBytesFromPage( uint8_t sclPin, uint8_t i2cAdr, uint32_t ofs, uint8_t *buf, uint32_t len ) {
223
224     uint8_t rStat = ALL_OK;
225
226     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
227
228         printf( "nvmGetBytesFromPage: sclPin: %d, i2cAdr: 0x%x, ofs: 0x%x, buf: %p, len: %d\n",
229                 sclPin, i2cAdr, ofs, buf, len );
230     }
231
232     uint32_t nvmSize = (( sclPin == nvmSclPin ) ? nodeNvmSize : extNvmSize );
233
234     if ( nvmSize == M24C04_MAX_SIZE ) {
235
236         uint8_t tmpAdr  = i2cAdr | (( ofs >> 8 ) & 0x01 );
237         uint8_t tmpData = ofs & 0xFF;
238
239         rStat = CDC::i2cWrite( sclPin, tmpAdr, &tmpData, sizeof( tmpData ), true );
240         if ( rStat == ALL_OK ) rStat = CDC::i2cRead( sclPin, tmpAdr, buf, len );
241     }
242     else {
243
244         uint8_t adr[ 2 ];
245
246         adr[ 0 ] =  ( ofs  >> 8 ) & 0xFF;
247         adr[ 1 ] =  ofs & 0xFF;
248
249         rStat = CDC::i2cWrite( sclPin, i2cAdr, adr, 2, true );
250         if ( rStat == ALL_OK ) rStat = CDC::i2cRead( sclPin, i2cAdr, buf, len );
251     }
252
253   if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
254
255         printf( "nvmGetBytesFromPage: %d\n", rStat );
256     }
257
258     return ( rStat );
259 }
260
261 //-------------------------------------------------------------------------------------------------------
262 // "nvmPutBytesInPage" transmits a set of data bytes only within the page boundary. In general, a write
263 // cannot cross a chip internal page boundary. The Chip expects a write to be one sequence with the address
264 // bytes first followed by the data bytes with no stop or restart condition in between. This costed my
265 // quite some debugging to figure this out. We will have a local buffer where we combine the address and
266 // data and then send it.
267 //
268 //-------------------------------------------------------------------------------------------------------
269 uint8_t nvmPutBytesInPage( uint8_t sclPin, uint8_t i2cAdr, uint32_t ofs, uint8_t *buf, uint32_t len ) {
270
271     uint8_t rStat = ALL_OK;
272     uint8_t dataBuf[ BUFFER_BLOCK_SIZE + 2 ];
273
274     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
275
276         printf( "nvmPutBytesInPage: sclPin: %d, i2cAdr: 0x%x, ofs: 0x%x, bufAdr: %p, len: %d\n",
277         sclPin, i2cAdr, ofs, buf, len );
278     }
279
280     uint32_t nvmSize = (( sclPin == nvmSclPin ) ? nodeNvmSize : extNvmSize );
281
282     if ( nvmSize == M24C04_MAX_SIZE ) {
283
284         dataBuf[ 0 ] = ofs & 0xFF;
285         for ( int i = 0; i < len; i++ ) dataBuf[ i + 1 ] = buf[ i ];
286
287         uint8_t tmpAdr = i2cAdr | (( ofs >> 8 ) & 0x01 );
288         rStat = CDC::i2cWrite( sclPin, tmpAdr, dataBuf, len + 1 );
289     }
290     else {
291
292         dataBuf[ 0 ]    = ( ofs  >> 8 ) & 0xFF;
293         dataBuf[ 1 ]    = ofs & 0xFF;
294
295         for ( int i = 0; i < len; i++ ) dataBuf[ i + 2 ] = buf[ i ];
296
```

```
297            rStat = CDC::i2cWrite( sclPin, i2cAdr, dataBuf, len + 2 );
298        }
299
300        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
301
302            printf( "nvmPutBytesInPage: ret: %d\n", rStat );
303        }
304
305        return ( rStat );
306    }
307
308    //-----------------------------------------------------------------------------------------------------------
309    // "nvmGetBytes" reads a set of data bytes from the memory. Although read operations do not have a page
310    // boundary issue, we stick to the concept to read within page boundaries as we may one day use more than
311    // chip to build NVMs and then we have no problems with crossing chip boundaries.
312    //
313    //-----------------------------------------------------------------------------------------------------------
314    uint8_t nvmGetBytes( uint8_t sclPin, uint8_t i2cAdr, uint32_t ofs, uint8_t *buf, uint32_t len ) {
315
316        uint8_t rStat = ALL_OK;
317
318        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
319
320            printf( "nvmGetBytes: scl: %d, i2c: 0x%x, ofs: 0x%x, bufAdr: %p, len: %d\n",
321                    sclPin, i2cAdr, ofs, (uint32_t) buf, len );
322        }
323
324        uint32_t nvmSize = (( sclPin == nvmSclPin ) ? nodeNvmSize : extNvmSize );
325        if ( ofs + len > nvmSize ) return ( ERR_NVM_SIZE_EXCEEDED );
326
327        uint32_t  bytesLeft     = len;
328        uint32_t  pageBytesLeft = BUFFER_BLOCK_SIZE - ofs % BUFFER_BLOCK_SIZE;
329
330        while ( bytesLeft > pageBytesLeft ) {
331
332            rStat = nvmGetBytesFromPage( sclPin, i2cAdr, ofs + len - bytesLeft, buf + len - bytesLeft, pageBytesLeft );
333            if ( rStat != ALL_OK ) break;
334
335            bytesLeft       -= pageBytesLeft;
336            pageBytesLeft   = BUFFER_BLOCK_SIZE;
337        }
338
339        if (( rStat == ALL_OK ) && ( bytesLeft > 0 )) {
340
341            rStat = nvmGetBytesFromPage( sclPin, i2cAdr, ofs + len - bytesLeft, buf + len - bytesLeft, bytesLeft );
342        }
343
344        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
345
346            printf( "nvmGetBytes: ret: %d\n", rStat );
347        }
348
349        return( rStat );
350    }
351
352    //-----------------------------------------------------------------------------------------------------------
353    // "nvmPutBytes" transmits a set of data bytes to the memory. We cannot write across the internal NVM page
354    // boundary and also across a chip boundary. This routine will split the data to write only within one page
355    // in a given write cycle.
356    //
357    // There is a quirk with figuring out that a chip is ready for the next write instruction. The data sheet
358    // suggest a writing of one byte to see of the chip acknowledges. If not it is still in a write operation.
359    // This approach does not seem to work with the PICO i2c libraries. So, we will go the "slow" way of giving
360    // the chip the time to complete the write cycle before issuing another one. Since we do not often write
361    // to the NVM, the slow mode is perhaps acceptable for now.
362    //
363    //-----------------------------------------------------------------------------------------------------------
364    uint8_t nvmPutBytes( uint8_t sclPin, uint8_t i2cAdr, uint32_t ofs, uint8_t *buf, uint32_t len ) {
365
366        uint8_t rStat = ALL_OK;
367
368        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
369
370            printf( "nvmPutBytes: scl: %d, i2c: 0x%x, ofs: 0x%x, buf: %p, len: %d\n", sclPin, i2cAdr, ofs, buf, len );
371         }
372
373        uint32_t nvmSize = (( sclPin == nvmSclPin ) ? nodeNvmSize : extNvmSize );
374        if ( ofs + len > nvmSize ) return ( ERR_NVM_SIZE_EXCEEDED );
375
376        uint32_t  bytesLeft     = len;
377        uint32_t  pageBytesLeft = BUFFER_BLOCK_SIZE - ofs % BUFFER_BLOCK_SIZE;
378
379        while ( bytesLeft > pageBytesLeft ) {
380
381            rStat = nvmPutBytesInPage( sclPin, i2cAdr, ofs + len - bytesLeft, buf + len - bytesLeft, pageBytesLeft );
382            if ( rStat != ALL_OK ) break;
383
384            bytesLeft       -= pageBytesLeft;
385            pageBytesLeft   = BUFFER_BLOCK_SIZE;
386
387            CDC::sleepMillis( NVM_WRITE_DELAY );
388        }
389
390        if (( rStat == ALL_OK ) && ( bytesLeft > 0 )) {
391
392            rStat = nvmPutBytesInPage( sclPin, i2cAdr, ofs + len - bytesLeft, buf + len - bytesLeft, bytesLeft );
393            CDC::sleepMillis( NVM_WRITE_DELAY );
394        }
395
```

```
396        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
397
398            printf( "nvmPutBytes: ret: %d\n", rStat );
399        }
400
401        return( rStat );
402  }
403
404  //-------------------------------------------------------------------------------------------------------
405  // "nvmClearArea" wipes out an area of the NVM chip. To speed up the writing, we fill a local buffer with
406  // the value and then write blocks at a time.
407  //
408  //-------------------------------------------------------------------------------------------------------
409  uint8_t nvmClearArea( uint8_t sclPin, uint8_t i2cAdr, uint32_t ofs, uint32_t len, uint8_t val ) {
410
411        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
412
413            printf( "nvmClearArea: scl: %d, i2c: 0x%x, ofs: 0x%x, len: %d, val: %d\n", sclPin, i2cAdr, ofs, len, val );
414        }
415
416        uint8_t     tmpBuf[ BUFFER_BLOCK_SIZE ];
417        uint8_t     rStat   = ALL_OK;
418        uint32_t    nvmSize = (( sclPin == nvmSclPin ) ? nodeNvmSize : extNvmSize );
419        uint32_t    limit   = ofs + len;
420
421        if ( ofs + len > nvmSize ) return ( ERR_NVM_SIZE_EXCEEDED );
422
423        for ( int i = 0; i < BUFFER_BLOCK_SIZE; i ++ ) tmpBuf[ i ] = val;
424
425        while ( len > BUFFER_BLOCK_SIZE ) {
426
427            rStat = nvmPutBytes( sclPin, i2cAdr, ofs, tmpBuf, sizeof( tmpBuf ));
428            if ( rStat != ALL_OK ) break;
429
430            ofs += BUFFER_BLOCK_SIZE;
431            len -= BUFFER_BLOCK_SIZE;
432        }
433
434        if (( rStat == ALL_OK ) && ( len > 0 )) {
435
436            rStat = nvmPutBytes( sclPin, i2cAdr, ofs, tmpBuf, len );
437        }
438
439        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_NVM_ACCESS )) {
440
441            printf( "nvmClearArea: ret: %d\n", rStat );
442        }
443
444        return( rStat );
445  }
446
447  }; // namespace
448
449
450  //-------------------------------------------------------------------------------------------------------
451  // The LCS name space routines declared in this file.
452  //
453  //-------------------------------------------------------------------------------------------------------
454  namespace LCS {
455
456  //-------------------------------------------------------------------------------------------------------
457  // "configNvm" will setup the module local variables. We copy the I2C hardware pins and the NVM related data
458  // from the CDC descriptors. The CDC descriptor also contains the configured sizes for the NVM chips.
459  //
460  //-------------------------------------------------------------------------------------------------------
461  uint8_t configNvm( CDC::CdcConfigDesc *ci ) {
462
463        nvmSclPin    = ci -> NVM_I2C_SCL_PIN;
464        nvmSdaPin    = ci -> NVM_I2C_SDA_PIN;
465        extSclPin    = ci -> EXT_I2C_SCL_PIN;
466        extSdaPin    = ci -> EXT_I2C_SDA_PIN;
467        nodeNvmSize  = ci -> NODE_NVM_SIZE;
468        extNvmSize   = ci -> EXT_NVM_SIZE;
469
470        if ( nodeNvmSize > NVM_MAX_NVM_SIZE )   nodeNvmSize = NVM_MAX_NVM_SIZE;
471        if ( extNvmSize > NVM_MAX_EXT_SIZE )    extNvmSize  = NVM_MAX_EXT_SIZE;
472
473        return( ALL_OK );
474  }
475
476  //-------------------------------------------------------------------------------------------------------
477  // Controller Board Runtime Map access routines. The runtime map occupies the first 8 Kbytes of the main
478  // controller NVM chip. There are routines for getting and setting a word as well as routines to read and
479  // write a buffer. All access routines are prefixed with "rt".
480  //
481  //-------------------------------------------------------------------------------------------------------
482  uint8_t rtNvmPutWord( uint32_t ofs, uint16_t word ) {
483
484        return( nvmPutBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, (uint8_t *) &word, sizeof( uint16_t )));
485  }
486
487  uint8_t rtNvmGetWord( uint32_t ofs, uint16_t *word ) {
488
489        return( nvmGetBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, (uint8_t *) word, sizeof( uint16_t )));
490  }
491
492  uint8_t rtNvmPutBytes( uint32_t ofs, uint8_t *buf, uint32_t len ) {
493
494        return( nvmPutBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, buf, len ));
```

```
495  }
496
497  uint8_t rtNvmGetBytes( uint32_t ofs, uint8_t *buf, uint32_t len ) {
498
499      return( nvmGetBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, buf, len ));
500  }
501
502  uint8_t rtNvmClearArea( uint32_t ofs, uint32_t len, uint8_t val ) {
503
504      return( nvmClearArea( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, len, val ));
505  }
506
507  uint32_t rtNvmGetSize( ) {
508
509      return( NVM_RUNTIME_MAP_SIZE );
510  }
511
512  //----------------------------------------------------------------------------------------------------------------
513  // Extension Board Map access routines. These routines access the NVM on the extension board. The I2C address
514  // is formed by the chip common I2C address plus the address bits of the chip to select the chip on the
515  // particular extension board. Similar to the runtime NVM access routines, there are routines for getting
516  // and setting a word as well as routines to read and  write a buffer. All access routines are prefixed with
517  // "ext".
518  //
519  //----------------------------------------------------------------------------------------------------------------
520  uint8_t extNvmPutWord( uint8_t boardId, uint32_t ofs, uint16_t word ) {
521
522      uint8_t i2cAdr = EXT_I2C_ADR_ROOT + (( boardId % MAX_EXT_BOARD_MAP_ENTRIES ) << 1 );
523      return( nvmPutBytes( extSclPin, i2cAdr, ofs, (uint8_t *) &word, sizeof( uint16_t )));
524  }
525
526  uint8_t extNvmGetWord( uint8_t boardId, uint32_t ofs, uint16_t *word ) {
527
528      uint8_t i2cAdr = EXT_I2C_ADR_ROOT + (( boardId % MAX_EXT_BOARD_MAP_ENTRIES ) << 1 );
529      return( nvmGetBytes( extSclPin, i2cAdr, ofs, (uint8_t *) word, sizeof( uint16_t )));
530  }
531
532  uint8_t extNvmPutBytes( uint8_t boardId, uint32_t ofs, uint8_t *buf, uint32_t len ) {
533
534      uint8_t i2cAdr = EXT_I2C_ADR_ROOT + (( boardId % MAX_EXT_BOARD_MAP_ENTRIES ) << 1 );
535      return( nvmPutBytes( extSclPin, i2cAdr, ofs, buf, len ));
536  }
537
538  uint8_t extNvmGetBytes( uint8_t boardId, uint32_t ofs, uint8_t *buf, uint32_t len ) {
539
540      uint8_t i2cAdr = EXT_I2C_ADR_ROOT + (( boardId % MAX_EXT_BOARD_MAP_ENTRIES ) << 1 );
541      return( nvmGetBytes( extSclPin, i2cAdr, ofs, buf, len ));
542  }
543
544  uint8_t extNvmClearArea( uint8_t boardId, uint32_t ofs, uint32_t len, uint8_t val ) {
545
546      uint8_t i2cAdr = EXT_I2C_ADR_ROOT + (( boardId % MAX_EXT_BOARD_MAP_ENTRIES ) << 1 );
547      return( nvmClearArea( extSclPin, i2cAdr, ofs, len, val ));
548  }
549
550  uint32_t extNvmGetSize( ) {
551
552      return( extNvmSize );
553  }
554
555  //----------------------------------------------------------------------------------------------------------------
556  // Controller Board User Map access routines. The area between the main controller NVM chip runtime area and
557  // the chips hardware maximum size is the memory area available for the firmware programmer. Again, there
558  // are routines for getting and setting a word as well as routines to read and  write a buffer. All access
559  // routines are prefixed with "nvm".
560  //
561  //----------------------------------------------------------------------------------------------------------------
562  uint8_t usrNvmPutWord( uint32_t ofs, uint16_t word ) {
563
564      ofs = ofs + NVM_USER_MAP_START;
565      return( nvmPutBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, (uint8_t *) &word, sizeof( uint16_t )));
566  }
567
568  uint8_t usrNvmGetWord( uint32_t ofs, uint16_t *word ) {
569
570      ofs = ofs + NVM_USER_MAP_START;
571      return( nvmGetBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, (uint8_t *) word, sizeof( uint16_t )));
572  }
573
574  uint8_t usrNvmPutBytes( uint32_t ofs, uint8_t *buf, uint32_t len ) {
575
576      ofs = ofs + NVM_USER_MAP_START;
577      return( nvmPutBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, buf, len ));
578  }
579
580  uint8_t usrNvmGetBytes( uint32_t ofs, uint8_t *buf, uint32_t len ) {
581
582      ofs = ofs + NVM_USER_MAP_START;
583      return( nvmGetBytes( nvmSclPin, NVM_I2C_ADR_ROOT + 0, ofs, buf, len ));
584  }
585
586  uint32_t usrNvmGetSize( ) {
587
588      return ( nodeNvmSize - NVM_USER_MAP_START );
589  }
590
591  }; // namespace LCS
```

APPENDIX A. LISTINGS TEST

```
1    //-------------------------------------------------------------------------------------------------------
2    //
3    // Layout Control System - Runtime setup file.
4    //
5    //-------------------------------------------------------------------------------------------------------
6    // The file implements a part of the LcsRuntimeLib that deals with the setup and start sequence of a node.
7    // There is a lot to do. First, we need to initialize the CDC layer, our lower layer foundation. Next the
8    // NVM of the nodeMap is located and checked for validity. The nodeMap contains all the information for
9    // setting up the entire node. If this steps fails, we either need to configure the nodeMap, or we have a
10   // data error and the node is not usable.
11   //
12   // With a correct node map in place, the memory structures for the node, the ports, events, callbacks and
13   // periodic tasks are created. The node is basically ready to do work. For a node that has no extension
14   // boards connected, we are done.
15   //
16   // Next is the extension board setup. We try to locate all connected extension boards and install the
17   // corresponding driver. A driver is just a procedure that knows how to talk to the particular extension
18   // board. A failure in this part of the sequence sequence does not necessarily mean that the node cannot be
19   // used.
20   //
21   // Assuming all went fine, the runtime library is ready to accept calls for registering callbacks and a few
22   // other library calls. Once all this work is done, the last call of the node firmware would be to start
23   // the runtime, which would as the very first thing invoke all registered initialization callbacks and the
24   // enter the processing loop. We will not return from that routine.
25   //
26   // An error in the setup sequence does not necessarily mean that the node is unusable. For example, when
27   // the nodeMap is not valid, the setup routine will report an error, but we can still call the runtime
28   // loop. The runtime loop will handle LCS messages and also provide the console IO, which in turn allows us
29   // manually correct the node data for a successful restart. In a similar way, extension board errors can be
30   // be addressed.
31   //
32   // This file contains the library global data declarations if the LCS runtime library. All other files will
33   // refer to them as "extern".
34   //
35   //-------------------------------------------------------------------------------------------------------
36   //
37   // LCS - Core Library
38   // Copyright (C) 2021 - 2024  Helmut Fieres
39   //
40   // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
41   // General Public License as published by the Free Software Foundation, either version 3 of the License,
42   // or any later version.
43   //
44   // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
45   // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
46   // License for more details. You should have received a copy of the GNU General Public License along with
47   // this program.  If not, see <http://www.gnu.org/licenses/>.
48   //
49   //-------------------------------------------------------------------------------------------------------
50   #include "LcsRuntimeLib.h"
51   #include "LcsRtLibInt.h"
52   #include "LcsDrvOccDetectLib.h"
53   #include "LcsDrvServoLib.h"
54
55   //-------------------------------------------------------------------------------------------------------
56   // Runtime globals. This file contains the global data structure declarations. They are declared in the LCS
57   // name space. All other files in the runtime library will declare them as "extern" if needed.
58
59   // There is also the debug mask. The idea is to have a debug mask where each major part of the library has a
60   // bit. There could also be bits reserved for the firmware. Then we have control items to set these bits.
61   // Wherever debugging or tracing is needed, the bit mask will be used to determine whether to print debugging
62   // data or not. From a performance perspective, the test will take just a couple of ARM instructions. In other
63   // words we do not take out debugging code when going into production. Never liked this approach of conditional
64   // debug code via "ifdefs".
65   //
66   //-------------------------------------------------------------------------------------------------------
67   namespace LCS {
68
69       uint16_t                debugMask    = 0;
70       uint16_t                startOptions = 0;
71
72       LcsCdcMap               cdcMap;
73       LcsMsgBusCAN            *msgBus;
74       LcsNodeData             nodeData;
75       LcsNodeMap              nodeMap;
76       LcsPortMap              portMap;
77       LcsEventMap             eventMap;
78       LcsCallbackMap          callbackMap;
79       LcsPendingReqMap        pendingReqMap;
80       LcsTaskMap              taskMap;
81       LcsDrvFuncMap           drvFuncMap;
82       LcsDrvMap               drvMap;
83   }
84
85   //-------------------------------------------------------------------------------------------------------
86   // The LcsCoreLibConfig implementation file local declarations and routines.
87   //
88   //-------------------------------------------------------------------------------------------------------
89   namespace {
90
91   using namespace LCS;
92
93   //-------------------------------------------------------------------------------------------------------
94   // Utility routines and constants.
95   //
96   //-------------------------------------------------------------------------------------------------------
97   const char  *nodeDefName  = "Node Name";
98
```

```
99   uint16_t roundup( uint16_t elements, uint16_t alignSize ) {
100
101        return ((( elements + alignSize - 1 ) / alignSize ) * alignSize );
102  }
103
104  bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
105
106        return (( val >= lower ) && ( val <= upper ));
107  }
108
109  uint16_t buildNpId( uint16_t nodeId, uint16_t portId ) {
110
111        return(( nodeId << 4 ) | ( portId & 0xF ));
112  }
113
114  uint16_t nodeId( uint16_t npId ) {
115
116        return( npId >> 4 );
117  }
118
119  uint16_t portId( uint16_t npId ) {
120
121        return( npId & 0xF );
122  }
123
124  //-------------------------------------------------------------------------------------------------------
125  // "buildDefaultNodeMap" build a nodeMap with the default values from the declaration structure. The default
126  // nodeMap is used for initializing the memory runtime node map for formatting a new or corrupted runtime NVM.
127  //
128  //-------------------------------------------------------------------------------------------------------
129  void buildDefaultNodeMap( LcsNodeMap *nMap ) {
130
131        LcsNodeMap tmp;
132
133        snprintf( tmp.name, MAX_NODE_NAME_SIZE, "Node" );
134        tmp.nodeUID = CDC::createUid( );
135
136        *nMap = tmp;
137  }
138
139  //-------------------------------------------------------------------------------------------------------
140  // "buildDefaultPortMap" will initialize the portMap data structure on MEM or NVM, It is just an array of
141  // portMap entries. Each port will get a default name.
142  //
143  //-------------------------------------------------------------------------------------------------------
144  void buildDefaultPortMap( LcsPortMap *pMap ) {
145
146        for ( uint16_t i = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
147
148            LcsPortMapEntry pEntry;
149
150            snprintf( pEntry.name, MAX_PORT_NAME_SIZE, "Port-%d", i + 1 );
151            pMap -> map[ i ] = pEntry;
152        }
153  }
154
155  //-------------------------------------------------------------------------------------------------------
156  // "buildDefaultEventMap" initializes the event map on MEM or NVM. It is just an array of eventMap entries.
157  //
158  //-------------------------------------------------------------------------------------------------------
159  void buildDefaultEventMap( LcsEventMap *eMap ) {
160
161        LcsEventMapEntry e;
162        for ( uint16_t i = 0; i < MAX_EVENT_MAP_ENTRIES; i++ ) eMap -> map[ i ] = e;
163  }
164
165  //-------------------------------------------------------------------------------------------------------
166  // "buildDefaultNodeData" initializes the node data map on MEM or NVM. It is just an array of variables. We
167  // clear them out.
168  //
169  //-------------------------------------------------------------------------------------------------------
170  void buildDefaultNodeData( LcsNodeData *nData ) {
171
172        memset( nData -> map, 0, MAX_NODE_DATA_BLOCKS * MAX_ATTR_MAP_ENTRIES * sizeof( uint16_t));
173  }
174
175  //-------------------------------------------------------------------------------------------------------
176  // "buildNvmRuntimeStructures" initializes a new or corrupt runtime NVM with default data. After successful
177  // completion, we will have a valid runtime map.
178  //
179  // ??? CDC map business ???
180  //-------------------------------------------------------------------------------------------------------
181  uint8_t buildNvmRuntimeStructures( ) {
182
183        uint8_t rStat;
184
185        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "buildNvmRuntimeStructures\n" );
186
187        rtNvmClearArea( NVM_NODE_MAP_START, NVM_RUNTIME_AREA_SIZE );
188
189        // ??? build default CDC map ?
190
191        buildDefaultNodeMap( &nodeMap );
192        buildDefaultPortMap( &portMap );
193        buildDefaultEventMap( &eventMap );
194        buildDefaultNodeData( &nodeData );
195
196        rStat = rtNvmPutBytes( NVM_NODE_MAP_START, (uint8_t *) &nodeMap, sizeof( LcsNodeMap ));
197        if ( rStat == ALL_OK ) rtNvmPutBytes( NVM_PORT_MAP_START, (uint8_t *) &portMap, sizeof( LcsPortMap ));
```

```
198          if ( rStat == ALL_OK ) rtNvmPutBytes( NVM_EVENT_MAP_START, (uint8_t *) &eventMap, sizeof( LcsEventMap ));
199          if ( rStat == ALL_OK ) rtNvmPutBytes( NVM_NODE_DATA_START, (uint8_t *) &nodeData, sizeof( LcsNodeData ));
200
201          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
202              printf( "buildNvmRuntimeStructures, stat: %d\n", rStat  );
203
204          return( rStat );
205      }
206
207      //---------------------------------------------------------------------------------------------------------------
208      // "buildDefaultBoardDesc" initializes the extension board structure. An extension board has a header
209      // structure identical to the nodeMap structure. In addition, there is the driver data area.
210      //
211      //---------------------------------------------------------------------------------------------------------------
212      void buildDefaultBoardDesc( LcsDrvBoardDesc *bDesc ) {
213
214          LcsNvmHeader tmp;
215
216          bDesc -> head = tmp;
217          memset( bDesc -> driverData, 0, MAX_DRV_DATA_SIZE * sizeof( uint16_t ));
218      }
219
220      //---------------------------------------------------------------------------------------------------------------
221      // "buildDefaultDrvMap" initializes the driver map memory structure.
222      //
223      //---------------------------------------------------------------------------------------------------------------
224      void buildDefaultDrvMap( LcsDrvMap *drv ) {
225
226          LcsDrvBoardDesc initDesc;
227
228          for ( uint16_t i = 0; i < MAX_EXT_BOARD_MAP_ENTRIES; i ++ ) {
229
230              drvMap.map[ i ].flags       = 0;
231              drvMap.map[ i ].drvFunc     = nullptr;
232              drvMap.map[ i ].extBoard    = initDesc;
233          }
234      }
235
236      //---------------------------------------------------------------------------------------------------------------
237      // "buildNvmRuntimeStructures" initializes a new or corrupt runtime NVM with default data. However, the write
238      // will only succeed when we have the board write enabled. Otherwise an error is returned.
239      //
240      //---------------------------------------------------------------------------------------------------------------
241      uint8_t buildNvmExtBoardStructure( uint8_t boardId ) {
242
243          uint8_t     rStat;
244          LcsDrvEntry entry;
245
246          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
247
248              printf( "buildNvmExtBoardStructure for board: %d\n", boardId );
249          }
250
251          rStat = extNvmClearArea( boardId, 0, sizeof( LcsDrvEntry ));
252          if ( rStat == ALL_OK ) extNvmPutBytes( boardId, 0, (uint8_t *) &entry, sizeof( entry ));
253
254          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
255
256              printf( "buildNvmExtBoardStructure, stat: %d\n", rStat  );
257          }
258
259          return( rStat ); // ??? own error constant ?
260      }
261
262      }; // namespace
263
264
265      //---------------------------------------------------------------------------------------------------------------
266      // The LCS name space routines declared in this file.
267      //
268      //---------------------------------------------------------------------------------------------------------------
269      namespace LCS {
270
271      //---------------------------------------------------------------------------------------------------------------
272      // When the node is powered on, the very first thing to do is to setup the CDC library and setup the "active"
273      // and "ready" LED pins used by the board. The pins need to to be configured. We also make a call to to
274      // initialize the CDC. Note that this may have been done before, when for example the firmware programmer
275      // wants to use the HW before calling any library setup code. It is no problem to call the CDC init routine
276      // several times.
277      //
278      // There are two basic modes. The first is when we have a console connected. We will prompt and wait for a
279      // start command. There are several options for starting a node. The easiest is "R" which just starts the
280      // node. The "D" command will start with debugging enabled. We will set the setup debug flags to check any
281      // issues during the startup phase. Finally, there is there "F" command, which will format the NVM runtime
282      // area. However, all that is happening in this routine is to set these options to be executed at the right
283      // place in the setup sequence.
284      //
285      // The second mode is when there no console connected. In this case, Debug is disabled and we just setup
286      // the node. This mode should be the normal case for all the nodes in a layout.
287      //
288      // Perhaps one day, this routine could be enhanced to allow commands to pile up the start options followed
289      // by the final start command to get the show going. especially the debug mask would be a candidate.
290      //
291      //---------------------------------------------------------------------------------------------------------------
292      uint8_t initCdcLayer( CDC::CdcConfigDesc *ci ) {
293
294          const uint32_t CONSOLE_TIMEOUT = 1024 * 1024 * 4;
295
296          cdcMap.cfg = *ci;
```

```
297
298        CDC::init( ci );
299
300        if ( ci -> READY_LED_PIN != CDC::UNDEFINED_PIN ) CDC::configureDio( ci -> READY_LED_PIN, CDC::OUT );
301        if ( ci -> ACTIVE_LED_PIN != CDC::UNDEFINED_PIN ) CDC::configureDio( ci -> ACTIVE_LED_PIN, CDC::OUT );
302
303        if ( CDC::isConsoleConnected( )) {
304
305            CDC::writeDio( ci -> READY_LED_PIN, true );
306
307            while ( true ) {
308
309                printf( "=>" );
310
311                char ch = CDC::getConsoleChar( CONSOLE_TIMEOUT );
312
313                if (( ch == 'R' ) || ( ch == 'r' )) {
314
315                    printf( "Starting - normal mode\n" );
316
317                    debugMask        &= ~ DBG_CONFIG;
318                    startOptions     = NOPT_NIL;
319                    return( ALL_OK );
320                }
321                else if (( ch == 'D' ) || ( ch == 'd' )) {
322
323                     printf( "Starting - debug mode\n" );
324
325                    debugMask        = DBG_CONFIG | DBG_SETUP | DBG_EVENTS;
326                    startOptions     = NOPT_NIL;
327                    return( ALL_OK );
328                }
329                else if (( ch == 'F' ) || ( ch == 'f' )) {
330
331                    printf( "Starting - format mode\n" );
332
333                    debugMask        &= ~ DBG_CONFIG;
334
335                    debugMask        = DBG_CONFIG | DBG_SETUP | DBG_NVM_ACCESS;
336
337                    startOptions     = NOPT_FORMAT_RUNTIME;
338                    return( ALL_OK );
339                }
340                else if ( ch == '?' ) {
341
342                    printf( "Setup options:\n" );
343                    printf( "r, R -> start the node with debug initially disabled\n" );
344                    printf( "d, D -> start the node with \"setup\" debug options enabled\n" );
345                    printf( "f, F -> start the node with a newly formatted runtime map\n" );
346                }
347                else printf( "\n" );
348            }
349        }
350        else {
351
352            debugMask        &= ~ DBG_CONFIG;
353            startOptions     = NOPT_NIL;
354            return ( ALL_OK );
355        }
356 }
357
358 //-------------------------------------------------------------------------------------------------------------
359 // The NVM library functions will work after this routine. We first set up the I2C channels, which are the
360 // heart of any internal board communication. After the I2C channels are initialized, we will configure the
361 // NVM library. If all is OK, we can talk to all NVMs on the boards making up the node.
362 //
363 // ??? should we assume a "architectural" setting of the IC2 channels and not rely on CDC map ?
364 //-------------------------------------------------------------------------------------------------------------
365 uint8_t initNvmChannels( CDC::CdcConfigDesc *ci ) {
366
367     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
368
369         printf( "initNvmChannels: nvmSCL: %d, nvmSDA: %d, extSCL: %d, extSDA: %d\n",
370                 ci -> NVM_I2C_SCL_PIN, ci -> NVM_I2C_SDA_PIN, ci -> EXT_I2C_SCL_PIN, ci -> EXT_I2C_SDA_PIN );
371     }
372
373     uint8_t rStat;
374
375     if (( ci -> NVM_I2C_SCL_PIN != CDC::UNDEFINED_PIN ) && ( ci -> NVM_I2C_SDA_PIN != CDC::UNDEFINED_PIN )) {
376
377         rStat = CDC::configureI2C( ci -> NVM_I2C_SCL_PIN , ci -> NVM_I2C_SDA_PIN );
378         if ( rStat != ALL_OK ) return( rStat );
379     }
380
381     if (( ci -> EXT_I2C_SCL_PIN != CDC::UNDEFINED_PIN ) && ( ci -> EXT_I2C_SDA_PIN != CDC::UNDEFINED_PIN )) {
382
383         rStat = CDC::configureI2C( ci -> EXT_I2C_SCL_PIN , ci -> EXT_I2C_SDA_PIN );
384         if ( rStat != ALL_OK ) return( rStat );
385     }
386
387     rStat = configNvm( ci );
388
389     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
390         printf( "initNvmChannels, status: %d\n", rStat );
391
392     return ( rStat );
393 }
394
395 //-------------------------------------------------------------------------------------------------------------
```

```
396  // Next is CAN bus setup. The message bus is the central communication mechanism. If we can also get it up
397  // early we could use it not only for configurations and operations but perhaps for remote troubleshooting.
398  //
399  // ??? should we assume a "architectural" setting of the CAN channel and not rely on CDC map ?
400  //-----------------------------------------------------------------------------------------------------------
401  uint8_t initCanBus( CDC::CdcConfigDesc *ci ) {
402
403      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "initCanBus\n" );
404
405      msgBus = new LcsMsgBusCAN( );
406
407      uint8_t rStat = msgBus -> init( 0, ci -> CAN_BUS_RX_PIN, ci -> CAN_BUS_TX_PIN, ci -> CAN_BUS_CTRL_MODE );
408      if ( rStat != ALL_OK ) {
409
410          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
411              printf( "initCanBus, CAN status: %d\n", rStat );
412
413          rStat = ERR_CAN_SETUP;
414      }
415
416      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
417          printf( "initCanBus, status: %d\n", rStat );
418
419      return ( rStat );
420  }
421
422  //-----------------------------------------------------------------------------------------------------------
423  // "setupNodeMap" sets up the nodeMap. It is the first routine after all the basic hardware settings is in
424  // place. Unless the start options tell us to just format a new runtime area, we read in the nodeMap from
425  // the node NVM. A quick check of the magic words and the the nodeMap size field will tell us whether this
426  // nodeMap was initialized before. If this is not the case, we must assume a corrupt nodeMap or a new board.
427  // The runtime area data structures are created with default values and written to the NVM.
428  //
429  // In any case, the follow-on setup routines can assume a valid data structure to work from and just read
430  // the NVM as normal. If this routine has an error it should be considered as a fatal error.
431  //
432  // ??? check the sizes of the maps, load CDC map if we only have a board type ?
433  //-----------------------------------------------------------------------------------------------------------
434  uint8_t setupNodeMap( LcsConfigDesc *cfg ) {
435
436      uint8_t rStat = ALL_OK;
437
438      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupNodeMap\n" );
439
440      if ( startOptions & NOPT_FORMAT_RUNTIME ) {
441
442          rStat = buildNvmRuntimeStructures( );
443      }
444
445      rStat = rtNvmGetBytes( NVM_NODE_MAP_START, (uint8_t *) &nodeMap, sizeof( LcsNodeMap ));
446      if ( rStat != ALL_OK ) return( rStat );
447
448       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
449
450          uint16_t *ptr = (uint16_t *) &nodeMap;
451
452          printf( "NodeMap Head: " );
453          for ( int i = 0; i < 16; i++ ) printf( "0x%x ", ptr[ i ] );
454          printf( "\n" );
455      }
456
457      if (( nodeMap.head.magicWord1 != NVM_MWORD_1 ) ||
458          ( nodeMap.head.magicWord2 != NVM_MWORD_2 ) ||
459          ( nodeMap.nodeMapSize != sizeof( LcsNodeMap ))) {
460
461              // ??? check the sizes of the maps ???
462
463          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
464              printf( "setupNodeMap: invalid header, re-format\n" );
465
466          rStat = buildNvmRuntimeStructures( );
467      }
468
469      nodeMap.nodeOptions = cfg -> options;
470
471      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
472          printf( "setupNodeMap, status: %d\n", rStat );
473
474      return ( rStat );
475  }
476
477  //-----------------------------------------------------------------------------------------------------------
478  // "setupPortMap" will read the port data the NVM port map data area into the memory counterpart.
479  //
480  //-----------------------------------------------------------------------------------------------------------
481  uint8_t setupPortMap( ) {
482
483      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupPortMap\n" );
484
485      uint8_t rStat = rtNvmGetBytes( NVM_PORT_MAP_START, (uint8_t *) &portMap, sizeof( LcsPortMap ));
486
487      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
488          printf( "setupPortMap, status: %d\n", rStat );
489
490      return ( rStat );
491  }
492
493  //-----------------------------------------------------------------------------------------------------------
494  // "setupNodeDataMap" will read the node data blocks.
```

```
495  //
496  //-----------------------------------------------------------------------------------------------------------------
497  uint8_t setupNodeDataMap( ) {
498
499      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupNodeDataMap\n" );
500
501      uint8_t rStat = rtNvmGetBytes( NVM_NODE_DATA_START, (uint8_t *) &nodeData.map, sizeof( nodeData.map ));
502
503      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
504          printf( "setupNodeDataMap, status: %d\n", rStat );
505
506      return ( rStat );
507  }
508
509  //-----------------------------------------------------------------------------------------------------------------
510  // "setupCdcMap" will read the CDC descriptor from the NVM.
511  //
512  // ??? we should read it from the NVM, which implies that we need a way to handle vanilla boards...
513  // ??? we should also have a file with CDC descriptors for all boards we currently have...
514  // ??? if we detect a board with the vanilla board type, we can set the correct board type and the
515  // reboot...
516  //-----------------------------------------------------------------------------------------------------------------
517  uint8_t setupCdcMap( CDC::CdcConfigDesc *cdcConfig ) {
518
519      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupCdcMap\n" );
520
521      uint8_t rStat = ALL_OK;
522
523
524      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
525          printf( "setupCdcMap, status: %d\n", rStat );
526
527      return ( rStat );
528  }
529
530  //-----------------------------------------------------------------------------------------------------------------
531  // The event map stores all event/port pairs this node is interested to process. The map is a sorted map and
532  // there is a high water mark, so that we only read up to the last used entry in the map. Just like other
533  // data structures we could just read in all entries. However, this is a large map. It would be better to
534  // just read up to the HWM, if the HWM is valid. If this is not the case, we have to assume that there are
535  // bigger issues with the event map. In this case we will read the entire map entry by entry, add used
536  // entries, i.e. entries with a non-NIL event ID to the memory map. After reading all entries, the newly
537  // created event map is written back to the NVM place.
538  //
539  //-----------------------------------------------------------------------------------------------------------------
540  uint8_t setupEventMap( ) {
541
542      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
543
544          printf( "setupEventMap, entries: %d, HWM: %d\n", nodeMap.eventMapEntries, nodeMap.eventMapHwm );
545      }
546
547      uint8_t rStat = ALL_OK;
548
549      if ( nodeMap.eventMapHwm <= MAX_EVENT_MAP_ENTRIES ) {
550
551          for ( uint16_t i = 0; i < nodeMap.eventMapHwm; i++ ) {
552
553              rStat = rtNvmGetBytes(  NVM_EVENT_MAP_START + i * sizeof( LcsEventMapEntry),
554                                      (uint8_t *) &eventMap.map[ i ],
555                                      sizeof( LcsEventMapEntry ));
556          }
557      }
558      else {
559
560          LcsEventMapEntry e;
561          for ( uint16_t i = 0; i < nodeMap.eventMapEntries; i++ ) eventMap.map[ i ] = e;
562
563          nodeMap.eventMapHwm = 0;
564          for ( uint16_t i = 0; i < nodeMap.eventMapEntries; i++ ) {
565
566              LcsEventMapEntry eventEntry;
567
568              rStat = rtNvmGetBytes(  NVM_EVENT_MAP_START + i * sizeof(LcsEventMapEntry),
569                                      (uint8_t *) &eventEntry,
570                                      sizeof(LcsEventMapEntry));
571
572              if (( rStat == ALL_OK ) && ( eventEntry.eventId != NIL_EVENT_ID )) {
573
574                  addEvent( eventEntry.eventId, eventEntry.portId );
575              }
576          }
577
578          rStat = syncEventMap( );
579      }
580
581      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
582          printf( "setupEventMap, status: %d\n", rStat );
583
584      return ( rStat );
585  }
586
587  //-----------------------------------------------------------------------------------------------------------------
588  // The user map is the additional NVM storage that the chip set offers beyond the area allocated for the
589  // system. Since we have no idea what the user is doing, we do nothing for now. It is just a placeholder.
590  //
591  //-----------------------------------------------------------------------------------------------------------------
592  uint8_t setupUserMap( ) {
593
```

```
594        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupUserMap\n" );
595
596        uint8_t rStat = ALL_OK;
597
598        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
599            printf( "setupUserMap, status: %d\n", rStat );
600
601        return ( ALL_OK );
602    }
603
604    //------------------------------------------------------------------------------------------------------------
605    // "setupCallbackMap" initializes the callback map. We expect the user to register their callbacks between
606    // the runtime init and runtime start routine.
607    //
608    //------------------------------------------------------------------------------------------------------------
609    uint8_t setupCallbackMap( ) {
610
611        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupCallbackMap\n" );
612
613        uint8_t rStat = ALL_OK;
614
615        callbackMap.lcsMsgCallback      = nullptr;
616        callbackMap.dccMsgCallback      = nullptr;
617        callbackMap.cmdLineCallback     = nullptr;
618
619        callbackMap.initCallback        = nullptr;
620        callbackMap.resetCallback       = nullptr;
621        callbackMap.pfailCallback       = nullptr;
622
623        callbackMap.eventCallback       = nullptr;
624        callbackMap.reqCallback         = nullptr;
625        callbackMap.repCallback         = nullptr;
626
627        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
628            printf( "setupCallbackMap, status: %d\n", rStat );
629
630        return( rStat );
631    }
632
633    //------------------------------------------------------------------------------------------------------------
634    // "setupTaskMap" initializes the task map. A user can register routines that are executed on a periodic
635    // basis.
636    //
637    //------------------------------------------------------------------------------------------------------------
638    uint8_t setupTaskMap( ) {
639
640        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupTaskMap\n" );
641
642        uint8_t rStat = ALL_OK;
643
644        nodeMap.taskMapEntries  = MAX_TASK_MAP_ENTRIES;
645        nodeMap.taskMapHwm      = 0;
646
647        for ( int i = 0; i < MAX_TASK_MAP_ENTRIES; i++ ) {
648
649            taskMap.map[ i ].task      = nullptr;
650            taskMap.map[ i ].interval  = 0;
651            taskMap.map[ i ].timeStamp = 0;
652        }
653
654        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
655            printf( "setupTaskMap, status: %d\n", rStat );
656
657        return( rStat );
658    }
659
660    //------------------------------------------------------------------------------------------------------------
661    // "setupPendingReqMap" initializes the pending request map. Currently, we do not use a HWM approach, but
662    // just use all entries when searching the map.
663    //
664    //------------------------------------------------------------------------------------------------------------
665    uint8_t setupPendingReqMap( ) {
666
667        uint8_t rStat = ALL_OK;
668
669        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupPendingReqMap\n" );
670
671        nodeMap.pendingMapEntries   = MAX_PENDING_REQ_MAP_ENTRIES;
672        nodeMap.pendingMapHwm       = MAX_PENDING_REQ_MAP_ENTRIES;
673
674        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
675            printf( "setupPendingReqMap, status: %d\n", rStat );
676
677        return( rStat );
678    }
679
680    //------------------------------------------------------------------------------------------------------------
681    // "setupDrvFuncMap" initializes the driver function label map. This table is used when we need to find the
682    // driver for an extension board type.
683    //
684    // ??? we could pre register all known drivers... a user could still register a new one and also overwrite
685    // a pre-registered driver with a new func label.
686    //------------------------------------------------------------------------------------------------------------
687    uint8_t setupDrvFuncMap( ) {
688
689        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupDrvLabelMap\n" );
690
691        uint8_t rStat = ALL_OK;
692
```

```
693        nodeMap.drvFuncMapEntries = MAX_DRV_TYPES;
694        nodeMap.drvFuncMapHwm      = MAX_DRV_TYPES;
695
696        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
697            printf( "setupDrvLabelMap, status: %d\n", rStat );
698
699        return( rStat );
700    }
701
702    //----------------------------------------------------------------------------------------------------
703    // "setupDrvMap" initializes the driver map. For each possible extension board, up to four, there is an
704    // entry in this map.
705    //
706    //----------------------------------------------------------------------------------------------------
707    uint8_t setupDrvMap( ) {
708
709        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupDrvMap\n" );
710
711        uint8_t rStat = ALL_OK;
712
713        nodeMap.pendingMapEntries   = MAX_PENDING_REQ_MAP_ENTRIES;
714        nodeMap.pendingMapHwm       = MAX_PENDING_REQ_MAP_ENTRIES;
715
716        buildDefaultDrvMap( &drvMap );
717
718        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
719            printf( "setupDrvMap, status: %d\n", rStat  );
720
721        return( rStat );
722    }
723
724    //----------------------------------------------------------------------------------------------------
725    // The runtime library will one day perhaps a set of internal functions to execute periodically. Right now,
726    // this routine will do nothing.
727    //
728    //----------------------------------------------------------------------------------------------------
729    uint8_t registerInternalTasks( ) {
730
731        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "registerInternalTasks\n" );
732
733        uint8_t rStat = ALL_OK;
734
735
736        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
737            printf( "registerInternalTasks, status: %d\n" );
738
739        return( rStat );
740    }
741
742    //----------------------------------------------------------------------------------------------------
743    // With the node properly initialized, it is time to see whether we have connected extension boards. An
744    // extension board has also a small NVM on the board that will tell us what the board type is and keep driver
745    // configuration data. There can be up to four boards, numbered from 0 to 3. The runtime has a driver map
746    // with four extension descriptor entries. After initializing the driver map, we attempt to read from each
747    // extension NVM on an extension board. If the read fails, there is no board at that location, which will
748    // mark in the flags field. The drvMap HWM will tell us how many board we actually found. Note that the
749    // boards are by hardware always connected in the order 0,1,2 and 3. If for example only two boards are
750    // connected, the HWM would be 2.
751    //
752    //----------------------------------------------------------------------------------------------------
753    uint8_t detectExtensionBoards( ) {
754
755        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "detectExtensionBoards\n" );
756
757        uint8_t rStat = ALL_OK;
758
759        for ( int i = 0; i < MAX_EXT_BOARD_MAP_ENTRIES; i++ ) {
760
761            if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
762                printf( "detectExtensionBoard, boardId: %d\n", i );
763
764            LcsDrvEntry *drvEntry = &drvMap.map[ i ];
765
766            rStat = extNvmGetBytes( i, 0, (uint8_t *) &drvEntry -> extBoard, sizeof( LcsDrvBoardDesc ));
767            if ( rStat == ALL_OK ) {
768
769                uint16_t *ptr = (uint16_t *) &drvEntry -> extBoard;
770
771                if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
772
773                    printf( "Extension Board Desc Head: " );
774                    for ( int j = 0; j < 16; j++ ) printf( "0x%x ", ptr[ j ] );
775                    printf( "\n" );
776                }
777
778                nodeMap.nodeFlags |= NFLAGS_EXT_PRESENT;
779                nodeMap.drvMapHwm ++;
780
781                drvEntry -> flags |= BF_EXT_BOARD_PRESENT;
782
783                if (( drvEntry -> extBoard.head.magicWord1 == NVM_MWORD_1 ) &&
784                    ( drvEntry -> extBoard.head.magicWord2 == NVM_MWORD_2 )) {
785
786                    drvEntry -> flags |= BF_EXT_BOARD_VALID;
787
788                    if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
789                        printf( "detectExtensionBoard, boardId: %d -> valid\n", i );
790                }
791                else  {
```

```
792
793                     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
794                         printf( "detectExtensionBoard, boardId: %d -> inValid\n", i );
795                 }
796             }
797             else {
798
799                 if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
800                     printf( "detectExtensionBoard, boardId: %d, rStat: %d\n", i, rStat );
801             }
802         }
803
804         if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
805             printf( "detectExtensionBoards, status: %d\n", ALL_OK );
806
807         return ( ALL_OK );
808 }
809
810 //------------------------------------------------------------------------------------------------------------
811 // "lookupDrvFunc" searches the driver function label map. It is called when we setup the extension board.
812 // When the type is unknown, a nullptr is returned.
813 //
814 //------------------------------------------------------------------------------------------------------------
815 LcsDrvReqFunc lookupDrvFunc( uint16_t drvType ) {
816
817     for ( int i = 0; i < MAX_DRV_TYPES; i++ ) {
818
819         if ( drvFuncMap.map[ i ].drvType == drvType ) return( drvFuncMap.map[ i ].drvFunc );
820     }
821
822     return( nullptr );
823 }
824
825 //------------------------------------------------------------------------------------------------------------
826 // For all detected extension boards, we will first check that the board descriptor at slot "n" is there and
827 // that the board descriptor is reasonable. If so, the board type is used to load the respective driver.
828 // Note that during normal operations we cannot manipulate the NVM, as it is read protected. The jumper on
829 // the extension board needs to be removed for this. When removed, the extension board NVM can be written to
830 // with commands from the runtime.
831 //
832 // When the driver function is not pre registered, we do not have a function to set in the driver map.
833 // In this case the driver is not usable yet. The problem is that we can only make driver registration
834 // calls after LcsInitRuntime. But the all driver boards have been detected. There are two ways. For driver
835 // know already, we "pre-register" them. For any other driver, the driver function registration routine will
836 // check the driver table for the driver type and the patch the function label. All this should takes place
837 // before the final call to "startRuntime".
838 //
839 //------------------------------------------------------------------------------------------------------------
840 uint8_t setupExtensionBoards( ) {
841
842     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "setupExtensionBoards\n" );
843
844     uint8_t rStat = ALL_OK;
845
846     for ( int i = 0; i < MAX_EXT_BOARD_MAP_ENTRIES; i++ ) {
847
848         LcsDrvEntry *drvEntry = &drvMap.map[ i ];
849
850         if (( drvEntry -> flags & BF_EXT_BOARD_PRESENT ) && ( drvEntry -> flags & BF_EXT_BOARD_VALID )) {
851
852             LcsDrvReqFunc drvFunc = lookupDrvFunc( drvEntry -> extBoard.head.boardType );
853
854             if ( drvFunc != nullptr ) {
855
856                 drvEntry -> drvFunc = drvFunc;
857                 drvEntry -> flags   |= BF_EXT_BOARD_READY;
858                 drvEntry -> lastErr = drvEntry -> drvFunc( i, ITEM_ID_RESET, nullptr, nullptr );
859
860                 if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
861
862                     printf( "Driver setup, type: %d, stat: %d\n",
863                         drvEntry -> extBoard.head.boardType, drvEntry -> lastErr );
864                 }
865             }
866             else {
867
868                 if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) {
869
870                     printf( "Driver setup, type not found: %d\n", drvEntry -> extBoard.head.boardType );
871                 }
872             }
873         }
874     }
875
876     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
877         printf( "setupExtensionBoards, status: %d\n", rStat );
878
879     return ( rStat );
880 }
881
882 //------------------------------------------------------------------------------------------------------------
883 // Driver function registration. There is a simple table which maintains extension boards types and the
884 // driver function form them. If the type is already registered, we just overwrite the function signature.
885 // Otherwise we find a free entry and use it.
886 //
887 // The driver function registration can only be called after the initialization of the LCS runtime. By then
888 // the extension boards are however already detected, and if there are no drivers pre-registered no driver
889 // function was registered. The extension board is therefore not ready and was also not reseted. Consequently,
890 // // the  registration call will check or detected valid extension boards and patch the driver function label
```

```
891  // and invoke the RESET request.
892  //
893  //------------------------------------------------------------------------------------------------------------
894  uint8_t registerDrvFunc( uint16_t drvType, LcsDrvReqFunc drvReqFunction ) {
895
896      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
897          printf( "registerDrvFunc, type: %d, func: %p\n", drvType, drvReqFunction );
898
899      bool found = false;
900
901      for ( int i = 0; i < MAX_DRV_TYPES; i++ ) {
902
903          if ( drvFuncMap.map[ i ].drvType == drvType ) {
904
905              if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
906                  printf( "registerDrvFunc, overwrite: %d\n", i );
907
908              drvFuncMap.map[ i ].drvFunc = drvReqFunction;
909              found = true;
910              break;
911          }
912      }
913
914      if ( ! found ) {
915
916          for ( int i = 0; i < MAX_DRV_TYPES; i++ ) {
917
918              if ( drvFuncMap.map[ i ].drvType == BT_NIL ) {
919
920                  if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
921                      printf( "registerDrvFunc, allocate: %d\n", i );
922
923                  drvFuncMap.map[ i ].drvType = drvType;
924                  drvFuncMap.map[ i ].drvFunc = drvReqFunction;
925                  found = true;
926                  break;
927              }
928          }
929      }
930
931      if ( ! found ) {
932
933          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
934              printf( "registerDrvFunc, table full\n" );
935
936          return( ERR_DRV_FUNC_MAP_FULL );
937      }
938
939      for ( int i = 0; i < MAX_EXT_BOARD_MAP_ENTRIES; i++ ) {
940
941          LcsDrvEntry *drvEntry = &drvMap.map[ i ];
942
943          if (( drvEntry -> flags & BF_EXT_BOARD_PRESENT ) && ( drvEntry -> flags & BF_EXT_BOARD_VALID )) {
944
945              if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
946                  printf( "registerDrvFunc, set func for board: %d\n", i );
947
948              if ( drvEntry -> extBoard.head.boardType == drvType ) {
949
950                  drvEntry -> drvFunc    = drvReqFunction;
951                  drvEntry -> flags     |= BF_EXT_BOARD_READY;
952                  drvEntry -> lastErr    = drvEntry -> drvFunc( i, ITEM_ID_RESET, nullptr, nullptr );
953              }
954
955          }
956      }
957
958      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
959              printf( "registerDrvFunc, ret: ALL_OK\n" );
960
961      return( ALL_OK );
962  }
963
964  //------------------------------------------------------------------------------------------------------------
965  // "powerFailHandler" is the routine called when the hardware detects an imminent loss of power. We will save
966  // crucial data to NVM. Finally, the optionally registered firmware power fail callback is called. The node
967  // state becomes "PFAIL".
968  //
969  //------------------------------------------------------------------------------------------------------------
970  uint8_t powerFailHandler( ) {
971
972      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "powerFailHandler\n" );
973
974      uint8_t rStat = ALL_OK;
975
976      nodeMap.nodeState = NS_PFAIL;
977      rStat = rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeState ), NS_PFAIL );
978
979      if ( callbackMap.pfailCallback != nullptr ) callbackMap.pfailCallback( nodeMap.nodeId );
980
981      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
982          printf( "powerFailHandler, status: %d\n", rStat );
983
984      return ( rStat );
985  }
986
987  //------------------------------------------------------------------------------------------------------------
988  // "resetNode" restarts a node. We first rebuild the MEM areas from their NVM counterparts. Next, the optional
989  // reset call back is invoked. Finally, all ports are reseted as well.
```

```
990   //
991   // ??? read NVM to MEM.
992   // ??? would a node reset clear any outstanding requests ? or do we need to inform potential waiters ?
993   // ??? would it just drop all periodic tasks ? who registers them again ?
994   // ??? how do we make sure we only cover ports that are used ?
995   // ??? or would we need to be a bit more sensible what reset mean ?
996   //-------------------------------------------------------------------------------------------------------------
997   uint8_t resetNode( uint16_t npId ) {
998
999       uint8_t rStat = ALL_OK;
1000
1001       if ( callbackMap.resetCallback != nullptr ) {
1002
1003           // ??? load MEM from NVM....
1004
1005           if ( callbackMap.resetCallback != nullptr ) {
1006
1007               rStat = callbackMap.resetCallback( buildNpId( nodeMap.nodeId, 0  ));
1008           }
1009
1010
1011       }
1012
1013       if ( rStat == ALL_OK ) {
1014
1015           for ( uint8_t i = 1; i <= MAX_PORT_MAP_ENTRIES; i++ ) {
1016
1017               // ??? load MEM from NVM....
1018
1019               if ( callbackMap.resetCallback != nullptr ) {
1020
1021                   rStat = callbackMap.resetCallback( buildNpId( nodeMap.nodeId, i ));
1022               }
1023           }
1024       }
1025
1026       if ( rStat == ALL_OK ) {
1027
1028           // ??? reset the drivers...
1029       }
1030
1031       return ( rStat );
1032   }
1033
1034   //-------------------------------------------------------------------------------------------------------------
1035   // The LCS library has a set of configuration parameters. Currently this is only the "options" field. In the
1036   // future there may be more fields. This routines returns a config structure with reasonable defaults set.
1037   //
1038   //-------------------------------------------------------------------------------------------------------------
1039   LcsConfigDesc getConfigDefault( ) {
1040
1041       LcsConfigDesc cfg;
1042
1043       cfg.options = 0;
1044
1045       return( cfg );
1046   }
1047
1048   //-------------------------------------------------------------------------------------------------------------
1049   // "initRuntime" is the routine that takes a controller board and initializes the whole show. It is the very
1050   // first thing to call in a node firmware program. There is a lot to do. First, the CDC layer is initialized.
1051   // NVM and CanBus follow. An error in this stage will result in a fatal error, we are not able to set up a
1052   // valid runtime.
1053   //
1054   // If the HW setup worked, we are ready to read in the nodeMap. A nodeMap can be valid or not. It is defined
1055   // as a map with valid "magic" words and reasonable values for the other fields. In case of an invalid
1056   // nodeMap, a new default map is created and written back to the NVM. An invalid nodeMap could result from
1057   // erroneous writes to NVM locations or simply a brand new HW board. If all is OK, we have a valid basic
1058   // nodeMap that we can work from.
1059   //
1060   // The setup of the portMap follows. The flag field contains dynamic flags that are always reseted on node
1061   // start or reset. Other fields in a map are read in from the NVM first and set to a default state this way.
1062   //
1063   // The eventMap initialization is a bit special, in that it is a rather large map and potentially only a
1064   // portion is used. There is an eventMao high water mark field in the nodeMap that will tell how many entries
1065   // are actually used in the event map. Adding increases, deleting decreases the high water mark. Note that
1066   // the eventMap is a sorted map. Every time we insert or remove the eventMap is rebuilt. Instead of
1067   // immediately updating the NVM storage, a dedicated command will SYNC between the MEM and the NVM eventMap.
1068   //
1069   // Next, we will set up the pending request map, callback function and task map. They are just memory data
1070   // areas to be initialized. Up to here an error detected will result in a fatal error. If a console is
1071   // connected the error messages are listed for analysis.
1072   //
1073   // If all is OK so far, extension boards are located, and if there are any, their initialization follows.
1074   // First, we try to detect any. For all detected entries we validate the extension board NVM header and
1075   // set the driver for a valid header found. The driver data area is copied to its memory counter part.
1076   // All drivers are ready by then.
1077   //
1078   // The overall logic of the startup routine code below is that if there is a fault, the follow on steps are
1079   // simply  skipped and the node is put into the FAIL state. Note that we still are able to access the node
1080   // via the USB console and one day also via diagnostic LCS messages. The idea is to allow the correct
1081   // configuration  of the nodeMap, so that we can restart with a correct nodeMap.
1082   //
1083   // ??? how do we deal wit PFAIL restarts ?
1084   // ??? we could have also callbacks for the "restart" case ? or pass to init a flag...
1085   //-------------------------------------------------------------------------------------------------------------
1086   uint8_t initRuntime( LcsConfigDesc *lcsConfig, CDC::CdcConfigDesc *cdcConfig ) {
1087
1088       uint8_t rStat = ALL_OK;
```

```
1089
1090        if ( rStat == ALL_OK )  rStat = initCdcLayer( cdcConfig );
1091        if ( rStat != ALL_OK )  CDC::fatalErrorMsg((char *) "Fatal: CDC Setup failed", 1, rStat );
1092
1093        CDC::writeDio( cdcConfig -> READY_LED_PIN, false );
1094        CDC::writeDio( cdcConfig -> ACTIVE_LED_PIN, true );
1095
1096        if ( rStat == ALL_OK )  rStat = initCanBus( cdcConfig );
1097        if ( rStat == ALL_OK )  rStat = initNvmChannels( cdcConfig );
1098        if ( rStat != ALL_OK )  CDC::fatalErrorMsg((char *) "Fatal: CAN bus or NVM Setup failed", 2, rStat );
1099
1100        if ( rStat == ALL_OK )  rStat = setupNodeMap( lcsConfig );
1101        if ( rStat == ALL_OK )  rStat = setupCdcMap( cdcConfig );
1102        if ( rStat == ALL_OK )  rStat = setupPortMap( );
1103        if ( rStat == ALL_OK )  rStat = setupNodeDataMap( );
1104        if ( rStat == ALL_OK )  rStat = setupEventMap( );
1105        if ( rStat == ALL_OK )  rStat = setupUserMap( );
1106        if ( rStat == ALL_OK )  rStat = setupCallbackMap( );
1107        if ( rStat == ALL_OK )  rStat = setupTaskMap( );
1108        if ( rStat == ALL_OK )  rStat = setupPendingReqMap( );
1109        if ( rStat == ALL_OK )  rStat = setupDrvFuncMap( );
1110        if ( rStat == ALL_OK )  rStat = setupDrvMap( );
1111        if ( rStat == ALL_OK )  rStat = registerInternalTasks( );
1112        if ( rStat != ALL_OK )  CDC::fatalErrorMsg((char *) "Node setup Setup failed", 3, rStat );
1113
1114        if ( rStat == ALL_OK )  rStat = detectExtensionBoards( );
1115        if ( rStat == ALL_OK )  rStat = setupExtensionBoards( );
1116        if ( rStat != ALL_OK )  printf( "Extension boards setup Setup failed, stat: %d\n", rStat );
1117
1118        if ( rStat == ALL_OK )  nodeMap.nodeState = NS_INIT;
1119        else                    nodeMap.nodeState = NS_FAIL;
1120
1121        if ( rStat == ALL_OK )  {
1122
1123            CDC::writeDio( cdcConfig -> READY_LED_PIN, true );
1124            CDC::writeDio( cdcConfig -> ACTIVE_LED_PIN, false );
1125        }
1126
1127        if ( debugMask & ( DBG_CONFIG && DBG_SETUP )) printf( "init LCS runtime, status: %d \n", rStat );
1128        return ( rStat );
1129 }
1130
1131 //------------------------------------------------------------------------------------------------------------
1132 // "startRuntime" is the main routine of the node activity processing. All it does is to call the node
1133 // state machine.
1134 //
1135 //------------------------------------------------------------------------------------------------------------
1136 void startRuntime( ) {
1137
1138        if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP )) printf( "Start LCS runtime\n");
1139
1140        handleNodeState( );
1141 }
1142
1143 }; // namespace LCS
```

```
1   //--------------------------------------------------------------------------------------------------------------
2   //
3   // "LcsRtMsgBus" - implementation file.
4   //
5   //--------------------------------------------------------------------------------------------------------------
6   // At the message level, the LCS runtime offers a message to which all nodes are connected. Currently, it is
7   // a CAN bus. Pretty straightforward and robust. This file contains the routines to set up the communication
8   // as well as a set of convenience functions for sending a LCS message taking care of filling the message
9   // frame. Some LCS message are of a "request/reply" nature. When a request is sent out a entry is made in
10  // the pending request map. Since the message layer sees all reply message, this pending map is used to
11  // filter for the request we are waiting for.
12  //
13  //--------------------------------------------------------------------------------------------------------------
14  //
15  // LCS - Core Library
16  // Copyright (C) 2021 - 2024  Helmut Fieres
17  //
18  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
19  // General Public License as published by the Free Software Foundation, either version 3 of the License,
20  // or any later version.
21  //
22  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
23  // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
24  // License for more details. You should have received a copy of the GNU General Public License along with
25  // this program.  If not, see <http://www.gnu.org/licenses/>.
26  //
27  //--------------------------------------------------------------------------------------------------------------
28  #include "LcsRuntimeLib.h"
29  #include "LcsRtLibInt.h"
30
31  //--------------------------------------------------------------------------------------------------------------
32  // External declaration to global structures defined in "LcsRtSetup".
33  //
34  //--------------------------------------------------------------------------------------------------------------
35  namespace LCS {
36
37      extern uint16_t              debugMask;
38      extern LCS::LcsNodeMap       nodeMap;
39      extern LCS::LcsCallbackMap   callbackMap;
40      extern LCS::LcsPendingReqMap pendingReqMap;
41      extern LCS::LcsTaskMap       taskMap;
42      extern LCS::LcsMsgBusCAN     *msgBus;
43  };
44
45  //--------------------------------------------------------------------------------------------------------------
46  // File local declarations.
47  //
48  //--------------------------------------------------------------------------------------------------------------
49  namespace {
50
51  using namespace LCS;
52
53  //--------------------------------------------------------------------------------------------------------------
54  // Little helper functions and constants.
55  //
56  //--------------------------------------------------------------------------------------------------------------
57  const uint32_t DEF_REQ_TIMEOUT_VAL_MS = 50000;
58
59  bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
60
61    return (( val >= lower ) && ( val <= upper ));
62  }
63
64  uint16_t buildNpId( uint16_t nodeId, uint16_t portId ) {
65
66      return(( nodeId << 4 ) | ( portId & 0xF ));
67  }
68
69  uint16_t nodeId( uint16_t npId ) {
70
71      return( npId >> 4 );
72  }
73
74  uint16_t portId( uint16_t npId ) {
75
76      return( npId & 0xF );
77  }
78
79  uint8_t lowByte( uint16_t arg ) {
80
81      return( arg & 0xFF );
82  }
83
84  uint8_t highByte( uint16_t arg ) {
85
86      return( arg >> 8 );
87  }
88
89  //--------------------------------------------------------------------------------------------------------------
90  // There are some LCS messages that expect a reply message. The library maintains a small pending request
91  // buffer. When a request type message is sent we add the target node and a timer value to the buffer. Easy
92  // and simple. Note that there can be more than one entry for the same node / port combination in the buffer.
93  // If the buffer is full, an error is returned. We have too many outstanding requests then.
94  //
95  // A request can also be registered with a timeout value. When the timeout expires, the caller is informed
96  // that the request timed out. A timeout value of zero means that we wait indefinitely.
97  //
98  //--------------------------------------------------------------------------------------------------------------
```

```
99   uint8_t addToPendingReqMap ( uint16_t npId , uint32_t timeoutVal = 0 ) {
100
101      uint32_t ts = CDC::getMillis ( );
102
103      for ( uint8_t i = 0; i < MAX_PENDING_REQ_MAP_ENTRIES; i++ ) {
104
105          if ( pendingReqMap.map[ i ].npId == 0 ) {
106
107              pendingReqMap.map[ i ].npId = npId;
108              pendingReqMap.map[ i ].reqTimeoutTs = (( timeoutVal != 0 ) ? ts + timeoutVal : timeoutVal );
109              return ( ALL_OK );
110          }
111      }
112
113      return ( ERR_PENDING_REQ_MAP_FULL );
114  }
115
116  //-----------------------------------------------------------------------------------------------------------------
117  // "removeFromPendingReqMap" removes an entry from the pending reply buffer. If the entry is not found, we
118  // received a reply for a request that we do not know. Right now, we just ignore this error.
119  //
120  //-----------------------------------------------------------------------------------------------------------------
121  uint8_t removeFromPendingReqMap ( uint16_t npId ) {
122
123      for ( uint8_t i = 0; i < MAX_PENDING_REQ_MAP_ENTRIES; i++ ) {
124
125          if ( pendingReqMap.map[ i ].npId == npId ) pendingReqMap.map[ i ].npId = NIL_NODE_ID;
126      }
127
128      return ( ALL_OK );
129  }
130
131  //-----------------------------------------------------------------------------------------------------------------
132  // "searchPendingReqMap" searches the pending request buffer for a matching node. We just return a boolean
133  // answer whether the entry is there or not.
134  //
135  //-----------------------------------------------------------------------------------------------------------------
136  bool searchPendingReqMap ( uint16_t npId ) {
137
138      for ( uint8_t i = 0; i < MAX_PENDING_REQ_MAP_ENTRIES; i++ ) {
139
140          if ( pendingReqMap.map[ i ].npId == npId ) return ( true );
141      }
142
143      return ( false );
144  }
145
146  }; // namespace
147
148
149  //-----------------------------------------------------------------------------------------------------------------
150  // The LCS name space routines declared in this file.
151  //
152  //-----------------------------------------------------------------------------------------------------------------
153  namespace LCS {
154
155  //-----------------------------------------------------------------------------------------------------------------
156  // "setupMsgBus" is called during node initialization to setup the LCS message bus interface. Right now,
157  // only the CAN bus is supported. We first create the CAN Bus object and then call its initialization routine.
158  // The canId and nodeId are identical. We ensure through LCS configuration that the nodeIds are unique.
159  //
160  //
161  // ??? how do we configure the CAN control mode ?
162  //-----------------------------------------------------------------------------------------------------------------
163  uint8_t setupMsgBus ( ) {
164
165      uint8_t    rStat          = ALL_OK;
166      uint16_t   canBusCtrlMode = CAN_BUS_LIB_PICO_PIO_125K_M_CORE;
167      uint8_t    canBusTxPin    = 0;
168      uint8_t    canBusRxPin    = 0;
169
170      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_MSG_BUS )) {
171
172          printf( "setupMsgBus -> %d:%d:%d%d\n", nodeMap.nodeId, canBusRxPin, canBusTxPin, canBusCtrlMode );
173      }
174
175      switch ( canBusCtrlMode ) {
176
177          case CAN_BUS_LIB_PICO_PIO_125K:
178          case CAN_BUS_LIB_PICO_PIO_250K:
179          case CAN_BUS_LIB_PICO_PIO_500K:
180          case CAN_BUS_LIB_PICO_PIO_1000K:
181          case CAN_BUS_LIB_PICO_PIO_125K_M_CORE:
182          case CAN_BUS_LIB_PICO_PIO_250K_M_CORE:
183          case CAN_BUS_LIB_PICO_PIO_500K_M_CORE:
184          case CAN_BUS_LIB_PICO_PIO_1000K_M_CORE: {
185
186              msgBus = new LcsMsgBusCAN ( );
187              rStat = (( LcsMsgBusCAN *) msgBus ) -> init ( nodeMap.nodeId, canBusRxPin, canBusTxPin, canBusCtrlMode );
188
189          } break;
190
191          default: rStat = ERR_CAN_SETUP;
192      }
193
194      if ( rStat != ALL_OK ) {
195
196          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_MSG_BUS ))
197              printf( "setup CAN Bus failed: %d\n", rStat );
```

```
198
199            return ( ERR_CAN_SETUP );
200        }
201         else {
202
203             if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_MSG_BUS )) printf( " -> OK\n" );
204            return ( ALL_OK );
205        }
206 }
207
208 //-----------------------------------------------------------------------------------------------------------
209 // The primary task of the receive function is to receive an LCS messages and pass them to the respective
210 // handler method. In order to not always check whether a valid message was processed, this routine will
211 // always return a valid message opCode. The "LCS_NO_MSG" pseudo message is used to indicate that something
212 // else happened and no further message processing is required. We also maintain a request / reply map to
213 // keep track of outstanding requests transparently to the caller.
214 //
215 // ??? should we have a pre-filter for message ID and nodeId match ? this would be perhaps useful, when we
216 // run CAN bus on two cores on the pico. Then the checking would run on the interrupt handler processor.
217 // However, the pending request map is then accessed by two cores and we need to sync the access.
218 //-----------------------------------------------------------------------------------------------------------
219 uint8_t receiveLcsMsg( uint8_t *msg ) {
220
221     int rStat = msgBus -> receiveLcsMsg( msg );
222
223     if ( rStat == ALL_OK )  {
224
225             if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_MSG_BUS )) {
226
227                 printf( "Can Msg Received (OpCode): 0x%x\n", msg[ 0 ] );
228            }
229
230            if (( msg[ 0 ] == LCS_OP_NODE_REP ) || ( msg[ 0 ] == LCS_OP_ACK ) || ( msg[ 0 ] == LCS_OP_ERR )) {
231
232                 uint16_t nodeId = (( msg[1] << 8 ) + msg[2] ) >> 4;
233
234                if ( searchPendingReqMap( nodeId )) {
235
236                     removeFromPendingReqMap( nodeId );
237                     return ( msg[ 0 ] );
238
239                } else return ( LCS_OP_NO_MSG );
240
241            } else return ( msg[ 0 ] );
242
243     } else return ( LCS_OP_NO_MSG );
244 }
245
246 //-----------------------------------------------------------------------------------------------------------
247 // A simple helper to print an LCS message.
248 //
249 //-----------------------------------------------------------------------------------------------------------
250 void printLcsMsg( uint8_t *msg ) {
251
252     printf( "LCS MSG: op: %d, data: ", msg[ 0 ] & 0x1F );
253     for ( int i = 0; i < ( msg[ 0 ] >> 5 ) + 1; i ++ ) printf( "0x%x ", msg[ i ] );
254     printf( "\n" );
255 }
256
257 //-----------------------------------------------------------------------------------------------------------
258 // "processPendingReqMapTimeouts" is part of the periodic processing of the node. It will check wether any
259 // requests waiting for a reply have timed out. In this case, we should invoke the reply callback with an
260 // error code.
261 //
262 //-----------------------------------------------------------------------------------------------------------
263 void processPendingReqMapTimeouts( ) {
264
265     uint32_t ts = CDC::getMillis( );
266
267     for ( uint8_t i = 0; i < MAX_PENDING_REQ_MAP_ENTRIES; i++ ) {
268
269         if ( pendingReqMap.map[ i ].reqTimeoutTs != 0 ) {
270
271             if ( pendingReqMap.map[ i ].reqTimeoutTs < ts ) {
272
273                 if ( callbackMap.repCallback != nullptr ) {
274
275                     callbackMap.repCallback( pendingReqMap.map[ i ].npId, 0, 0, 0, ERR_REQ_TIMEOUT );
276                 }
277
278                 // ??? clear entry ?
279
280             }
281         }
282     }
283 }
284
285 //-----------------------------------------------------------------------------------------------------------
286 // Some messages are requests that expect a reply. We maintain a pending request map which keeps track of
287 // outstanding requests.
288 //
289 //-----------------------------------------------------------------------------------------------------------
290 uint8_t sendTimedReq( uint16_t npId, uint8_t *msg, uint8_t msgPri, uint32_t timeout ) {
291
292     if ( addToPendingReqMap( npId ) == ALL_OK ) {
293
294         return ( msgBus -> sendLcsMsg( msg, msgPri ));
295     }
296     else return ( ERR_NODE_OUTSTANDING_REQ_LIMIT );
```

```
297 | }
298 |
299 | //---------------------------------------------------------------------------------------------------------------
300 | // LCB message send routines. They all follow the same pattern. There is a method for each message opcode,
301 | // which maps the input parameters to the byte array and then send it. Straightforward. For messages that are
302 | // a part of a request / reply pair, the requesting messages will also add the requesting nodeId to the
303 | // pending request map. This way we know that there is an outstanding request. The receiving message handler
304 | // will clear the entry upon the matching receipt.
305 | //
306 | //---------------------------------------------------------------------------------------------------------------
307 | uint8_t sendCfg( uint16_t npId ) {
308 |
309 |     uint8_t msgBuf[ 8 ] = { LCS_OP_CFG };
310 |     msgBuf[ 1 ] = highByte( npId );
311 |     msgBuf[ 2 ] = lowByte( npId );
312 |
313 |     return( sendTimedReq( npId, msgBuf,  MSG_PRI_HIGH , 0 ));
314 | }
315 |
316 | uint8_t sendOps( uint16_t npId ) {
317 |
318 |     uint8_t msgBuf[ 8 ] = { LCS_OP_OPS };
319 |     msgBuf[ 1 ] = highByte( npId );
320 |     msgBuf[ 2 ] = lowByte( npId );
321 |
322 |     return( sendTimedReq( npId, msgBuf,  MSG_PRI_HIGH , 0 ));
323 | }
324 |
325 | uint8_t sendReset( uint16_t npId ) {
326 |
327 |     uint8_t msgBuf[ 8 ] = { LCS_OP_RESET };
328 |     msgBuf[ 1 ] = highByte( npId );
329 |     msgBuf[ 2 ] = lowByte( npId );
330 |
331 |     return ( sendTimedReq( npId, msgBuf, MSG_PRI_HIGH, 0 ));
332 | }
333 |
334 | uint8_t sendBusOn( ) {
335 |
336 |     uint8_t msgBuf[ 8 ] = { LCS_OP_BON };
337 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_VERY_HIGH ));
338 | }
339 |
340 | uint8_t sendBusOff( ) {
341 |
342 |     uint8_t msgBuf[ 8 ] = { LCS_OP_BOF };
343 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_VERY_HIGH ));
344 | }
345 |
346 | uint8_t sendErr( uint16_t npId, uint8_t errCode, uint8_t arg1, uint8_t arg2 ) {
347 |
348 |     uint8_t msgBuf[ 8 ] = { LCS_OP_ERR };
349 |     msgBuf[ 1 ] = highByte( npId );
350 |     msgBuf[ 2 ] = lowByte( npId );
351 |     msgBuf[ 3 ] = errCode;
352 |     msgBuf[ 4 ] = arg1;
353 |     msgBuf[ 5 ] = arg2;
354 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
355 | }
356 |
357 | uint8_t sendPing( uint16_t npId ) {
358 |
359 |     uint8_t msgBuf[ 8 ] = { LCS_OP_PING };
360 |     msgBuf[ 1 ] = highByte( npId );
361 |     msgBuf[ 2 ] = lowByte( npId );
362 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
363 | }
364 |
365 | uint8_t sendAck( uint16_t npId ) {
366 |
367 |     uint8_t msgBuf[ 8 ] = { LCS_OP_ACK };
368 |     msgBuf[ 1 ] = highByte( npId );
369 |     msgBuf[ 2 ] = lowByte( npId );
370 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
371 | }
372 |
373 | uint8_t sendReqNodeId( uint16_t npId, uint32_t nodeUID, uint8_t flags ) {
374 |
375 |     uint8_t msgBuf[ 8 ] = { LCS_OP_REQ_NID };
376 |     msgBuf[ 1 ] = highByte( npId );
377 |     msgBuf[ 2 ] = lowByte( npId );
378 |     msgBuf[ 3 ] = ( nodeUID & 0xFF000000 ) >> 24;
379 |     msgBuf[ 4 ] = ( nodeUID & 0x00FF0000 ) >> 16;
380 |     msgBuf[ 5 ] = ( nodeUID & 0x0000FF00 ) >> 8;
381 |     msgBuf[ 6 ] = ( nodeUID & 0x000000FF );
382 |     msgBuf[ 7 ] = flags;
383 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
384 | }
385 |
386 | uint8_t sendRepNodeId( uint16_t npId, uint32_t nodeUID ) {
387 |
388 |     uint8_t msgBuf[ 8 ] = { LCS_OP_REP_NID };
389 |     msgBuf[ 1 ] = highByte( npId );
390 |     msgBuf[ 2 ] = lowByte( npId );
391 |     msgBuf[ 3 ] = ( nodeUID & 0xFF000000 ) >> 24;
392 |     msgBuf[ 4 ] = ( nodeUID & 0x00FF0000 ) >> 16;
393 |     msgBuf[ 5 ] = ( nodeUID & 0x0000FF00 ) >> 8;
394 |     msgBuf[ 6 ] = ( nodeUID & 0x000000FF );
395 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
```

```
396   }
397
398   uint8_t sendSetNodeId( uint16_t npId, uint32_t nodeUID ) {
399
400       uint8_t msgBuf[ 8 ] = { LCS_OP_SET_NID };
401       msgBuf[ 1 ] = highByte( npId );
402       msgBuf[ 2 ] = lowByte( npId );
403       msgBuf[ 3 ] = ( nodeUID & 0xFF000000 ) >> 24;
404       msgBuf[ 4 ] = ( nodeUID & 0x00FF0000 ) >> 16;
405       msgBuf[ 5 ] = ( nodeUID & 0x0000FF00 ) >> 8;
406       msgBuf[ 6 ] = ( nodeUID & 0x000000FF );
407       return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
408   }
409
410   uint8_t sendNodeIdCollision( uint16_t npId, uint32_t nodeUID ) {
411
412       uint8_t msgBuf[ 8 ] = { LCS_OP_NCOL };
413       msgBuf[ 1 ] = highByte( npId );
414       msgBuf[ 2 ] = lowByte( npId );
415       msgBuf[ 3 ] = ( nodeUID & 0xFF000000 ) >> 24;
416       msgBuf[ 4 ] = ( nodeUID & 0x00FF0000 ) >> 16;
417       msgBuf[ 5 ] = ( nodeUID & 0x0000FF00 ) >> 8;
418       msgBuf[ 6 ] = ( nodeUID & 0x000000FF );
419       return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_HIGH ));
420   }
421
422   uint8_t sendGetNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2 ) {
423
424       uint8_t msgBuf[ 8 ] = { LCS_OP_NODE_GET };
425       msgBuf[ 1 ] = highByte( npId );
426       msgBuf[ 2 ] = lowByte( npId );
427       msgBuf[ 3 ] = item;
428       msgBuf[ 4 ] = highByte( val1 );
429       msgBuf[ 5 ] = lowByte( val1 );
430       msgBuf[ 6 ] = highByte( val2 );
431       msgBuf[ 7 ] = lowByte( val2 );
432       return( sendTimedReq( npId, msgBuf,  MSG_PRI_NORMAL, 0 ));
433   }
434
435   uint8_t sendSetNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2 ) {
436
437       uint8_t msgBuf[ 8 ] = { LCS_OP_NODE_PUT };
438       msgBuf[ 1 ] = highByte( npId );
439       msgBuf[ 2 ] = lowByte( npId );
440       msgBuf[ 3 ] = item;
441       msgBuf[ 4 ] = highByte( val1 );
442       msgBuf[ 5 ] = lowByte( val1 );
443       msgBuf[ 6 ] = highByte( val2 );
444       msgBuf[ 7 ] = lowByte( val2 );
445       return( sendTimedReq( npId, msgBuf,  MSG_PRI_NORMAL, 0 ));
446   }
447
448   uint8_t sendReqNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2 ) {
449
450       uint8_t msgBuf[ 8 ] = { LCS_OP_NODE_REQ };
451       msgBuf[ 1 ] = highByte( npId );
452       msgBuf[ 2 ] = lowByte( npId );
453       msgBuf[ 3 ] = item;
454       msgBuf[ 4 ] = highByte( val1 );
455       msgBuf[ 5 ] = lowByte( val1 );
456       msgBuf[ 6 ] = highByte( val2 );
457       msgBuf[ 7 ] = lowByte( val2 );
458       return( sendTimedReq( npId, msgBuf,  MSG_PRI_LOW, 0 ));
459   }
460
461   uint8_t sendRepNode( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2 ) {
462
463       uint8_t msgBuf[ 8 ] = { LCS_OP_NODE_REP };
464       msgBuf[ 1 ] = highByte( npId );
465       msgBuf[ 2 ] = lowByte( npId );
466       msgBuf[ 3 ] = item;
467       msgBuf[ 4 ] = highByte( val1 );
468       msgBuf[ 5 ] = lowByte( val1 );
469       msgBuf[ 6 ] = highByte( val2 );
470       msgBuf[ 7 ] = lowByte( val2 );
471       return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
472   }
473
474   uint8_t sendEventOn( uint16_t npId, uint16_t eventId ) {
475
476       uint8_t msgBuf[ 8 ] = { LCS_OP_EVT_ON };
477       msgBuf[ 1 ] = highByte( npId );
478       msgBuf[ 2 ] = lowByte( npId );
479       msgBuf[ 3 ] = highByte( eventId );
480       msgBuf[ 4 ] = lowByte( eventId );
481
482        if ( nodeId( npId ) == nodeMap.nodeId ) {
483
484           handleMsgEvent( msgBuf );
485           return( ALL_OK );
486       }
487       else return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
488   }
489
490   uint8_t sendEventOff( uint16_t npId, uint16_t eventId ) {
491
492       uint8_t msgBuf[ 8 ] = { LCS_OP_EVT_OFF };
493       msgBuf[ 1 ] = highByte( npId );
494       msgBuf[ 2 ] = lowByte( npId );
```

```
495        msgBuf[ 3 ] = highByte( eventId );
496        msgBuf[ 4 ] = lowByte( eventId );
497
498        if ( nodeId( npId ) == nodeMap.nodeId ) {
499
500            handleMsgEvent( msgBuf );
501            return( ALL_OK );
502        }
503        else return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
504    }
505
506    uint8_t sendEvent( uint16_t npId, uint16_t eventId, uint16_t arg ) {
507
508        uint8_t msgBuf[ 8 ] = { LCS_OP_EVT };
509        msgBuf[ 1 ] = highByte( npId );
510        msgBuf[ 2 ] = lowByte( npId );
511        msgBuf[ 3 ] = highByte( eventId );
512        msgBuf[ 4 ] = lowByte( eventId );
513        msgBuf[ 5 ] = highByte( arg );
514        msgBuf[ 6 ] = lowByte( arg );
515
516        if ( nodeId( npId ) == nodeMap.nodeId ) {
517
518            handleMsgEvent( msgBuf );
519            return( ALL_OK );
520        }
521        else return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
522    }
523
524    uint8_t sendTrackOn( ) {
525
526        uint8_t msgBuf[ 8 ] = { LCS_OP_TON };
527        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_HIGH ));
528    }
529
530    uint8_t sendTrackOff( ) {
531
532        uint8_t msgBuf[ 8 ] = { LCS_OP_TOF };
533        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_HIGH ));
534    }
535
536    uint8_t sendEstop( ) {
537
538        uint8_t msgBuf[ 8 ] = { LCS_OP_ESTP };
539        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_VERY_HIGH ));
540    }
541
542    uint8_t sendReqLoc( uint16_t locAdr, uint8_t flags ) {
543
544        uint8_t msgBuf[ 8 ] = { LCS_OP_REQ_LOC };
545        msgBuf[ 1 ] = highByte( locAdr );
546        msgBuf[ 2 ] = lowByte( locAdr );
547        msgBuf[ 3 ] = flags;
548        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
549    }
550
551    uint8_t sendRelLoc( uint8_t sId ) {
552
553        uint8_t msgBuf[ 8 ] = { LCS_OP_REL_LOC };
554        msgBuf[ 1 ] = sId;
555        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
556    }
557
558    uint8_t sendRepLoc( uint8_t sId, uint16_t locAdr, uint8_t spDir, uint8_t fn1, uint8_t fn2, uint8_t fn3 ) {
559
560        uint8_t msgBuf[ 8 ] = { LCS_OP_REP_LOC };
561        msgBuf[ 1 ] = sId;
562        msgBuf[ 2 ] = highByte( locAdr );
563        msgBuf[ 3 ] = lowByte( locAdr );
564        msgBuf[ 4 ] = spDir;
565        msgBuf[ 5 ] = fn1;
566        msgBuf[ 6 ] = fn2;
567        msgBuf[ 7 ] = fn3;
568        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
569    }
570
571    uint8_t sendLocConsist( uint8_t sId, uint8_t consId, uint8_t flags ) {
572
573        uint8_t msgBuf[ 8 ] = { LCS_OP_SET_LCON };
574        msgBuf[ 1 ] = sId;
575        msgBuf[ 2 ] = consId;
576        msgBuf[ 3 ] = flags;
577        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
578    }
579
580    uint8_t sendQueryLoc( uint8_t sId ) {
581
582        uint8_t msgBuf[ 8 ] = { LCS_OP_QRY_LOC };
583        msgBuf[ 1 ] = sId;
584        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
585    }
586
587    uint8_t sendKeepLoc( uint8_t sId ) {
588
589        uint8_t msgBuf[ 8 ] = { LCS_OP_KEEP_LOC };
590        msgBuf[ 1 ] = sId;
591        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
592    }
593
```

```
594 | uint8_t sendSetLocSpDir( uint8_t sId, uint8_t spDir ) {
595 |
596 |     uint8_t msgBuf[ 8 ] = { LCS_OP_SET_LSPD };
597 |     msgBuf[ 1 ] = sId;
598 |     msgBuf[ 2 ] = spDir;
599 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
600 | }
601 |
602 | uint8_t sendSetLocMode( uint8_t sId, uint8_t mode ) {
603 |
604 |     uint8_t msgBuf[ 8 ] = { LCS_OP_SET_LMOD };
605 |     msgBuf[ 1 ] = sId;
606 |     msgBuf[ 2 ] = mode;
607 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
608 | }
609 |
610 | uint8_t sendSetLocFuncOn( uint8_t sId, uint8_t fNum ) {
611 |
612 |     uint8_t msgBuf[ 8 ] = { LCS_OP_LOC_FON };
613 |     msgBuf[ 1 ] = sId;
614 |     msgBuf[ 2 ] = fNum;
615 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
616 | }
617 |
618 | uint8_t sendSetLocFuncOff( uint8_t sId, uint8_t fNum ) {
619 |
620 |     uint8_t msgBuf[ 8 ] = { LCS_OP_LOC_FOF };
621 |     msgBuf[ 1 ] = sId;
622 |     msgBuf[ 2 ] = fNum;
623 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
624 | }
625 |
626 | uint8_t sendSetLocFgroup( uint8_t sId, uint8_t fGroup, uint8_t data ) {
627 |
628 |     uint8_t msgBuf[ 8 ] = { LCS_OP_LOC_FGRP };
629 |     msgBuf[ 1 ] = sId;
630 |     msgBuf[ 2 ] = fGroup;
631 |     msgBuf[ 3 ] = data;
632 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
633 | }
634 |
635 | uint8_t sendSetLocCvMain( uint8_t sId, uint16_t cvId, uint8_t mode, uint8_t val ) {
636 |
637 |     uint8_t msgBuf[ 8 ] = { LCS_OP_SET_CVM };
638 |     msgBuf[ 1 ] = sId;
639 |     msgBuf[ 2 ] = highByte( cvId );
640 |     msgBuf[ 3 ] = lowByte( cvId );
641 |     msgBuf[ 4 ] = mode;
642 |     msgBuf[ 5 ] = val;
643 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
644 | }
645 |
646 | uint8_t sendSetLocCvProg( uint16_t cvId, uint8_t mode, uint8_t val ) {
647 |
648 |     uint8_t msgBuf[ 8 ] = { LCS_OP_SET_CVS };
649 |     msgBuf[ 1 ] = highByte( cvId );
650 |     msgBuf[ 2 ] = lowByte( cvId );
651 |     msgBuf[ 3 ] = mode;
652 |     msgBuf[ 4 ] = val;
653 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
654 | }
655 |
656 | uint8_t sendReqLocCvProg( uint16_t cvId, uint8_t mode ) {
657 |
658 |     uint8_t msgBuf[ 8 ] = { LCS_OP_REQ_CVS };
659 |     msgBuf[ 1 ] = highByte( cvId );
660 |     msgBuf[ 2 ] = lowByte( cvId );
661 |     msgBuf[ 3 ] = mode;
662 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
663 | }
664 |
665 | uint8_t sendRepLocCvProg( uint16_t cvId, uint8_t val ) {
666 |
667 |     uint8_t msgBuf[ 8 ] = { LCS_OP_REP_CVS };
668 |     msgBuf[ 1 ] = highByte( cvId );
669 |     msgBuf[ 2 ] = lowByte( cvId );
670 |     msgBuf[ 3 ] = val;
671 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
672 | }
673 |
674 | uint8_t sendSetBacc( uint16_t accAdr, uint8_t flags ) {
675 |
676 |     uint8_t msgBuf[ 8 ] = { LCS_OP_BACC };
677 |     msgBuf[ 1 ] = highByte( accAdr );
678 |     msgBuf[ 2 ] = lowByte( accAdr );
679 |     msgBuf[ 3 ] = flags;
680 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
681 | }
682 |
683 | uint8_t sendSetEacc( uint16_t accAdr, uint8_t val ) {
684 |
685 |     uint8_t msgBuf[ 8 ] = { LCS_OP_EACC };
686 |     msgBuf[ 1 ] = highByte( accAdr );
687 |     msgBuf[ 2 ] = lowByte( accAdr );
688 |     msgBuf[ 3 ] = val;
689 |     return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
690 | }
691 |
692 | uint8_t sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3 ) {
```

```
693
694        uint8_t msgBuf[ 8 ] = { LCS_OP_SEND_DCC3 };
695        msgBuf[ 1 ] = arg1;
696        msgBuf[ 2 ] = arg2;
697        msgBuf[ 3 ] = arg3;
698        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
699 }
700
701 uint8_t sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4 ) {
702
703        uint8_t msgBuf[ 8 ] = { LCS_OP_SEND_DCC4 };
704        msgBuf[ 1 ] = arg1;
705        msgBuf[ 2 ] = arg2;
706        msgBuf[ 3 ] = arg3;
707        msgBuf[ 4 ] = arg4;
708        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
709 }
710
711 uint8_t sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4, uint8_t arg5 ) {
712
713        uint8_t msgBuf[ 8 ] = { LCS_OP_SEND_DCC5 };
714        msgBuf[ 1 ] = arg1;
715        msgBuf[ 2 ] = arg2;
716        msgBuf[ 3 ] = arg3;
717        msgBuf[ 4 ] = arg4;
718        msgBuf[ 5 ] = arg5;
719        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
720 }
721
722 uint8_t sendDccPacket( uint8_t arg1, uint8_t arg2, uint8_t arg3, uint8_t arg4, uint8_t arg5, uint8_t arg6 ) {
723
724        uint8_t msgBuf[ 8 ] = { LCS_OP_SEND_DCC6 };
725        msgBuf[ 1 ] = arg1;
726        msgBuf[ 2 ] = arg2;
727        msgBuf[ 3 ] = arg3;
728        msgBuf[ 4 ] = arg4;
729        msgBuf[ 5 ] = arg5;
730        msgBuf[ 6 ] = arg6;
731        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_NORMAL ));
732 }
733
734 uint8_t sendDccAck( ) {
735
736        uint8_t msgBuf[ 8 ] = { LCS_OP_DCC_ACK };
737        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
738 }
739
740 uint8_t sendDccErr( uint8_t errCode, uint8_t arg1, uint8_t arg2 ) {
741
742        uint8_t msgBuf[ 8 ] = { LCS_OP_DCC_ERR };
743        msgBuf[ 1 ] = errCode;
744        msgBuf[ 2 ] = arg1;
745        msgBuf[ 3 ] = arg2;
746        return ( msgBus -> sendLcsMsg( msgBuf, MSG_PRI_LOW ));
747 }
748
749 }; // namespace LCS
```

```
1   //-------------------------------------------------------------------------------------------------------------
2   //
3   // Layout Control System - node access routines.
4   //
5   //-------------------------------------------------------------------------------------------------------------
6   // The file contains the LCS runtime routines that implement node access. There are three routines that allow
7   // to manipulate node and port data as well as issue requests to a node or port. The key are the node/port ID
8   // and the item number. The "npId" will indicate which node and port the call refers to. The node portion is
9   // typically our own node Id, the port Id refers to a ports on the node, with a port Id of zero referring to
10  // the node itself. Any node can access another node. In this case request comes via a message and the
11  // message handler will call the local routines in this file.
12  //
13  //-------------------------------------------------------------------------------------------------------------
14  //
15  // LCS - Core Library
16  // Copyright (C) 2021 - 2024  Helmut Fieres
17  //
18  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
19  // General Public License as published by the Free Software Foundation, either version 3 of the License,
20  // or any later version.
21  //
22  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
23  // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
24  // License for more details. You should have received a copy of the GNU General Public License along with
25  // this program.  If not, see <http://www.gnu.org/licenses/>.
26  //
27  //-------------------------------------------------------------------------------------------------------------
28  #include "LcsRuntimeLib.h"
29  #include "LcsRtLibInt.h"
30
31  //-------------------------------------------------------------------------------------------------------------
32  // External declaration to global structures defined in "LcsRtSetup".
33  //
34  //-------------------------------------------------------------------------------------------------------------
35  namespace LCS {
36
37      extern uint16_t             debugMask;
38      extern LcsCdcMap            cdcMap;
39      extern LcsNodeMap           nodeMap;
40      extern LcsNodeData          nodeData;
41      extern LcsPortMap           portMap;
42      extern LcsCallbackMap       callbackMap;
43  };
44
45  //-------------------------------------------------------------------------------------------------------------
46  // The LcsCoreLib implementation file local declarations and routines.
47  //
48  //-------------------------------------------------------------------------------------------------------------
49  namespace {
50
51      using namespace LCS;
52
53      //---------------------------------------------------------------------------------------------------------
54      // The node or port name cannot be set with a single LCS message. We will store the parts in this
55      // temporary buffer and set the name when all parts are received.
56      //
57      //---------------------------------------------------------------------------------------------------------
58      char tempName[ MAX_NODE_NAME_SIZE + 1 ] = { 0 };
59
60      //---------------------------------------------------------------------------------------------------------
61      // Utility routines.
62      //
63      //---------------------------------------------------------------------------------------------------------
64      bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
65
66          return (( val >= lower ) && ( val <= upper ));
67      }
68
69      uint8_t lowByte( uint16_t arg ) {
70
71          return( arg & 0xFF );
72      }
73
74      uint8_t highByte( uint16_t arg ) {
75
76          return( arg >> 8 );
77      }
78
79       uint16_t nodeId( uint16_t arg ) {
80
81          return( arg >> 4 );
82      }
83
84      uint16_t portId( uint16_t arg ) {
85
86          return( arg & 0xF);
87      }
88
89      //---------------------------------------------------------------------------------------------------------
90      // "readAttrMem" gets a value from the node or port attribute map in MEM. As an internal function, we
91      // expect a valid block and item argument. The "block" argument will refer to the node and port data
92      // attributes. Block 0 is the node, all others the port.
93      //
94      //---------------------------------------------------------------------------------------------------------
95      uint8_t readAttrMem( uint8_t block, uint8_t item, uint16_t *arg ) {
96
97          *arg = nodeData.map[ block ][ item - IR_ATTR_MEM_RANGE_START ];
98          return ( LCS::ALL_OK );
```

```
 99        }
100
101        //--------------------------------------------------------------------------------------------------------------
102        // "writeAttrMem" stores a value to a node or port attribute map in MEM. As an internal function, we
103        // expect a valid block and item argument. The "block" argument will refer to the node and port data
104        // attributes. Block 0 is the node, all others the port.
105        //
106        //--------------------------------------------------------------------------------------------------------------
107        uint8_t writeAttrMem( uint8_t block, uint8_t item, uint16_t arg ) {
108
109            nodeData.map[ block ][ item - IR_ATTR_MEM_RANGE_START ] = arg;
110            return ( LCS::ALL_OK );
111        }
112
113        //--------------------------------------------------------------------------------------------------------------
114        // "readAttrNvm" gets an attribute from the NVM storage. We read the value from NVM, store it in the MEM
115        // counterpart and then return it. For the NVM access, the byte offset into the storage needs to be
116        // computed. As an internal function, we expect a valid block and item argument.
117        //
118        //--------------------------------------------------------------------------------------------------------------
119        uint8_t readAttrNvm( uint8_t block, uint8_t item, uint16_t *arg ) {
120
121            if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_ATTRIBUTES )) {
122
123                printf( "readAttrNvm: block: 0x%x, item: %d\n", block, item );
124            }
125
126            uint16_t index  = item - IR_ATTR_NVM_RANGE_START;
127            uint16_t ofs    = NVM_NODE_DATA_START + (( block * MAX_ATTR_MAP_ENTRIES ) + index  ) * sizeof( uint16_t );
128
129            printf( "Ofs: 0x%x\n", ofs );
130
131            uint8_t rStat = rtNvmGetWord( ofs, &nodeData.map[ block ][ index ] );
132
133            printf( "rStat: 0x%x\n", rStat );
134
135            *arg = (( rStat == ALL_OK ) ? nodeData.map[ block ][ index ] : 0 );
136            return ( rStat );
137        }
138
139        //--------------------------------------------------------------------------------------------------------------
140        // "writeAttrNvm" stores an attribute to the NVM storage. We first update the corresponding MEM attribute
141        // and then write the value to NVM storage. For the NVM access, the byte offset into the storage needs to
142        // be computed. As an internal function, we expect a valid block and item argument.
143        //
144        //--------------------------------------------------------------------------------------------------------------
145        uint8_t writeAttrNvm( uint8_t block, uint8_t item, uint16_t arg ) {
146
147            if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_ATTRIBUTES )) {
148
149                printf( "readAttrNvm: block: 0x%x, item: %d\n", block, item );
150            }
151
152            uint16_t index  = item - IR_ATTR_NVM_RANGE_START;
153            uint16_t ofs    = NVM_NODE_DATA_START + (( block * MAX_ATTR_MAP_ENTRIES ) + index  ) * sizeof( uint16_t );
154
155            printf( "Ofs: 0x%x\n", ofs );
156
157            nodeData.map[ block ][ index ] = arg;
158            return ( rtNvmPutWord( ofs, arg ));
159        }
160
161        //--------------------------------------------------------------------------------------------------------------
162        // User callback function invocation routine. Items 64 to 127 are user defined items. We will simply
163        // invoke a previously registered callback passing the arguments.
164        //
165        //--------------------------------------------------------------------------------------------------------------
166        uint8_t invokeUserItemCallback( uint8_t portId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
167
168            if ( callbackMap.reqCallback != nullptr ) {
169
170                return ( callbackMap.reqCallback( portId, item, arg1, arg2 ));
171            }
172            else return( ERR_INVALID_ITEM_ID );
173        }
174
175 } // namespace
176
177
178 //--------------------------------------------------------------------------------------------------------------
179 // The LCS name space routines declared in this file.
180 //
181 //--------------------------------------------------------------------------------------------------------------
182 namespace LCS {
183
184 //--------------------------------------------------------------------------------------------------------------
185 // "nodeGet" will lookup a value from the node, port or the attribute data map. The "npId" argument contains
186 // the node and port Id. However, we will only use the portId portion, which represents the block index.
187 //
188 //--------------------------------------------------------------------------------------------------------------
189 uint8_t nodeGet( uint16_t npId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
190
191     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_ATTRIBUTES )) {
192
193         printf( "nodeGet: 0x%x:%d", npId, item  );
194         if ( arg1 != nullptr ) printf( ":%d", *arg1 ); else printf( " null" );
195         if ( arg2 != nullptr ) printf( ":%d", *arg2 ); else printf( " null" );
196     }
197
```

```
198        if ( isInRangeU( item, IR_ATTR_MEM_RANGE_START, IR_ATTR_MEM_RANGE_END )) {
199
200            return ( readAttrMem( portId( npId ), item, arg1 ));
201        }
202        else if ( isInRangeU( item, IR_ATTR_NVM_RANGE_START, IR_ATTR_NVM_RANGE_END )) {
203
204            return ( readAttrNvm( portId( npId ), item, arg1 ));
205        }
206        else {
207
208            switch ( item ) {
209
210                case ITEM_ID_DEBUG_MASK: {
211
212                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
213                    *arg1 = debugMask;
214                    return( ALL_OK );
215                }
216
217                case ITEM_ID_OPTIONS: {
218
219                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
220
221                    *arg1 = nodeMap.nodeOptions;
222                    return ( ALL_OK );
223                }
224
225                case ITEM_ID_FLAGS: {
226
227                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
228
229                    if ( portId( npId ) == 0 )   *arg1 = nodeMap.nodeFlags;
230                    else                         *arg1 = portMap.map[ portId( npId ) - 1 ].flags;
231
232                    return ( ALL_OK );
233                }
234
235                case ITEM_ID_VERSION: {
236
237                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
238
239                    *arg1 = nodeMap.nodeSwVersion;
240                    return ( ALL_OK );
241                }
242
243                case ITEM_ID_TYPE: {
244
245                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
246
247                    if ( portId( npId ) == 0 )   *arg1 = nodeMap. nodeType;
248                    else                         *arg1 = portMap.map[ portId( npId ) - 1 ].type;
249
250                    return ( ALL_OK );
251                }
252
253                case ITEM_ID_CONTROLLER_FAMILY: {
254
255                     if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
256
257                    *arg1 = nodeMap.head.controllerFamily;
258                    return ( ALL_OK );
259                }
260
261                case ITEM_ID_NODE_ID: {
262
263                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
264
265                    *arg1 = nodeMap.nodeId;
266                    return ( ALL_OK );
267                }
268
269                case ITEM_ID_NODE_UID: {
270
271                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
272                    if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
273
274                    *arg1 = nodeMap.nodeUID >> 16;
275                    *arg2 = nodeMap.nodeUID & 0xFFFF;
276                    return ( ALL_OK );
277                }
278
279                case ITEM_ID_RESTART_COUNT: {
280
281                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
282
283                    *arg1 = nodeMap.nodeRestartCnt;
284                    return ( ALL_OK );
285                }
286
287                case ITEM_ID_PORT_MAP_ENTRIES: {
288
289                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
290
291                    *arg1 = nodeMap.portMapEntries;
292                    return ( ALL_OK );
293                }
294
295                case ITEM_ID_EVENT_MAP_ENTRIES: {
296
```

```
297                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
298
299                *arg1 = nodeMap.eventMapEntries;
300                return ( ALL_OK );
301            }
302
303            case ITEM_ID_ATTR_MAP_ENTRIES: {
304
305                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
306
307                *arg1 = MAX_ATTR_MAP_ENTRIES;
308                return ( ALL_OK );
309            }
310
311            case ITEM_ID_GET_EVENT_MAP_ENTRY: {
312
313                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
314                if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
315
316                return ( getMemEmapEntry( *arg1, arg1, arg2 ));
317            }
318
319            case ITEM_ID_NAME_1: {
320
321                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
322                if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
323
324                if ( portId( npId ) == 0 ) {
325
326                    *arg1 = ((uint16_t) ( nodeMap.name[ 0 ] << 8  ) | nodeMap.name[ 1 ] );
327                    *arg2 = ((uint16_t) ( nodeMap.name[ 2 ] << 8  ) | nodeMap.name[ 3 ] );
328                }
329                else {
330
331                    LcsPortMapEntry *pEntry = &portMap.map[ portId( npId ) -1 ];
332
333                    *arg1 = ((uint16_t) ( pEntry -> name[ 0 ] << 8  ) | pEntry -> name[ 1 ] );
334                    *arg2 = ((uint16_t) ( pEntry -> name[ 2 ] << 8  ) | pEntry -> name[ 3 ] );
335                }
336
337                return ( ALL_OK );
338            }
339
340            case ITEM_ID_NAME_2: {
341
342                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
343                if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
344
345                if ( portId( npId ) == 0 ) {
346
347                    *arg1 = ((uint16_t) ( nodeMap.name[ 4 ] << 8  ) | nodeMap.name[ 5 ] );
348                    *arg2 = ((uint16_t) ( nodeMap.name[ 6 ] << 8  ) | nodeMap.name[ 7 ] );
349                }
350                else {
351
352                    LcsPortMapEntry *pEntry = &portMap.map[ portId( npId ) - 1 ];
353
354                    *arg1 = ((uint16_t) ( pEntry -> name[ 4 ] << 8  ) | pEntry -> name[ 5 ] );
355                    *arg2 = ((uint16_t) ( pEntry -> name[ 6 ] << 8  ) | pEntry -> name[ 7 ] );
356                }
357
358                return ( ALL_OK );
359            }
360
361            case ITEM_ID_NAME_3: {
362
363                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
364                if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
365
366                if ( portId( npId ) == 0 ) {
367
368                    *arg1 = ((uint16_t) ( nodeMap.name[ 8 ] << 8  ) | nodeMap.name[ 9 ] );
369                    *arg2 = ((uint16_t) ( nodeMap.name[ 10 ] << 8  ) | nodeMap.name[ 11 ] );
370                }
371                else {
372
373                    LcsPortMapEntry *pEntry = &portMap.map[ portId( npId ) - 1 ];
374
375                    *arg1 = ((uint16_t) ( pEntry -> name[ 8 ] << 8  ) | pEntry -> name[ 9 ] );
376                    *arg2 = ((uint16_t) ( pEntry -> name[ 10 ] << 8  ) | pEntry -> name[ 11 ] );
377                }
378
379                return ( ALL_OK );
380            }
381
382            case ITEM_ID_NAME_4: {
383
384                if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
385                if ( arg2 == nullptr ) return( ERR_INVALID_ATTR_ARG );
386
387                if ( portId( npId ) == 0 ) {
388
389                    *arg1 = ((uint16_t) ( nodeMap.name[ 12 ] << 8  ) | nodeMap.name[ 13 ] );
390                    *arg2 = ((uint16_t) ( nodeMap.name[ 14 ] << 8  ) | nodeMap.name[ 15 ] );
391                }
392                else {
393
394                    LcsPortMapEntry *pEntry = &portMap.map[ portId( npId ) - 1 ];
395
```

```
396                        *arg1 = ((uint16_t) ( pEntry -> name[ 12 ] << 8  ) | pEntry -> name[ 13 ] );
397                        *arg2 = ((uint16_t) ( pEntry -> name[ 14 ] << 8  ) | pEntry -> name[ 15 ] );
398                    }
399
400                    return ( ALL_OK );
401                }
402
403            case ITEM_ID_NVM_PROTECTED_ACCESS: {
404
405                    // ??? access to protected NVM data areas.
406                    // ??? arg 1 -> offset
407                    // ??? arg 2 -> value
408
409                    return ( ALL_OK );
410
411            } break;
412
413            case ITEM_ID_EVENT_DELAY_TICKS: {
414
415                    if ( arg1 == nullptr ) return( ERR_INVALID_ATTR_ARG );
416
417                    *arg1 = portMap.map[ portId( npId ) - 1 ].eventDelayTime;
418                    return ( ALL_OK );
419            }
420
421            default: return ( ERR_INVALID_ITEM_ID );
422        }
423    }
424 }
425
426 //-------------------------------------------------------------------------------------------------------------
427 // "nodePut" will write a value to the node, port or the attribute data map. The "npId" argument contains
428 // the node and port Id. However, we will only use the portId portion.
429 //
430 //-------------------------------------------------------------------------------------------------------------
431 uint8_t nodePut( uint16_t npId, uint8_t item, uint16_t val1, uint16_t val2 ) {
432
433     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_ATTRIBUTES )) {
434
435         printf( "nodePut: 0x%x:%d:%d:%d\n", npId, item, val1, val2  );
436     }
437
438    if ( isInRangeU( item, IR_ATTR_MEM_RANGE_START, IR_ATTR_MEM_RANGE_END )) {
439
440         return ( writeAttrMem( portId( npId ), item, val1 ));
441     }
442     else if ( isInRangeU( item, IR_ATTR_NVM_RANGE_START, IR_ATTR_NVM_RANGE_END )) {
443
444         return ( writeAttrNvm( portId( npId ), item, val1 ));
445     }
446     else {
447
448         switch ( item ) {
449
450             case ITEM_ID_DEBUG_MASK: {
451
452                 if ( CDC::isConsoleConnected( ))    debugMask = val1 | DBG_CONFIG;
453                 else                                debugMask = val1 & ~ DBG_CONFIG;
454
455                 return( ALL_OK );
456             }
457
458             case ITEM_ID_VERSION: {
459
460                 nodeMap.nodeSwVersion = val1;
461                 return( rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeSwVersion ), val1 ));
462             }
463
464             case ITEM_ID_OPTIONS: {
465
466                 nodeMap.nodeOptions = val1;
467                 return( rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeOptions ), val1 ));
468             }
469
470             case ITEM_ID_FLAGS: {
471
472                 nodeMap.nodeFlags = val1;
473                 return( rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeFlags ), val1 ));
474             }
475
476             case ITEM_ID_NODE_ID: {
477
478                 nodeMap.nodeId = val1;
479                 return( rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeId ), nodeMap.nodeId ));
480             }
481
482             case ITEM_ID_TYPE: {
483
484                 if ( portId( npId ) == 0 ) {
485
486                     nodeMap.nodeType = lowByte( val1 );
487                     return( rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeType ), val1 ));
488                 }
489                 else {
490
491                     portMap.map[ portId( npId ) - 1 ].type = lowByte( val1 );
492
493                     uint16_t ofs =  NVM_PORT_MAP_START +
494                                     offsetof( LcsPortMap, map ) +
```

```
495                               (( portId( npId ) - 1 ) * sizeof( LcsPortMapEntry )) +
496                               offsetof( LcsPortMapEntry, type );
497
498                     return ( rtNvmPutWord( ofs, portMap.map[ portId( npId ) - 1 ].type ));
499                 }
500             }
501
502             case ITEM_ID_EVENT_DELAY_TICKS: {
503
504                 if ( isInRangeU ( portId( npId ) - 1, 0, MAX_PORT_MAP_ENTRIES )) {
505
506                     portMap.map[ portId( npId ) - 1 ].eventDelayTime = val1;
507
508                     uint16_t ofs =  NVM_PORT_MAP_START +
509                               offsetof( LcsPortMap, map ) +
510                               (( portId( npId ) - 1 ) * sizeof( LcsPortMapEntry )) +
511                               offsetof( LcsPortMapEntry, eventDelayTime );
512
513                     return ( rtNvmPutWord( ofs, val1 ));
514                 }
515                 else return( ERR_INVALID_PORT_ID );
516             }
517
518             case ITEM_ID_NAME_1: {
519
520                 tempName[ 0 ] = highByte( val1 );
521                 tempName[ 1 ] = lowByte( val1 );
522                 tempName[ 2 ] = highByte( val2 );
523                 tempName[ 3 ] = lowByte( val2 );
524
525                 if ( portId( npId ) == 0 ) {
526
527                     memcpy((uint8_t *) nodeMap.name, (uint8_t *)tempName, MAX_NODE_NAME_SIZE );
528                     return( rtNvmPutBytes(  NVM_NODE_MAP_START + offsetof( LcsNodeMap, name ),
529                                            (uint8_t *)tempName,
530                                            MAX_NODE_NAME_SIZE ));
531                 }
532                 else {
533
534                     memcpy((uint8_t *) portMap.map[ portId( npId ) ].name, (uint8_t *)tempName, MAX_PORT_NAME_SIZE );
535                     uint16_t ofs =  NVM_PORT_MAP_START +
536                               offsetof( LcsPortMap, map ) +
537                               (( portId( npId ) - 1 ) * sizeof( LcsPortMapEntry )) +
538                               offsetof( LcsPortMapEntry, name );
539                     return( rtNvmPutBytes( ofs, (uint8_t *)tempName, MAX_PORT_NAME_SIZE ));
540                 }
541             }
542
543             case ITEM_ID_NAME_2: {
544
545                 tempName[ 4 ]   = highByte( val1 );
546                 tempName[ 5 ]   = lowByte( val1 );
547                 tempName[ 6 ]   = highByte( val2 );
548                 tempName[ 7 ]   = lowByte( val2 );
549                 return ( ALL_OK );
550             }
551
552             case ITEM_ID_NAME_3: {
553
554                 tempName[ 8 ]   = highByte( val1 );
555                 tempName[ 9 ]   = lowByte( val1 );
556                 tempName[ 10 ]  = highByte( val2 );
557                 tempName[ 11 ]  = lowByte( val2 );
558                 return ( ALL_OK );
559             }
560
561             case ITEM_ID_NAME_4: {
562
563                 memset( tempName, 0, MAX_NODE_NAME_SIZE );
564                 tempName[ 12 ]  = highByte( val1 );
565                 tempName[ 13 ]  = lowByte( val1 );
566                 tempName[ 14 ]  = highByte( val2 );
567                 tempName[ 15 ]  = lowByte( val2 );
568                 return ( ALL_OK );
569             }
570
571             case ITEM_ID_NVM_PROTECTED_ACCESS: {
572
573                 // ??? access to protected NVM data areas.
574                 // ??? arg 1 -> offset
575                 // ??? arg 2 -> value
576
577                 return ( ALL_OK );
578
579             } break;
580
581             default: return ( ERR_INVALID_ITEM_ID );
582         }
583     }
584 }
585
586 //---------------------------------------------------------------------------------------------------------------
587 // "nodeReq" will carry out a node or port function. A function, represented by an item, can be a node or port
588 // defined item, or a user defined item. For the latter we will invoke the user defined callback, if any.
589 //
590 // ??? have an option to set the debug level ?
591 //---------------------------------------------------------------------------------------------------------------
592 uint8_t nodeReq( uint16_t npId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
593
```

```cpp
594         if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_ATTRIBUTES )) {
595
596             printf( "nodeReq: 0x%x:%d", npId, item   );
597             if ( arg1 != nullptr ) printf( ":%d", *arg1 ); else printf( "null" );
598             if ( arg2 != nullptr ) printf( ":%d", *arg2 ); else printf( "null" );
599         }
600
601         if ( isInRangeU( item, IR_USER_RANGE_START, IR_USER_RANGE_END )) {
602
603             return( invokeUserItemCallback( npId, item, arg1, arg2 ));
604         }
605         else {
606
607             switch ( item ) {
608
609                 case ITEM_ID_RESET: {
610
611                     debugMask = *arg1;
612                     return ( resetNode( npId ));
613                 }
614
615                 case ITEM_ID_ADD_EVENT_MAP_ENTRY: {
616
617                     return ( addEvent( *arg1, *arg2 ));
618                 }
619
620                 case ITEM_ID_DEL_EVENT_MAP_ENTRY: {
621
622                     return ( removeEvent( *arg1, *arg2 ));
623                 }
624
625                 case ITEM_ID_SYNC: {
626
627                     // ??? options what to sync ? For now it is only the event map...
628                     // ??? use arg 1 as an option number... ?
629                     return( syncEventMap( ));
630                 }
631
632                 case ITEM_ID_NODE_ID: {
633
634                     if ( isInRangeU( *arg1, MIN_NODE_ID, MAX_NODE_ID )) {
635
636                         nodeMap.nodeId = nodeId( *arg1 );
637                         return( rtNvmPutBytes(  NVM_NODE_MAP_START +
638                                                 offsetof( LcsNodeMap, nodeId ),
639                                                 (uint8_t *) &nodeMap.nodeId,
640                                                 sizeof( uint16_t )));
641                     }
642                     else return ( ERR_INVALID_NODE_ID );
643                 }
644
645                 case ITEM_ID_ENABLE_EVENT_PROCESSING: {
646
647                     if ( *arg1 )    portMap.map[ portId( npId ) - 1 ].flags |= PF_PORT_EVENT_HANDLING_ENABLED;
648                     else            portMap.map[ portId( npId ) - 1 ].flags &= ~ PF_PORT_EVENT_HANDLING_ENABLED;
649
650                     return ( ALL_OK );
651                 }
652
653                 case ITEM_ID_SET_READY_LED: {
654
655                     return ( CDC::writeDio( cdcMap.cfg.READY_LED_PIN, *arg1 ));
656                 }
657
658                 case ITEM_ID_SET_ACTIVITY_LED: {
659
660                     return ( CDC::writeDio( cdcMap.cfg.ACTIVE_LED_PIN, *arg1 ));
661                 }
662
663                 case ITEM_ID_TOGGLE_READY_LED:  {
664
665                     return ( CDC::toggleDio( cdcMap.cfg.READY_LED_PIN ));
666                 }
667
668                 case ITEM_ID_TOGGLE_ACTIVITY_LED: {
669
670                     return ( CDC::toggleDio( cdcMap.cfg.ACTIVE_LED_PIN ));
671                 }
672
673                 default: return ( ERR_INVALID_ITEM_ID );
674             }
675         }
676 }
677
678 } // namespace LCS
```

```cpp
//---------------------------------------------------------------------------------------------------------------
//
// Layout Control System - implementation file.
//
//---------------------------------------------------------------------------------------------------------------
// The file contains the part of the LCS Runtime Library that implements the node event handling. At the
// heart of LCS is the concept of events. Events are broadcasted by a node and any other node that is
// interested in it registers a callback or this event. The runtime functions provide the management of the
// event map and the search routines.
//
// The event map can be found as a MEM and an NVM structure. During operations, the sorted MEM event map is
// the map to work with. Entries are sorted by eventId and as a secondary sort key the portId. New events
// can be added, old removed and the map can be searched. There is a SYNC function to write the contents
// of the MEM event map to the NV event map. The idea is that all changes are made to the MEM version and
// then written back in one swoop.
//
// On node start or reset, the NVM event map is read as part of the overall NVM read process. Since we only
// write a sorted version to the NVM event map, we can always assume a sorted NVM version, except when the
// eventMap high water mark is not valid. In this case we read entry by entry from the NVM and add it
// sorted to the MEM twin. The high water mark specifies the number of entires actually used.
//
//---------------------------------------------------------------------------------------------------------------
//
// LCS - Core Library
// Copyright (C) 2021 - 2024  Helmut Fieres
//
// This program is free software: you can redistribute it and/or modify it under the terms of the GNU
// General Public License as published by the Free Software Foundation, either version 3 of the License,
// or any later version.
//
// This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
// the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
// License for more details. You should have received a copy of the GNU General Public License along with
// this program.  If not, see <http://www.gnu.org/licenses/>.
//
//---------------------------------------------------------------------------------------------------------------
#include "LcsRuntimeLib.h"
#include "LcsRtLibInt.h"
#include <stdlib.h>

//---------------------------------------------------------------------------------------------------------------
// External declaration to global structures defined in "LcsRtSetup".
//
//---------------------------------------------------------------------------------------------------------------
namespace LCS {

    extern uint16_t            debugMask;
    extern LCS::LcsNodeMap     nodeMap;
    extern LCS::LcsEventMap    eventMap;
};

//---------------------------------------------------------------------------------------------------------------
// The LcsCoreLib implementation file local declarations and routines.
//
//---------------------------------------------------------------------------------------------------------------
namespace {

using namespace LCS;

//---------------------------------------------------------------------------------------------------------------
// Utility routines for number range check.
//
//---------------------------------------------------------------------------------------------------------------
bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {

    return (( val >= lower ) && ( val <= upper ));
}

//---------------------------------------------------------------------------------------------------------------
// "compareEventEntry" is a little helper function to compare event and portId to the data in an eventMap
// entry.
//
//---------------------------------------------------------------------------------------------------------------
int compareEventEntry( LcsEventMapEntry *e1, uint16_t eventId2, uint16_t portId2 ) {

    if      ( e1 -> eventId < eventId2 )  return ( -1 );
    else if ( e1 -> eventId > eventId2 )  return ( 1 );
    else if ( e1 -> portId < portId2 )    return ( -1 );
    else if ( e1 -> portId > portId2 )    return ( 1 );
    else return ( 0 );
}

int compareEventEntry( const LcsEventMapEntry *arg1, const LcsEventMapEntry *arg2 ) {

    LcsEventMapEntry *e1 = (LcsEventMapEntry *)  arg1;
    LcsEventMapEntry *e2 = (LcsEventMapEntry *)  arg2;

    if      ( e1 -> eventId < e2 -> eventId )  return ( -1 );
    else if ( e1 -> eventId > e2 -> eventId )  return ( 1 );
    else if ( e1 -> portId  < e2 -> portId )   return ( -1 );
    else if ( e1 -> portId  > e2 -> portId )   return ( 1 );
    else return ( 0 );
}

//---------------------------------------------------------------------------------------------------------------
// "addToMemEventMap" adds an event / port combination to the MEM event map if not already there. Given
// there is still room in the table, the entry is added in sorted order.
//
```

```
99  //--------------------------------------------------------------------------------------------------------
100 uint8_t addToMemEventMap( uint16_t eventId, uint16_t portId ) {
101
102     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
103
104         printf( "Add to MEM Event Map: %d : %d\n", eventId, portId );
105     }
106
107     if ( searchEvent( eventId, portId ) >= 0 )    return ( ALL_OK );
108     if ( nodeMap.eventMapHwm >= MAX_EVENT_MAP_ENTRIES )  return ( ERR_EVENT_MAP_FULL );
109
110     uint16_t index = nodeMap.eventMapHwm;
111
112     if ( nodeMap.eventMapHwm > 0 ) {
113
114         while (( index > 0 ) && ( compareEventEntry( &eventMap.map[ index - 1 ], eventId, portId ) > 0 )) {
115
116             eventMap.map[ index ] = eventMap.map[ index - 1 ];
117             index --;
118         }
119     }
120
121     eventMap.map[ index ].eventId = eventId;
122     eventMap.map[ index ].portId  = portId;
123     nodeMap.eventMapHwm++;
124
125     return ( ALL_OK );
126 }
127
128 //--------------------------------------------------------------------------------------------------------
129 // "removeFromMemEventMap" removes an entry from the memory event map. The sorted order is maintained.
130 //
131 //--------------------------------------------------------------------------------------------------------
132 uint8_t removeFromMemEventMap( uint16_t eventId, uint16_t portId ) {
133
134      if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
135
136         printf( "Remove from MEM Event Map: %d : %d \n", eventId, portId );
137     }
138
139     int index = searchEvent( eventId, portId );
140
141     if ( index >= 0 ) {
142
143         nodeMap.eventMapHwm--;
144
145         for ( uint16_t i = index; i < nodeMap.eventMapHwm; i++ )
146             eventMap.map[ i ] = eventMap.map[ i + 1 ];
147     }
148
149     return ( ALL_OK );
150 }
151
152 } // namespace
153
154 //--------------------------------------------------------------------------------------------------------
155 // The LCS name space routines declared in this file.
156 //
157 //--------------------------------------------------------------------------------------------------------
158 namespace LCS {
159
160 //--------------------------------------------------------------------------------------------------------
161 // The "addEvent" routine will add an eventId/portId combination to the event map if not already there. If
162 // the portId parameter is a NIL_PORT_ID, the event is added to all portMap entries.
163 //
164 //--------------------------------------------------------------------------------------------------------
165 uint8_t addEvent( uint16_t eventId, uint16_t portId ) {
166
167     if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
168
169         printf( "Add Event: event: %d, port: %d\n", eventId, portId );
170     }
171
172     int rStat = ALL_OK;
173
174     if ( ! isInRangeU( eventId, MIN_EVENT_ID, MAX_EVENT_ID )) return ( ERR_INVALID_EVENT_ID );
175     if ( portId >  MAX_PORT_ID ) return ( ERR_INVALID_PORT_ID );
176
177     if ( portId == NIL_PORT_ID ) {
178
179         for ( uint8_t p = 1; p <= MAX_PORT_MAP_ENTRIES; p++ ) {
180
181             rStat = addToMemEventMap( eventId, p );
182             if ( rStat != ALL_OK ) break;
183         }
184     }
185     else {
186
187         rStat = addToMemEventMap( eventId, portId );
188     }
189
190     return ( rStat );
191 }
192
193 //--------------------------------------------------------------------------------------------------------
194 // The "removeEvent" routine will remove an event Id / port Id from the MEM event map. If the port ID is
195 // NIL_PORT_ID, all port map entries matching event Id are removed.
196 //
197 //--------------------------------------------------------------------------------------------------------
```

```
198   uint8_t removeEvent( uint16_t eventId, uint16_t portId ) {
199
200       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
201
202           printf( "Remove Event: %d : %d\n", eventId, portId );
203       }
204
205       int rStat = ALL_OK;
206
207       if ( ! isInRangeU( eventId, MIN_EVENT_ID, MAX_EVENT_ID )) return ( ERR_INVALID_EVENT_ID );
208
209       if ( portId == NIL_PORT_ID ) {
210
211           for ( uint16_t p = 1; p <= MAX_PORT_MAP_ENTRIES; p++ ) {
212
213               rStat = removeFromMemEventMap( eventId, p );
214               if ( rStat != ALL_OK ) break;
215           }
216       }
217       else if ( isInRangeU( portId, MIN_PORT_ID, MAX_PORT_ID )) {
218
219           rStat = removeFromMemEventMap( eventId, portId );
220       }
221       else rStat = ERR_INVALID_PORT_ID;
222
223       return ( rStat );
224   }
225
226   //-----------------------------------------------------------------------------------------------------------------
227   // The event search function performs a binary search of the event map using the event Id and the port Id.
228   // If the port Id is NIL, a matching entry with lowest portId is returned. All eventMap entries with the
229   // same eventId follow. If the entry cannot be found, a -1 is returned.
230   //
231   //-----------------------------------------------------------------------------------------------------------------
232   int searchEvent( uint16_t eventId, uint16_t portId ) {
233
234       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
235
236           printf( "Search Event: %d : %d", eventId, portId );
237       }
238
239       int   res   = -1;
240       int   low   = 0;
241       int   high  = nodeMap.eventMapHwm - 1;
242
243       if ( portId == NIL_PORT_ID ) {
244
245           while ( low <= high ) {
246
247               int mid = low + ( high - low + 1 ) / 2;
248
249               if      ( eventMap.map[ mid ].eventId < eventId ) low  = mid + 1;
250               else if ( eventMap.map[ mid ].eventId > eventId ) high = mid - 1;
251               else if ( eventMap.map[ mid ].eventId == eventId ) {
252
253                   res   = mid;
254                   high  = mid - 1;
255               }
256           }
257       }
258       else {
259
260           while ( low <= high ) {
261
262               int mid = low + ( high - low ) / 2;
263               int tst = compareEventEntry( &eventMap.map[ mid ], eventId, portId );
264
265               if      ( tst < 0 ) low   = mid + 1;
266               else if ( tst > 0 ) high  = mid - 1;
267               else {
268
269                   res = mid;
270                   break;
271               }
272           }
273       }
274
275       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) printf( "-> %d\n", res );
276       return ( res );
277   }
278
279   //-----------------------------------------------------------------------------------------------------------------
280   // "syncEventMap" will write back the sorted MEM event map. We only write up to the HWM mark, which points
281   // right after the last element in the sorted MEM event map. The idea is that all adds and removes are done
282   // on the MEM event map and a SYNC control call will flush the sorted MEM event map to NVM.
283   //
284   //-----------------------------------------------------------------------------------------------------------------
285   uint8_t syncEventMap( ) {
286
287       if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) printf( "sync EventMap \n" );
288
289       uint8_t rStat =  rtNvmPutBytes( NVM_EVENT_MAP_START,
290                                       (uint8_t *) eventMap.map,
291                                       nodeMap.eventMapHwm * sizeof( LcsEventMapEntry ));
292
293       if ( rStat == ALL_OK ) {
294
295           uint32_t ofs = NVM_NODE_MAP_START + offsetof( LcsNodeMap, eventMapHwm );
296           rStat = rtNvmPutWord( ofs, nodeMap.eventMapHwm );
```

```
297          }
298
299          return ( rStat );
300    }
301
302    //-------------------------------------------------------------------------------------------------------------
303    // "getMemEmapEntry" returns the eventId and portId pair from the MEM event map. It is used by the console
304    // command interface and also the LCS message handler to obtain that data. The index starts at 0.
305    //
306    //-------------------------------------------------------------------------------------------------------------
307    uint8_t getMemEmapEntry( uint16_t index, uint16_t *evId, uint16_t *pId ) {
308
309          if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_EVENTS )) {
310
311              printf( "Get Emap Entry: %d\n", index );
312          }
313
314          if ( index <  nodeMap.eventMapHwm ) {
315
316              *evId = eventMap.map[ index ].eventId;
317              *pId  = eventMap.map[ index ].portId;
318              return ( ALL_OK );
319          }
320          else return ( ERR_INVALID_EVENT_MAP_INDEX );
321    }
322
323    };
```

APPENDIX A. LISTINGS TEST

```cpp
//-----------------------------------------------------------------------------------------------------------
//
// LCS Runtime - command line interface.
//
//-----------------------------------------------------------------------------------------------------------
// Based on the Raspberry Pi PICO controller USB interface, the LCS node has an option to accept commands and
// display data. This interface is used for manual node and extension board configuration as well as debug
// and troubleshooting. Most commands are sensitive to the node/port ID. If there is another node than our
// own node, specified with a zero node ID value, the commands is sent to the bus.
//
//-----------------------------------------------------------------------------------------------------------
//
// LCS - Core Library
// Copyright (C) 2021 - 2024  Helmut Fieres
//
// This program is free software: you can redistribute it and/or modify it under the terms of the GNU
// General Public License as published by the Free Software Foundation, either version 3 of the License,
// or any later version.
//
// This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
// the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
// License for more details. You should have received a copy of the GNU General Public License along with
// this program.  If not, see <http://www.gnu.org/licenses/>.
//
//-----------------------------------------------------------------------------------------------------------
#include "LcsRuntimeLib.h"
#include "LcsRtLibInt.h"

//-----------------------------------------------------------------------------------------------------------
// External declaration to global structures defined in "LcsRtSetup".
//
//-----------------------------------------------------------------------------------------------------------
namespace LCS {

    extern uint16_t             debugMask;
    extern LcsCdcMap            cdcMap;
    extern LcsNodeMap           nodeMap;
    extern LcsNodeData          nodeData;
    extern LcsPortMap           portMap;
    extern LcsEventMap          eventMap;
    extern LcsCallbackMap       callbackMap;
    extern LcsTaskMap           taskMap;
    extern LcsPendingReqMap     pendingReqMap;
    extern LcsDrvFuncMap        drvFuncMap;
    extern LcsDrvMap            drvMap;
    extern LcsMsgBusCAN         *msgBus;
};

//-----------------------------------------------------------------------------------------------------------
// Local declarations.
//
//-----------------------------------------------------------------------------------------------------------
namespace {

using namespace LCS;

//-----------------------------------------------------------------------------------------------------------
// The command line buffer.
//
//-----------------------------------------------------------------------------------------------------------
char  commandBuf [ MAX_COMMAND_LINE_SIZE ];

//-----------------------------------------------------------------------------------------------------------
// "dumpMemData" lists the memory data content of the storage area passed. The data is displayed in 16-bit
// quantities.  Because the PICO uses little-endian format, ASCII characters may appear reversed when
// interpreted directly.
//
//-----------------------------------------------------------------------------------------------------------
void dumpMemData( uint16_t *area, uint16_t len, uint8_t itemsPerLine = 8, bool printAscii = false ) {

    uint16_t  index   = 0;
    uint16_t  limit   = ( len + 1 ) / 2;
    uint16_t  *ptr    = area;

    while ( index < limit ) {

        printf( "0x%08x: ", index * sizeof( uint16_t ));

        for ( uint16_t i = 0; i < itemsPerLine; i++ ) {

            if ( index + i < limit ) printf( "0x%04x ", ptr[ index + i ] );
        }

        if ( printAscii ) {

            if ( index + itemsPerLine >= limit ) {

                int tmp = index + itemsPerLine - limit;
                for ( int i = 0; i < tmp; i++ ) printf( "       " );
            };

            printf( "  " );

            for ( uint16_t i = 0; i < itemsPerLine; i++ ) {

                if ( index + i < limit ) {

                    if ( isprint( ptr[ index + i ] >> 8  )) printf( "%c", ptr[ index + i ] >> 8 );
```

```
 99                                else                                     printf( "." );
100
101                                if ( isprint( ptr[ index + i ] & 0xff )) printf( "%c ", ptr[ index + i ] & 0xff );
102                                else                                      printf( ". " );
103                        }
104                    }
105            }
106
107
108            index += itemsPerLine;
109            printf( "\n" );
110        }
111 }
112
113 //----------------------------------------------------------------------------------------------------
114 // List the NVM storage data. The function receives the absolute byte offset within the NVM area and the
115 // length in bytes. The data is displayed in 16-bit quantities. Because the PICO uses little-endian format,
116 // ASCII characters may appear reversed when interpreted directly.
117 //
118 //----------------------------------------------------------------------------------------------------
119 void dumpNvmData( uint32_t start, uint32_t len, uint32_t itemsPerLine = 8, bool printAscii = false ) {
120
121      uint8_t     rStat = ALL_OK;
122      uint32_t    limit = start + len;
123      uint16_t    val   = 0;
124
125      while ( start < limit ) {
126
127          printf( "0x%08x: ", start );
128
129          for ( uint16_t i = 0; i < itemsPerLine; i++ ) {
130
131              uint32_t ofs = ( start + ( i * sizeof(uint16_t)));
132
133              if ( ofs < limit ) {
134
135                  rStat = rtNvmGetWord( ofs, &val );
136                  if ( rStat == ALL_OK ) printf( "0x%04x ", val );
137              }
138          }
139
140          if ( printAscii ) {
141
142              if ( start + ( itemsPerLine * sizeof(uint16_t)) >= limit ) {
143
144                  int tmp = ( start + ( itemsPerLine * sizeof(uint16_t)) - limit ) / sizeof( uint16_t);
145                  for ( int i = 0; i < tmp; i++ ) printf( "        " );
146              };
147
148              printf( "  " );
149
150              for ( uint16_t i = 0; i < itemsPerLine; i++ ) {
151
152                  uint32_t ofs = start + ( i * sizeof(uint16_t));
153
154                  if ( ofs < limit ) {
155
156                      rStat = rtNvmGetWord( ofs, &val );
157                      if ( rStat == ALL_OK ) {
158
159                          if ( isprint( val >> 8  )) printf( "%c", val >> 8 );
160                          else                       printf( "." );
161
162                          if ( isprint( val & 0xff )) printf( "%c ", val & 0xFF );
163                          else                        printf( ". " );
164                      }
165                  }
166              }
167          }
168
169          start = start + ( itemsPerLine * sizeof(uint16_t));
170          printf( "\n" );
171      }
172 }
173
174 //----------------------------------------------------------------------------------------------------
175 // List extension board NVM storage data. We are passed the absolute offset into the NVM area and the
176 // length in bytes.
177 //
178 //----------------------------------------------------------------------------------------------------
179 void dumpExtNvmData( uint8_t boardId, uint32_t start, uint32_t len, uint32_t itemsPerLine = 8 ) {
180
181      uint8_t     rStat = ALL_OK;
182      uint32_t    limit = start + len;
183      uint16_t    val   = 0;
184
185      while ( start < limit ) {
186
187          printf( "0x%08x: ", start );
188
189          for ( uint16_t i = 0; i < itemsPerLine; i++ ) {
190
191              uint32_t ofs = ( start + ( i * sizeof(uint16_t)));
192
193              if ( ofs < limit ) {
194
195                  rStat = extNvmGetWord( boardId, ofs, &val );
196                  if ( rStat == ALL_OK ) printf( "0x%04x ", val );
197              }
```

```
198            }
199
200            for ( uint16_t i = 0; i < itemsPerLine; i++ ) {
201
202                uint32_t ofs = ( start + ( i * sizeof(uint16_t)));
203
204                if ( ofs < limit ) {
205
206                    rStat = extNvmGetWord( boardId, ofs, &val );
207                    if ( rStat == ALL_OK ) {
208
209                        if ( isprint( val >> 8  )) printf( "%c", val >> 8 );
210                        else                       printf( "." );
211
212                        if ( isprint( val & 0xff )) printf( "%c ", val & 0xFF );
213                        else                       printf( ". " );
214                    }
215                }
216            }
217
218            start = start + itemsPerLine * sizeof(uint16_t);
219            printf( "\n" );
220        }
221 }
222
223 //-------------------------------------------------------------------------------------------------------------------
224 // Routines to list contents of the various memory areas. Right now, we just dump out hex data. It would be
225 // nice to show formatted data. Perhaps one day...
226 //
227 //-------------------------------------------------------------------------------------------------------------------
228 void printSummary( ) {
229
230     printf( "LCS Node: \"" );
231     for ( uint8_t i = 0; i < MAX_NODE_NAME_SIZE; i++ ) {
232
233         if ( nodeMap.name[ i ] != 0 ) printf( "%c", nodeMap.name[ i ] );
234     }
235
236     printf( "\"\n" );
237     printf( "LCS Library Version: %d.%d\n", nodeMap.nodeSwVersion >> 8, nodeMap.nodeSwVersion & 0xFF );
238 }
239
240 void dumpMemNodeMap( ) {
241
242     printf( "MEM Node Map: \n\n" );
243     dumpMemData((uint16_t *) &nodeMap, sizeof( LcsNodeMap ), 8, true);
244     printf( "\n" );
245 }
246
247 void dumpMemCdcMap( ) {
248
249     printf( "MEM CDC Map: \n\n" );
250     // dumpMemData((uint16_t *) &nodeMap, sizeof( LcsNodeMap ));
251     printf( "\n" );
252 }
253
254 void dumpMemPortMap( ) {
255
256     printf( "MEM Port Map (Size: %d, Hwm: %d): \n\n", nodeMap.portMapEntries, nodeMap.portMapHwm );
257
258     for ( int i  = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
259
260         printf( "Port %d:\n", i + 1 );
261         dumpMemData((uint16_t *) &portMap.map[ i ], sizeof( LcsPortMapEntry ), 8, true );
262         printf( "\n" );
263     }
264 }
265
266 void dumpMemNodeData( ) {
267
268     printf( "MEM Node Data: \n\n" );
269
270     for ( int i  = 0; i < MAX_NODE_DATA_BLOCKS; i++ ) {
271
272         printf( "Port %d:\n", i );
273         dumpMemData((uint16_t *) &nodeData.map[ i ], MAX_ATTR_MAP_ENTRIES * sizeof( uint16_t ));
274         printf( "\n" );
275     }
276 }
277
278 void dumpMemEventMap( ) {
279
280     printf( "MEM Event Map (Size: %d, Hwm: %d): \n\n", nodeMap.eventMapEntries, nodeMap.eventMapHwm );
281     dumpMemData((uint16_t *) &eventMap, sizeof( LcsEventMap ));
282     printf( "\n" );
283 }
284
285 void dumpMemPendingReqMap( ) {
286
287     printf( "MEM Pending Req Map: (Size: %d, Hwm: %d) \n\n", nodeMap.pendingMapEntries, nodeMap.pendingMapHwm );
288     dumpMemData((uint16_t *) &pendingReqMap, sizeof( LcsPendingReqMap ));
289     printf( "\n" );
290 }
291
292 void dumpMemCallbackMap( ) {
293
294     printf( "MEM Callback Map: \n\n" );
295     dumpMemData((uint16_t *) &callbackMap, sizeof( LcsCallbackMap ));
296     printf( "\n" );
```

```
297   }
298
299   void dumpMemTaskMap( ) {
300
301       printf( "MEM Task Map: (Size: %d, Hwm: %d) \n\n", nodeMap.taskMapEntries, nodeMap.taskMapHwm );
302       dumpMemData((uint16_t *) &taskMap, sizeof( LcsTaskMap ));
303       printf( "\n" );
304   }
305
306   void dumpMemDrvFuncMap( ) {
307
308       printf( "MEM Driver Function Map: (Size: %d) \n\n", nodeMap.drvFuncMapEntries );
309
310       for ( int i  = 0; i < MAX_DRV_TYPES; i++ ) {
311
312           LcsDrvFuncEntry *entry = &drvFuncMap.map[ i ];
313           printf( "%d: Type: %d, Func: %p\n", i, entry -> drvType, entry -> drvFunc );
314       }
315
316        printf( "\n" );
317   }
318
319   void dumpMemDrvMap( ) {
320
321       printf( "MEM Driver Map: (Size: %d) \n\n", nodeMap.drvMapEntries );
322
323       for ( int i  = 0; i < MAX_EXT_BOARDS; i++ ) {
324
325           LcsDrvEntry *entry = &drvMap.map[ i ];
326
327           printf( "Board %d: ( Flags: 0x%04x, LastErr: %d, Drv: %p\n",
328                   i, entry -> flags, entry -> lastErr, entry -> drvFunc );
329
330           dumpMemData(( uint16_t*) &drvMap.map[ i ].extBoard, sizeof( LcsDrvBoardDesc ), 8, true );
331           printf( "\n" );
332       }
333
334        printf( "\n" );
335   }
336
337   void dumpMemRuntimeArea( ) {
338
339       printf( "MEM Area Dump: \n\n" );
340       dumpMemNodeMap( );
341       dumpMemCdcMap( );
342       dumpMemPortMap( );
343       dumpMemEventMap( );
344       dumpMemPendingReqMap( );
345       dumpMemTaskMap( );
346       dumpMemCallbackMap( );
347       dumpMemDrvFuncMap( );
348       dumpMemDrvMap( );
349       printf( "\n" );
350   }
351
352   //-------------------------------------------------------------------------------------------------------------
353   // Routines to list contents of the various NVM areas. Right now, we just dump out hex data. It would be
354   // nice to show formatted data. Perhaps one day...
355   //
356   //-------------------------------------------------------------------------------------------------------------
357   void dumpNvmNodeMap( ) {
358
359       printf( "NVM Node Map Dump: \n\n" );
360       dumpNvmData( NVM_NODE_MAP_START, sizeof( LcsNodeMap ), 8, true );
361       printf( "\n" );
362   }
363
364   void dumpNvmCdcMap( ) {
365
366       printf( "MEM CDC Map Dump: \n\n" );
367       dumpNvmData( NVM_CDC_MAP_START, sizeof( CDC::CdcConfigDesc ));
368       printf( "\n" );
369   }
370
371   void dumpNvmPortMap( ) {
372
373       printf( "NVM Port Map Dump: \n\n" );
374
375       for ( int i  = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
376
377           uint32_t ofs = NVM_PORT_MAP_START + ( i * sizeof( LcsPortMapEntry ));
378
379           printf( "Port %d, NVM ofs: 0x%04x \n", i + 1, ofs );
380           dumpNvmData( ofs, sizeof( LcsPortMapEntry ), 8, true );
381           printf( "\n" );
382       }
383
384       printf( "\n" );
385   }
386
387   void dumpNvmNodeData( ) {
388
389       printf( "NVM Port Map Dump: \n\n" );
390
391       for ( int i  = 0; i < MAX_NODE_DATA_BLOCKS; i++ ) {
392
393           uint32_t ofs = NVM_NODE_DATA_START + ( i * MAX_ATTR_MAP_ENTRIES  * sizeof( uint16_t ));
394
395           printf( "Node data block: %d, NVM ofs: 0x%04x \n", i, ofs );
```

```
396            dumpNvmData( ofs, MAX_ATTR_MAP_ENTRIES  * sizeof( uint16_t ));
397            printf( "\n" );
398        }
399
400        printf( "\n" );
401  }
402
403  void dumpNvmEventMap( ) {
404
405        printf( "NVM Node Event Dump: \n\n" );
406        dumpNvmData( NVM_EVENT_MAP_START, sizeof( LcsEventMap ));
407        printf( "\n" );
408  }
409
410  void dumpNvmRuntimeArea( ) {
411
412        printf( "NVM Runtime Area Dump: \n\n" );
413        dumpNvmData( 0, NVM_RUNTIME_AREA_SIZE , 8, true );
414        printf( "\n" );
415  }
416
417  void dumpNvmDrvData( uint16_t boardId ) {
418
419        if ( boardId >= MAX_EXT_BOARD_MAP_ENTRIES ) {
420
421            printf( "Invalid board ID\n" );
422            return;
423        }
424
425        if ( drvMap.map[ boardId ].flags & BF_EXT_BOARD_PRESENT ) {
426
427            printf( "NVM Driver Data( board: %d ): \n\n", boardId );
428            dumpExtNvmData( boardId, 0, sizeof( LcsDrvBoardDesc ));
429            printf( "\n" );
430        }
431        else printf( "No board found \n" );
432  }
433
434  void dumpNvmUserArea( ) {
435
436        printf( "NVM Area Dump: \n\n" );
437        dumpNvmData( NVM_USER_MAP_START, usrNvmGetSize( ), 8, true );
438        printf( "\n" );
439  }
440
441  //-------------------------------------------------------------------------------------------------------
442  // Print memory structures in a formatted way. Note that not all memory structures are printed. Some of the
443  // maps contain dynamic data, which changed rapidly. There is no point in showing that kind of data.
444  //
445  //-------------------------------------------------------------------------------------------------------
446  void printMemNodeMap( ) {
447
448        printf( "MEM Node Map: \n\n" );
449
450  /*
451      uint16_t        magicWord1                  = NVM_MWORD_1;
452      uint16_t        boardType                   = BT_NIL;
453      uint16_t        boardVersion                = 0;
454      uint16_t        controllerFamily            = CF_FAM_RPICO;
455      uint16_t        nvmChipFamily               = CF_FAM_MICROCHIP;
456      uint16_t        reservedArea[ 10 ]           = { 0 };
457      uint16_t        magicWord2                  = NVM_MWORD_2;
458
459      uint16_t        nodeState                   = NS_NIL;
460      uint16_t        nodeOptions                 = 0;
461      uint16_t        nodeFlags                   = 0;
462      uint16_t        nodeId                      = NIL_NODE_ID;
463      uint32_t        nodeUID                     = 0L;
464      uint16_t        nodeType                    = NIL_NODE_TYPE;
465      uint16_t        nodeSwVersion               = 0;
466      uint16_t        nodeSwPatchLevel            = 0;
467      uint16_t        nodeRestartCnt              = 0;
468      uint32_t        nodeSystemTime              = 0;
469      uint16_t        nodeMapSize                 = sizeof( LcsNodeMap );
470      char            name[ MAX_NODE_NAME_SIZE ]   = { 0 };
471
472      uint16_t        nvmNodeMapOfs               = NVM_NODE_MAP_START;
473      uint16_t        nvmCdcMapOfs                = NVM_CDC_MAP_START;
474      uint16_t        nvmPortMapOfs               = NVM_PORT_MAP_START;
475      uint16_t        nvmNodeDataOfs              = NVM_NODE_DATA_START;
476      uint16_t        nvmEventMapOfs              = NVM_EVENT_MAP_START;
477      uint16_t        nvmUserMapOfs               = NVM_USER_MAP_START;
478      uint32_t        nvmMemSize                  = NVM_RUNTIME_AREA_SIZE;
479
480      uint16_t        portMapEntries              = MAX_PORT_MAP_ENTRIES;
481      uint16_t        portMapHwm                  = 0;
482
483      uint16_t        eventMapEntries             = MAX_EVENT_MAP_ENTRIES;
484      uint16_t        eventMapHwm                 = 0;
485
486      uint16_t        taskMapEntries              = MAX_TASK_MAP_ENTRIES;
487      uint16_t        taskMapHwm                  = 0;
488
489      uint16_t        pendingMapEntries           = MAX_PENDING_REQ_MAP_ENTRIES;
490      uint16_t        pendingMapHwm               = 0;
491
492      uint16_t        drvFuncMapEntries           = MAX_DRV_TYPES;
493      uint16_t        drvFuncMapHwm               = 0;
494
```

```
495      uint16_t        drvMapEntries                = MAX_EXT_BOARD_MAP_ENTRIES;
496      uint16_t        drvMapHwm                    = 0;
497
498      // add the node data area ....
499 */
500
501      printf( "\n" );
502 }
503
504 void printMemCdcMap( ) {
505
506      printf( "MEM CDC Map: \n\n" );
507
508      // resort to CDC::printInfo command ?
509
510
511      printf( "\n" );
512 }
513
514 void printMemPortMap( ) {
515
516      printf( "MEM Port Map (Size: %d, Hwm: %d): \n\n", nodeMap.portMapEntries, nodeMap.portMapHwm );
517
518      for ( int i  = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
519
520          LcsPortMapEntry *ptr = &portMap.map[ i ];
521
522          printf( "Port %02d: Type: %02d, Options: 0x%04x, Flags: 0x%04x\n",
523                  i + 1,
524                  ptr -> type,
525                  ptr -> options,
526                  ptr -> flags );
527
528          /*
529          uint16_t  eventNodeId                = NIL_NODE_ID;
530          uint16_t  eventId                    = NIL_EVENT_ID;
531          uint16_t  eventValue                 = 0;
532          uint16_t  eventAction                = PEA_EVENT_IDLE;
533          uint16_t  eventDelayTime             = 0;
534          uint32_t  eventTimeStamp             = 0L;
535          char      name[ MAX_PORT_NAME_SIZE ]   = { 0 };
536
537          // add the port data area ?
538
539          */
540
541          printf( "\n" );
542      }
543 }
544
545 void printMemEventMap( ) {
546
547      printf( "MEM Event Map (Size: %d, Hwm: %d): \n\n", nodeMap.eventMapEntries, nodeMap.eventMapHwm );
548
549      // print my entries, hwm
550
551      // print the entries up to the HWM, 4 in a row ?
552
553      printf( "\n" );
554 }
555
556 void printMemDrvMap( ) {
557
558      printf( "MEM Driver Map: (Size: %d) \n\n", nodeMap.drvMapEntries );
559
560      for ( int i  = 0; i < MAX_EXT_BOARDS; i++ ) {
561
562          LcsDrvEntry *entry = &drvMap.map[ i ];
563
564          printf( "Board %d: ( Flags: 0x%04x, LastErr: %d, Drv: %p\n",
565                  i, entry -> flags, entry -> lastErr, entry -> drvFunc );
566
567          // add to print the driver data area...
568
569          printf( "\n" );
570      }
571
572       printf( "\n" );
573 }
574
575 //-------------------------------------------------------------------------------------------------------------
576 // "scanI2CBus" and "listDevicesI2C" are two routines that will list all chips found on the NVM and EXT bus.
577 //
578 //-------------------------------------------------------------------------------------------------------------
579 void scanI2CBus( uint8_t sclPin ) {
580
581      uint8_t rStat      = 0;
582      uint8_t i2cAdr     = 0;
583      uint8_t nDevices   = 0;
584      uint8_t buf        = 0;
585
586      for ( i2cAdr = 1; i2cAdr < 127; i2cAdr++ ) {
587
588          rStat = CDC::i2cRead( sclPin, i2cAdr, &buf, 1 );
589
590          if ( rStat == 0 ) {
591
592              printf( "I2C device found at i2cAdr 0x%x\n", i2cAdr );
593              nDevices ++;
```

```
594            }
595        }
596
597        if ( nDevices == 0 )  printf( "No I2C devices found\n" );
598        else                  printf( "Scan done\n" );
599    }
600
601    void listDevicesI2C( ) {
602
603        if ( cdcMap.cfg.NVM_I2C_SCL_PIN != CDC::UNDEFINED_PIN ) {
604
605            printf( "Scanning NVM I2C Bus: scl:%d, sda: %d \n", cdcMap.cfg.NVM_I2C_SCL_PIN, cdcMap.cfg.NVM_I2C_SDA_PIN );
606            scanI2CBus(  cdcMap.cfg.NVM_I2C_SCL_PIN );
607            printf( "\n" );
608        }
609
610        if ( cdcMap.cfg.EXT_I2C_SCL_PIN != CDC::UNDEFINED_PIN ) {
611
612            printf( "Scanning EXT I2C Bus: scl:%d, sda: %d \n", cdcMap.cfg.EXT_I2C_SCL_PIN, cdcMap.cfg.EXT_I2C_SDA_PIN );
613            scanI2CBus(  cdcMap.cfg.EXT_I2C_SCL_PIN );
614            printf( "\n" );
615        }
616    }
617
618    //-------------------------------------------------------------------------------------------------------------
619    // Little helper functions.
620    //
621    //-------------------------------------------------------------------------------------------------------------
622    bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
623
624        return (( val >= lower ) && ( val <= upper ));
625    }
626
627    uint16_t buildNpId( uint16_t nodeId, uint16_t portId ) {
628
629        return(( nodeId << 4 ) | ( portId & 0xF ));
630    }
631
632    uint16_t nodeId( uint16_t npId ) {
633
634        return( npId >> 4 );
635    }
636
637    uint16_t portId( uint16_t npId ) {
638
639        return( npId & 0xF );
640    }
641
642    uint8_t lowByte( uint16_t arg ) {
643
644        return( arg & 0xFF );
645    }
646
647    uint8_t highByte( uint16_t arg ) {
648
649        return( arg >> 8 );
650    }
651
652    //-------------------------------------------------------------------------------------------------------------
653    // Helper routines for error status handling.
654    //
655    // ??? one day, combine all error strings in one routine and print them from there...
656    //-------------------------------------------------------------------------------------------------------------
657    void errorArgList( ) {
658
659        printf( "Argument list error, use \"?\" )for help\n" );
660    }
661
662    void errorStatusMsg( char *msg, uint8_t ret ) {
663
664        printf( "Error: %s ( %d )\n", msg, ret );
665    }
666
667    }; // namespace
668
669
670    //-------------------------------------------------------------------------------------------------------------
671    // Routines in LCS name space.
672    //
673    //-------------------------------------------------------------------------------------------------------------
674    namespace LCS {
675
676    //-------------------------------------------------------------------------------------------------------------
677    // "c" switches a node to CFG mode. For a local node command, we construct the LCS_OP_CFG message payload
678    // data and invoke the msg handler for switching the node mode. For any other node, we will just send a LCS
679    // message.
680    //
681    //    c [ npId ]
682    //
683    //    returns: none
684    //
685    //-------------------------------------------------------------------------------------------------------------
686    void switchToConfigCommand( char *s ) {
687
688        int npId = NIL_NODE_ID;
689
690        if ( sscanf( s, "%i", &npId ) < 1 ) return( errorArgList( ));
691
692        uint16_t tmpNpId = (uint16_t) npId;
```

```
693
694        if (( npId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
695
696            uint8_t msg[ 8 ] = { LCS_OP_CFG };
697            handleMsgLcsMgt( msg );
698        }
699        else {
700
701            uint8_t ret = sendCfg( tmpNpId );
702            if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node send error", ret );
703        }
704 }
705
706 //-----------------------------------------------------------------------------------------------------
707 // "o" switches the nodes to OPS mode. For a local node command, we construct the LCS_OP_OPS message payload
708 // data and invoke the msg handler for switching the node mode. For any other node, we will just send a LCS
709 // message.
710 //
711 //     o [ npId ]
712 //
713 //-----------------------------------------------------------------------------------------------------
714 void switchToOperationsCommand( char *s ) {
715
716     int npId = NIL_NODE_ID;
717
718     if ( sscanf( s, "%i", &npId ) < 1 ) return( errorArgList( ));
719
720     uint16_t tmpNpId = (uint16_t) npId;
721
722     if (( npId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
723
724         uint8_t msg[ 8 ] = { LCS_OP_OPS };
725         handleMsgLcsMgt( msg );
726     }
727     else {
728
729         uint8_t ret = sendOps( tmpNpId );
730         if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node send error", ret );
731     }
732 }
733
734 //-----------------------------------------------------------------------------------------------------
735 // "a" adds an eventId / portId to the event map. If the portId is omitted, every port of the node will be
736 // registered for the event. For a non-local npId we will send a message.
737 //
738 //     a npId eventId [ portId ]
739 //
740 //     npId     - the node and port Id for which the event is added.
741 //     eventId  - the eventId.
742 //     portId   - the port number.
743 //
744 //-----------------------------------------------------------------------------------------------------
745 void enterEventCommand( char *s ) {
746
747     int  npId    = NIL_NODE_ID;
748     int  eventId = NIL_EVENT_ID;
749     int  portId  = NIL_PORT_ID;
750
751     if ( sscanf( s, "%i %i %i ", &npId, &eventId, &portId ) < 2 ) return( errorArgList( ));
752
753     uint16_t tmpNpId  = (uint16_t) npId;
754     uint16_t tmpEvent = (uint16_t) eventId;
755     uint16_t tmpPort  = (uint16_t) portId;
756
757    if (( tmpNpId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
758
759         uint8_t ret = nodeReq((uint16_t) tmpNpId, ITEM_ID_ADD_EVENT_MAP_ENTRY, &tmpEvent, &tmpPort );
760        if ( ret != ALL_OK ) errorStatusMsg((char *) "Node enter event error", ret );
761     }
762     else {
763
764         uint8_t ret = sendReqNode( nodeId( tmpNpId ), ITEM_ID_ADD_EVENT_MAP_ENTRY, tmpEvent, tmpPort );
765         if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node send error", ret );
766     }
767 }
768
769 //-----------------------------------------------------------------------------------------------------
770 // "r"  removes a eventId / portId combination from the event map. If the portId is omitted, all eventMap
771 // entries with the eventId are removed.
772 //
773 //     r npId eventId [ portId ]
774 //
775 //     npId     - the node and port Id for which the event is added.
776 //     eventId  - the eventId.
777 //     portId   - the port number.
778 //
779 //-----------------------------------------------------------------------------------------------------
780 void removeEventCommand( char *s ) {
781
782     int  npId    = NIL_NODE_ID;
783     int  eventId = NIL_EVENT_ID;
784     int  portId  = NIL_PORT_ID;
785
786     if ( sscanf( s, "%i %i %i ", &npId, &eventId, &portId ) < 1 ) return( errorArgList( ));
787
788     uint16_t tmpNpId  = (uint16_t) npId;
789     uint16_t tmpEvent = (uint16_t) eventId;
790     uint16_t tmpPort  = (uint16_t) portId;
791
```

```
792         if (( tmpNpId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
793
794             int ret = nodeReq( tmpNpId, ITEM_ID_DEL_EVENT_MAP_ENTRY, &tmpEvent, &tmpPort );
795             if ( ret != ALL_OK ) errorStatusMsg((char *) "Node remove event error", ret );
796         }
797         else {
798
799             uint8_t ret = sendReqNode( tmpNpId, ITEM_ID_DEL_EVENT_MAP_ENTRY, tmpEvent, tmpPort );
800             if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node send error", ret );
801         }
802 }
803
804 //---------------------------------------------------------------------------------------------------------
805 // "f" searches the event map for the eventId / portId combination and returns the index if found. If the
806 // portId is omitted, the first event map entry with the matching eventId is returned. This is a local
807 // command and cannot be called from a remote node.
808 //
809 //      f eventId [ portId ]
810 //
811 //      eventId  - the eventId.
812 //      portId   - the port number.
813 //
814 //---------------------------------------------------------------------------------------------------------
815 void findEventCommand( char *s ) {
816
817     int  eventId   = NIL_EVENT_ID;
818     int  portId    = NIL_PORT_ID;
819
820     if ( sscanf( s, "%i %i ", &eventId, &portId ) < 1 ) return( errorArgList( ));
821
822     uint16_t tmpEvent   = (uint16_t) eventId;
823     uint16_t tmpPort    = (uint16_t) portId;
824
825     int ret = searchEvent( tmpEvent, tmpPort );
826     printf( "Event map index: %d", ret );
827 }
828
829 //---------------------------------------------------------------------------------------------------------
830 // "e" will send an event. We will broadcast a message and also simulates receiving an event on the local
831 // node. Sending to ourselves is also quite useful for debugging event callback handlers.
832 //
833 //     e mode npId eventId [ arg ]
834 //
835 //     mode       - 0 - ON, 1 - OFF, 2 - DATA
836 //     npId       - the sending node / port Id
837 //     eventId    - the event Id
838 //     arg        - optional data argument for the event.
839 //
840 //---------------------------------------------------------------------------------------------------------
841 void sendEventCommand( char *s ) {
842
843     uint8_t msg[ 8 ]    = { };
844     int     npId        = NIL_NODE_ID;
845     int     eventId     = NIL_EVENT_ID;
846     int     mode        = 0;
847     int     arg         = 0;
848     int     len         = 0;
849     uint8_t ret         = ALL_OK;
850
851     len = sscanf( s, "%i %i %i %i", &mode, &npId, &eventId, &arg );
852
853     uint16_t tmpNpId    = (uint16_t) npId;
854     uint16_t tmpEvent   = (uint16_t) eventId;
855     uint16_t tmpArg     = (uint16_t) arg;
856
857     if ( len < 3 ) return( errorArgList( ));
858
859     msg[ 0 ] = 0;
860     msg[ 1 ] = highByte( tmpNpId );
861     msg[ 2 ] = lowByte( tmpNpId );
862     msg[ 3 ] = highByte( tmpEvent );
863     msg[ 4 ] = lowByte( tmpEvent );
864     msg[ 5 ] = highByte( tmpArg );
865     msg[ 6 ] = lowByte( tmpArg );
866     msg[ 7 ] = 0;
867
868     if ( mode == 0 ) {
869
870         msg[ 0 ] = LCS_OP_EVT_ON;
871         ret = sendEventOn( tmpNpId, tmpEvent );
872     }
873     else if ( mode == 0 ) {
874
875         msg[ 0 ] = LCS_OP_EVT_OFF;
876         ret = sendEventOn( tmpNpId, tmpEvent );
877     }
878     else if ( mode == 2 ) {
879
880         msg[ 0 ] = LCS_OP_EVT;
881         ret = sendEvent( tmpNpId, tmpEvent, tmpArg );
882     }
883
884     if ( ret != ALL_OK ) errorStatusMsg((char *) "Send event error", ret );
885 }
886
887 //---------------------------------------------------------------------------------------------------------
888 // "g" handles the node/port attribute query command. If the node is our node, we call the local access
889 // routines. Otherwise we send a message.
890 //
```

```
891  //     <!g npId item [ val1 [ val2 ]]>
892  //
893  //     npId        - the node/port Id.
894  //     item        - the node item to query, the result items will be listed in HEX format.
895  //     val1        - the argument 1 on input.
896  //     val2        - the argument 2 on input.
897  //
898  //-------------------------------------------------------------------------------------------------------
899  void getNodeCommand( char *s ) {
900
901      int      npId    = 0;
902      int      item    = 0;
903      int      arg1    = 0;
904      int      arg2    = 0;
905      uint8_t ret      = ALL_OK;
906
907      if ( sscanf(  s, "%i %i %i %i", &npId, &item, &arg1, &arg2 ) < 2 ) return( errorArgList( ));
908
909      uint16_t tmpNpId    = (uint16_t) npId;
910      uint8_t  tmpItem    = (uint8_t) item;
911      uint16_t tmpArg1    = (uint16_t) arg1;
912      uint16_t tmpArg2    = (uint16_t) arg2;
913
914      if (( tmpNpId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
915
916          ret = nodeGet ( tmpNpId, tmpItem, &tmpArg1, &tmpArg2 );
917          if ( ret != ALL_OK ) errorStatusMsg((char *) "Node GET error", ret );
918          else printf( "Node: 0x%x, item: %d, arg1: 0x%x, arg2: 0x%x\n", tmpNpId, tmpItem, tmpArg1, tmpArg2 );
919      }
920      else {
921
922          ret = sendGetNode( tmpNpId, tmpItem, tmpArg1, tmpArg2 );
923           if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node GET error", ret );
924      }
925  }
926
927  //-------------------------------------------------------------------------------------------------------
928  // "p" handles the node or port attribute value set command. If the node is out node, we call the local
929  // access routines. Otherwise we send a message.
930  //
931  //     <!p npId item [ val1 [ val2 ]]>
932  //
933  //     npId        - the node/port Id.
934  //     item        - the port item to control
935  //     val1        - the item value 1
936  //     val2        - the item value 2 ( optional )
937  //
938  //-------------------------------------------------------------------------------------------------------
939  void putNodeCommand( char *s ) {
940
941      int      npId    = 0;
942      int      item    = 0;
943      int      val1    = 0;
944      int      val2    = 0;
945      uint8_t ret      = ALL_OK;
946
947      if ( sscanf(  s, "%i %i %i %i", &npId, &item, &val1, &val2 ) < 2 ) return( errorArgList( ));
948
949      uint16_t tmpNpId    = (uint16_t) npId;
950      uint8_t  tmpItem    = (uint8_t)  item;
951      uint16_t tmpVal1    = (uint16_t) val1;
952      uint16_t tmpVal2    = (uint16_t) val2;
953
954      printf ( "val1: %d\n", val1 );
955
956      if (( tmpNpId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
957
958          ret = nodePut( tmpNpId, tmpItem, tmpVal1, tmpVal2 );
959          if ( ret != ALL_OK ) errorStatusMsg((char *) "Node PUT error", ret );
960          else printf( "Node: 0x%x, item: %d, val1: 0x%x, val2: 0x%x\n", tmpNpId, tmpItem, tmpVal1, tmpVal2 );
961      }
962      else {
963
964          ret = sendSetNode( tmpNpId, tmpItem, tmpVal1, tmpVal2 );
965          if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node PUT error", ret );
966      }
967  }
968
969  //-------------------------------------------------------------------------------------------------------
970  // "r" handles the node / port request command. If the node is out node, we call the local access routines.
971  // Otherwise we send a message.
972  //
973  //     r npId item [ val1 [ val2 ]]
974  //
975  //     npId        - the node/port Id.
976  //     item        - the port item to control
977  //     val1        - the item value 1
978  //     val2        - the item value 2 ( optional )
979  //
980  //-------------------------------------------------------------------------------------------------------
981  void reqNodeCommand( char *s ) {
982
983      int      npId    = 0;
984      int      item    = 0;
985      int      val1    = 0;
986      int      val2    = 0;
987      uint8_t ret      = ALL_OK;
988
989      if ( sscanf(  s, "%i %i %i %i", &npId, &item, &val1, &val2 ) < 2 ) return( errorArgList( ));
```

```
990
991      uint16_t tmpNpId    = (uint16_t) npId;
992      uint8_t  tmpItem    = (uint8_t)  item;
993      uint16_t tmpVal1    = (uint16_t) val1;
994      uint16_t tmpVal2    = (uint16_t) val2;
995
996      if (( tmpNpId == 0 ) || ( nodeId( tmpNpId ) == nodeMap.nodeId )) {
997
998          ret = nodeReq( tmpNpId, tmpItem, &tmpVal1, &tmpVal2 );
999          if ( ret != ALL_OK ) errorStatusMsg((char *) "Node REQ error", ret );
1000         else printf( "Node: 0x%x, item: %d, val1: 0x%x, val2: 0x%x\n", tmpNpId, tmpItem, tmpVal1, tmpVal1 );
1001     }
1002     else {
1003
1004         ret = sendReqNode( tmpNpId, tmpItem, tmpVal1, tmpVal2 );
1005         if ( ret != ALL_OK ) errorStatusMsg((char *) "Remote Node REQ error", ret );
1006     }
1007 }
1008
1009 //-----------------------------------------------------------------------------------------------------------
1010 // "B" broadcasts a LCS message. Mainly used for debugging purposes. Although most commands in the LCS
1011 // console interface can also send messages to other nodes, not all messages are covered. This command sends
1012 // any kind of message, even undefined ones.
1013 //
1014 //     B byte1 [ byte2 ... byte8 ]
1015 //
1016 //     byte1 .. byte8   - the packet data in hexadecimal
1017 //
1018 //-----------------------------------------------------------------------------------------------------------
1019 void broadcastLcsMsgCommand( char *s ) {
1020
1021     int      inBuf[ 8 ]  = { 0 };
1022     uint8_t b[ 8 ]       = { 0 };
1023     uint8_t nBytes  = sscanf( s, "%i %i %i %i %i %i %i %i",
1024                               inBuf, inBuf + 1, inBuf + 2, inBuf + 3, inBuf + 4, inBuf + 5, inBuf + 6, inBuf + 7 );
1025
1026     if ( nBytes >= 1 && nBytes <= 8 ) {
1027
1028         for ( int i = 0; i < 8; i++ ) b[ i ] == (uint8_t) inBuf[ i ];
1029
1030         uint8_t ret = msgBus -> sendLcsMsg( b );
1031         if ( ret != ALL_OK ) errorStatusMsg((char *) "Can Bus send error", ret );
1032     }
1033     else errorArgList( );
1034 }
1035
1036 //-----------------------------------------------------------------------------------------------------------
1037 // "G" sends a GET request to a driver. The commands will typically work on the MEM image of the driver data.
1038 // We will use the same idea of item ranges for MEM and NVM, except that the NVM range will work only if the
1039 // extension board is write-enabled.
1040 //
1041 //     G board item
1042 //
1043 //     board - the extension board the driver handles.
1044 //     item  - the driver specific item which is the requested operation.
1045 //
1046 //-----------------------------------------------------------------------------------------------------------
1047 void drvGetCommand( char *s ) {
1048
1049     int   boardId    = 0;
1050     int   item       = 0;
1051     int   arg        = 0;
1052     int   ret        = ALL_OK;
1053
1054     if ( sscanf( s, "%i %i", &boardId, &item ) < 2 ) return( errorArgList( ));
1055
1056     uint16_t tmpBoard   = (uint8_t) boardId;
1057     uint8_t  tmpItem    = (uint8_t)  item;
1058     uint16_t tmpArg     = (uint16_t) arg;
1059
1060     ret = drvGet( tmpBoard, tmpItem, &tmpArg );
1061
1062     if ( ret != ALL_OK ) errorStatusMsg((char *) "Driver GET error", ret );
1063     else printf( "Board: %d, item: %d, arg: 0x%x\n", tmpBoard, tmpItem, tmpArg );
1064 }
1065
1066 //-----------------------------------------------------------------------------------------------------------
1067 // "P" sends a PUT request to a driver. The commands will typically work on the MEM image of the driver data.
1068 // We will use the same idea of item ranges for MEM and NVM, except that the NVM range will work only if the
1069 // extension board is write-enabled.
1070 //
1071 //     P board item arg
1072 //
1073 //     board - the extension board the driver handles.
1074 //     item  - the driver specific item which is the requested operation.
1075 //     arg   - the data argument to the driver.
1076 //
1077 //-----------------------------------------------------------------------------------------------------------
1078 void drvPutCommand( char *s ) {
1079
1080     int   boardId    = 0;
1081     int   item       = 0;
1082     int   val        = 0;
1083     int   ret        = ALL_OK;
1084
1085     if ( sscanf( s, "%i %i %i", &boardId, &item, &val ) < 3 ) return( errorArgList( ));
1086
1087     uint16_t tmpBoard   = (uint8_t) boardId;
1088     uint8_t  tmpItem    = (uint8_t)  item;
```

```
1089        uint16_t tmpVal      = (uint16_t) val;
1090
1091        ret = drvPut( tmpBoard, tmpItem, tmpVal );
1092
1093        if ( ret != ALL_OK ) errorStatusMsg((char *) "Driver PUT error", ret );
1094        else printf( "Board: %d, item: %d, arg: 0x%x\n", tmpBoard, tmpItem, tmpVal );
1095    }
1096
1097    //------------------------------------------------------------------------------------------------------------
1098    // "R" sends a REQ request to a driver.
1099    //
1100    //    R board item arg1 [ arg 2 ]
1101    //
1102    //    board - the extension board the driver handles.
1103    //    item  - the driver specific item which is the requested operation.
1104    //    arg1  - the first argument to the driver.
1105    //    arg2  - the optional second argument to the driver and also output from the driver.
1106    //
1107    //------------------------------------------------------------------------------------------------------------
1108    void drvReqCommand( char *s ) {
1109
1110        int     boardId  = 0;
1111        int     item     = 0;
1112        int     arg1     = 0;
1113        int     arg2     = 0;
1114        uint8_t ret      = ALL_OK;
1115
1116        if ( sscanf( s, "%i %i %i %i", &boardId, &item, &arg1, &arg2 ) < 2 ) return( errorArgList( ));
1117
1118        uint16_t tmpBoard  = (uint8_t) boardId;
1119        uint8_t  tmpItem   = (uint8_t)  item;
1120        uint16_t tmpArg1   = (uint16_t) arg1;
1121        uint16_t tmpArg2   = (uint16_t) arg2;
1122
1123        ret = drvReq( tmpBoard, tmpItem, &tmpArg1, &tmpArg2 );
1124
1125        if ( ret != ALL_OK ) errorStatusMsg((char *) "Driver REQ error", ret );
1126        else printf( "Board: %d, item: %d, arg1: 0x%x, arg2: 0x%x\n", tmpBoard, tmpItem, tmpArg1, tmpArg2 );
1127    }
1128
1129    //------------------------------------------------------------------------------------------------------------
1130    // "s" lists status information. The level argument specifies the what and the detail level.
1131    //
1132    //    s [ level ]
1133    //
1134    //    returns:  NONE.
1135    //
1136    //------------------------------------------------------------------------------------------------------------
1137    void listStatusCommand( char *s ) {
1138
1139        int level = 0;
1140
1141        if ( sscanf( s, " %i", &level ) > 0 ) {
1142
1143            switch ( level ) {
1144
1145                case 0:    printSummary( );            break;
1146
1147                case 1:    dumpMemNodeMap( );          break;
1148                case 2:    dumpNvmCdcMap( );           break;
1149                case 3:    dumpMemPortMap( );          break;
1150                case 4:    dumpMemNodeData( );         break;
1151                case 5:    dumpMemEventMap( );         break;
1152                case 6:    dumpMemPendingReqMap( );    break;
1153                case 7:    dumpMemTaskMap( );          break;
1154                case 8:    dumpMemCallbackMap( );      break;
1155                case 9:    dumpMemDrvFuncMap( );       break;
1156                case 10:   dumpMemDrvMap( );           break;
1157                case 11:   dumpMemRuntimeArea( );      break;
1158
1159                case 21:   dumpNvmNodeMap( );          break;
1160                case 22:   dumpNvmCdcMap( );           break;
1161                case 23:   dumpNvmPortMap( );          break;
1162                case 24:   dumpNvmNodeData( );         break;
1163                case 25:   dumpNvmEventMap( );         break;
1164                case 26:   dumpNvmRuntimeArea( );      break;
1165
1166                case 31:   printMemNodeMap( );         break;
1167                case 32:   printMemCdcMap( );          break;
1168                case 33:   printMemPortMap( );         break;
1169                case 35:   printMemEventMap( );        break;
1170                case 38:   printMemDrvMap( );          break;
1171
1172                case 40:   dumpNvmDrvData( 0 );        break;
1173                case 41:   dumpNvmDrvData( 1 );        break;
1174                case 42:   dumpNvmDrvData( 2 );        break;
1175                case 43:   dumpNvmDrvData( 3 );        break;
1176
1177                case 50:   listDevicesI2C( );          break;
1178
1179                default: printf( "Unknown help option, use '?' for help\n" );
1180            }
1181        }
1182        else printSummary( );
1183    }
1184
1185    //------------------------------------------------------------------------------------------------------------
1186    // "?" lists core library help information. We just list the available commands and a short description.
1187    //
```

```
1188  //    ?
1189  //
1190  //-----------------------------------------------------------------------------------------------------------
1191  void listCoreLibHelpCommand( ) {
1192
1193      printf( "\nCommands: \n" );
1194      printf( "c [ npId ] - enter config mode\n" );
1195      printf( "o [ npId ] - enter operations mode\n" );
1196
1197      printf( "a npId eventId [ npId ] - add an event to the event tab\n" );
1198      printf( "d npId eventId [ npId ] - remove an event from the event tab\n" );
1199      printf( "e npId eventId mode [ arg ] - simulate sending an event ( mode: 0 - ON, 1 - OFF, 2 - EVT\n" );
1200      printf( "f eventId [ npId ] - search an event on the event tab\n" );
1201
1202      printf( "g npId item - gets a node attribute\n" );
1203      printf( "p npId item val1 [ val2 ] - puts a node attribute\n" );
1204      printf( "r npId item val1 [ val2 ] - request a node function\n" );
1205
1206      printf( "B byte1 [ byte2 ... byte8 ] - broadcast a raw LCS message\n" );
1207
1208      printf( "G board item - send a GET request to an extension board n\n" );
1209      printf( "P board item arg - send a PUT request to an extension board n\n" );
1210      printf( "R board item [ arg1 [ arg2 ]] - send a REQ request to an extension board n\n" );
1211
1212      printf( "s [ level ] - list status, default is summary\n" );
1213      printf( "                  " " -   0  - summary\n" );
1214      printf( "                  " " -   1  - MEM Node Map\n" );
1215      printf( "                  " " -   2  - MEM CDC Map\n" );
1216      printf( "                  " " -   3  - MEM Port Map\n" );
1217      printf( "                  " " -   4  - MEM Node Data\n" );
1218      printf( "                  " " -   5  - MEM Event Map\n" );
1219      printf( "                  " " -   6  - MEM Pending Request Map\n" );
1220      printf( "                  " " -   7  - MEM Task Map\n" );
1221      printf( "                  " " -   8  - MEM Callback Map\n" );
1222      printf( "                  " " -   9  - MEM Driver Function Map\n" );
1223      printf( "                  " " -  10  - MEM Driver Map\n" );
1224      printf( "                  " " -  11  - MEM Runtime Area\n" );
1225
1226      printf( "                  " " -  21  - NVM Node Map\n" );
1227      printf( "                  " " -  22  - NVM CDC Map\n" );
1228      printf( "                  " " -  23  - NVM Port Map\n" );
1229      printf( "                  " " -  24  - NVM Node Data\n" );
1230      printf( "                  " " -  25  - NVM Event Map\n" );
1231      printf( "                  " " -  26  - NVM Runtime Area\n" );
1232
1233      printf( "                  " " -  31  - MEM Node Map formatted\n" );
1234      printf( "                  " " -  32  - MEM CDC Map formatted\n" );
1235      printf( "                  " " -  33  - NVM Port Map formatted\n" );
1236      printf( "                  " " -  35  - MEM Event Map formatted\n" );
1237      printf( "                  " " -  38  - MEM Driver Map formatted\n" );
1238
1239      printf( "                  " " -  40  - NVM Extension Board 0\n" );
1240      printf( "                  " " -  41  - NVM Extension Board 1\n" );
1241      printf( "                  " " -  42  - NVM Extension Board 2\n" );
1242      printf( "                  " " -  43  - NVM Extension Board 3\n" );
1243
1244      printf( "                  " " -  50  - I2C Devices\n" );
1245  }
1246
1247  //-----------------------------------------------------------------------------------------------------------
1248  // "setupSerialCommand" initializes the serial interface. We use the PICO USB as console IO. The CDC lib
1249  // contains functions for reading and writing to the console.
1250  //
1251  //-----------------------------------------------------------------------------------------------------------
1252  uint8_t setupSerialCommand( ) {
1253
1254      return ( CDC::configureConsoleIO( ));
1255  }
1256
1257  //-----------------------------------------------------------------------------------------------------------
1258  // "handleSerialCommand" reads characters from the console. The command interpreter is a simple character
1259  // based input. Note that this routine is called as part of the runtime loop. Consequently, it cannot not
1260  // block for IO. The interface is designed in a way that it assembles the character input when there are
1261  // characters until a carriage return is received. The first character is the command. If it is not a
1262  // command we know and there is a callback, the callback gets his chance to handle the input string.
1263  // Since we are pretty basic on a character by character basis, we also add a bit of luxury and echo back
1264  // the  what was typed in as well as process the backspace character.
1265  //
1266  //-----------------------------------------------------------------------------------------------------------
1267  uint8_t handleSerialCommand( ) {
1268
1269      char c;
1270
1271      while (( c = CDC::getConsoleChar( )) > 0 ) {
1272
1273          switch( c ) {
1274
1275              case '\r': {
1276
1277                  printf( "\n" );
1278
1279                  if ( strlen( commandBuf) > 0 ) {
1280
1281                      switch ( commandBuf[ 0 ] ) {
1282
1283                          case 'C': switchToConfigCommand( commandBuf + 1 );        break;
1284                          case 'O': switchToOperationsCommand( commandBuf + 1 );    break;
1285
1286                          case 'a': enterEventCommand( commandBuf + 1 );            break;
```

```
1287                    case 'd': removeEventCommand( commandBuf + 1 );        break;
1288                    case 'f': findEventCommand( commandBuf + 1 );          break;
1289                    case 'e': sendEventCommand( commandBuf + 1 );          break;
1290
1291                    case 'g': getNodeCommand( commandBuf + 1 );            break;
1292                    case 'p': putNodeCommand( commandBuf + 1 );            break;
1293                    case 'r': reqNodeCommand( commandBuf + 1 );            break;
1294
1295                    case 'B': broadcastLcsMsgCommand( commandBuf + 1 );    break;
1296
1297                    case 'G': drvGetCommand( commandBuf + 1 );             break;
1298                    case 'P': drvPutCommand( commandBuf + 1 );             break;
1299                    case 'R': drvReqCommand( commandBuf + 1 );             break;
1300
1301                    case 's': listStatusCommand( commandBuf + 1 );         break;
1302                    case '?': listCoreLibHelpCommand( );                   break;
1303
1304                    default: {
1305
1306                        if ( callbackMap.cmdLineCallback != nullptr ) {
1307
1308                            callbackMap.cmdLineCallback( commandBuf );
1309                        }
1310                        else printf( "<Unknown command, use '?' for help>" );
1311                    }
1312                }
1313            }
1314
1315            commandBuf[ 0 ] = '\0';
1316            printf( "->");
1317
1318        } break;
1319
1320        case '\b': {
1321
1322            printf( "\b \b" );
1323            if ( strlen( commandBuf ) > 0 ) commandBuf[ strlen( commandBuf ) - 1 ] = '\0';
1324
1325        } break;
1326
1327        default: {
1328
1329            printf( "%c", c );
1330            if ( strlen( commandBuf ) < MAX_COMMAND_LINE_SIZE ) strncat( commandBuf, &c, 1 );
1331        }
1332        }
1333    }
1334
1335    return( ALL_OK );
1336 }
1337
1338 }; // namespace LCS
```

APPENDIX A. LISTINGS TEST

```cpp
//-------------------------------------------------------------------------------------------------------------
//
// Layout Control System - node access routines.
//
//-------------------------------------------------------------------------------------------------------------
// The file contains the part of the LCS Runtime that implements the GET, SET and REQ access for the driver
// that manages an extension board.
//
// ??? what else to explain ?
//-------------------------------------------------------------------------------------------------------------
//
// LCS - Core Library
// Copyright (C) 2021 - 2024  Helmut Fieres
//
// This program is free software: you can redistribute it and/or modify it under the terms of the GNU
// General Public License as published by the Free Software Foundation, either version 3 of the License,
// or any later version.
//
// This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
// the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
// License for more details. You should have received a copy of the GNU General Public License along with
// this program.  If not, see <http://www.gnu.org/licenses/>.
//
//-------------------------------------------------------------------------------------------------------------
#include "LcsRuntimeLib.h"
#include "LcsRtLibInt.h"

//-------------------------------------------------------------------------------------------------------------
// External declaration to global structures defined in "LcsRtSetup".
//
//-------------------------------------------------------------------------------------------------------------
namespace LCS {

    extern uint16_t         debugMask;
    extern LcsCdcMap        cdcMap;
    extern LcsNodeMap       nodeMap;
    extern LcsDrvMap        drvMap;
};

//-------------------------------------------------------------------------------------------------------------
// The LcsCoreLib implementation file local declarations and routines.
//
//-------------------------------------------------------------------------------------------------------------
namespace {

using namespace LCS;

//-------------------------------------------------------------------------------------------------------------
// Utility routines.
//
//-------------------------------------------------------------------------------------------------------------
bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {

    return (( val >= lower ) && ( val <= upper ));
}

uint8_t lowByte( uint16_t arg ) {

    return( arg & 0xFF );
}

uint8_t highByte( uint16_t arg ) {

    return( arg >> 8 );
}

//-------------------------------------------------------------------------------------------------------------
// "buildDrvBoardDescArea" will create a default data area and initializes the extension board NVM with this
// data.
//
//-------------------------------------------------------------------------------------------------------------
uint8_t buildDrvBoardDescArea( uint8_t boardId ) {

    uint8_t         rStat;
    LcsDrvBoardDesc tmp;

    if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
        printf( "buildDrvBoardDescArea, boardId: %d\n", boardId );

    rStat = extNvmPutBytes( boardId, 0, (uint8_t *) &tmp, sizeof( tmp ));

    if (( debugMask & DBG_CONFIG ) && ( debugMask & DBG_SETUP ))
        printf( "buildDrvBoardDescArea, stat: %d\n", rStat  );

    return( rStat );
}

} // namespace


//-------------------------------------------------------------------------------------------------------------
// The LCS name space routines declared in this file.
//
//-------------------------------------------------------------------------------------------------------------
namespace LCS {

//-------------------------------------------------------------------------------------------------------------
//
```

```
99    //
100   //-------------------------------------------------------------------------------------------------------------
101   uint8_t drvInit( ) {
102
103       return ( ALL_OK );
104   }
105
106   //-------------------------------------------------------------------------------------------------------------
107   // "drvGet" returns a value from the driver data array.
108   //
109   //-------------------------------------------------------------------------------------------------------------
110   uint8_t drvGet( uint8_t boardId, uint8_t item, uint16_t *arg ) {
111
112       if ( boardId >= MAX_EXT_BOARD_MAP_ENTRIES )                return ( ERR_INVALID_BOARD_ID );
113       if ( ! drvMap.map[ boardId ].flags & BF_EXT_BOARD_PRESENT ) return( ERR_INVALID_BOARD_ID );
114
115       if ( isInRangeU( item, IR_ATTR_MEM_RANGE_START, IR_ATTR_MEM_RANGE_END )) {
116
117           *arg = drvMap.map[ boardId ].extBoard.driverData[ item - IR_ATTR_MEM_RANGE_START ];
118           return( ALL_OK );
119       }
120       else if ( isInRangeU( item, IR_ATTR_NVM_RANGE_START, IR_ATTR_NVM_RANGE_END )) {
121
122           uint32_t ofs =  offsetof( LcsDrvBoardDesc, driverData ) +
123                           (( item - IR_ATTR_NVM_RANGE_START ) * sizeof( uint16_t ));
124
125           if ( extNvmGetWord( boardId, ofs, arg ) != ALL_OK ) return( ERR_DRV_GET_ERR );
126           return( ALL_OK );
127       }
128       else if ( item == ITEM_ID_BOARD_VERSION ) {
129
130           *arg = drvMap.map[ boardId ].extBoard.head.boardVersion;
131           return( ALL_OK );
132       }
133       else if ( item == ITEM_ID_TYPE ) {
134
135           *arg = drvMap.map[ boardId ].extBoard.head.boardType;
136           return( ALL_OK );
137       }
138       else return( ERR_INVALID_ITEM_ID );
139   }
140
141   //-------------------------------------------------------------------------------------------------------------
142   // "drvPut" sets a value in the driver data array. Note that this is during normal operations only the MEM
143   // portion. The NVM chip on the extension board is write disabled after initial configuration. When the
144   // jumper on the board is taken out, writing to the NVM is enabled. The PUT and GET routines can be called
145   // for a board that has no driver associated yet. This way, for example, the driver type and other initial
146   // data can be set.
147   //
148   //
149   // ??? should we restart the extension board after setting the driver type ?
150   //-------------------------------------------------------------------------------------------------------------
151   uint8_t drvPut(uint8_t boardId, uint8_t item, uint16_t arg ) {
152
153       if ( boardId >= MAX_EXT_BOARD_MAP_ENTRIES )                return( ERR_INVALID_BOARD_ID );
154       if ( ! drvMap.map[ boardId ].flags & BF_EXT_BOARD_PRESENT ) return( ERR_INVALID_BOARD_ID );
155
156        if ( isInRangeU( item, IR_ATTR_MEM_RANGE_START, IR_ATTR_MEM_RANGE_END )) {
157
158           drvMap.map[ boardId ].extBoard.driverData[ item - IR_ATTR_MEM_RANGE_START ] = arg;
159           return( ALL_OK );
160       }
161       else if ( isInRangeU( item, IR_ATTR_NVM_RANGE_START, IR_ATTR_NVM_RANGE_END )) {
162
163           uint32_t ofs =  offsetof( LcsDrvBoardDesc, driverData ) +
164                           (( item - IR_ATTR_NVM_RANGE_START ) * sizeof( uint16_t ));
165
166           if ( extNvmPutWord( boardId, ofs, arg ) != ALL_OK ) return( ERR_DRV_PUT_ERR );
167           return( ALL_OK );
168       }
169       else if ( item == ITEM_ID_BOARD_VERSION ) {
170
171           uint8_t rStat = ALL_OK;
172
173           rStat = extNvmPutWord( boardId, offsetof( LcsDrvBoardDesc, head.boardVersion ), arg );
174           if ( rStat == ALL_OK ) drvMap.map[ boardId ].extBoard.head.boardVersion = arg;
175           return( rStat );
176       }
177       else if ( item == ITEM_ID_TYPE ) {
178
179           uint8_t rStat = ALL_OK;
180
181           rStat = extNvmPutWord( boardId, offsetof( LcsDrvBoardDesc, head.boardType ), arg );
182           if ( rStat == ALL_OK ) drvMap.map[ boardId ].extBoard.head.boardType = arg;
183           return( rStat );
184       }
185       else return( ERR_INVALID_ITEM_ID );
186   }
187
188   //-------------------------------------------------------------------------------------------------------------
189   // "drvReq" is the entry point to an extension board. For each extension board type there is driver function.
190   // This function is called when we access that extension board. Note that the REQ call will only work when
191   // there is a board with a driver associated. There is however the case that the header area is a new area
192   // or an invalid area. We have a board detected bit could not setup the driver for it. The "ITEM_ID_FORMAT"
193   // item is used to setup the extension board NVM. It works without checking for a valid driver.
194   //
195   // The PUT and GET routines can be called for a board that has no driver associated yet. This way, for
196   // example, the driver type and other initial data can be set.
197   //
```

APPENDIX A. LISTINGS TEST

```cpp
198    //----------------------------------------------------------------------------------------------------------------
199    uint8_t drvReq( uint8_t boardId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
200
201        if ( boardId >= MAX_EXT_BOARD_MAP_ENTRIES )                    return ( ERR_INVALID_BOARD_ID );
202        if ( ! drvMap.map[ boardId ].flags & BF_EXT_BOARD_PRESENT ) return( ERR_INVALID_BOARD_ID );
203
204        if ( item == ITEM_ID_FORMAT ) {
205
206            LcsDrvEntry entry;
207
208            entry.flags = BF_EXT_BOARD_PRESENT | BF_EXT_BOARD_VALID;
209
210            uint8_t rStat = buildDrvBoardDescArea( boardId );
211            if ( rStat == ALL_OK ) drvMap.map[ boardId ] = entry;
212
213            return( rStat );
214        }
215        else {
216
217            if ( drvMap.map[ boardId ].drvFunc != nullptr ) {
218
219                return( drvMap.map[ boardId ].drvFunc( boardId - 1, item, arg1, arg2 ));
220            }
221            else return( ERR_EXT_BOARD_NOT_VALID );
222        }
223    }
224
225    } // namespace LCS
```

APPENDIX A. LISTINGS TEST

```
1   //----------------------------------------------------------------------------------------------------
2   //
3   // Layout Control System - runtime core.
4   //
5   //----------------------------------------------------------------------------------------------------
6   // The file contains the runtime core routines. They implement the node state machine that reacts to messages
7   // and advances according to state. The routines are called from the runtime loop in the setup file.
8   //
9   //----------------------------------------------------------------------------------------------------
10  //
11  // LCS - Core Library
12  // Copyright (C) 2021 - 2024  Helmut Fieres
13  //
14  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU
15  // General Public License as published by the Free Software Foundation, either version 3 of the License,
16  // or any later version.
17  //
18  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even
19  // the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU General Public
20  // License for more details. You should have received a copy of the GNU General Public License along with
21  // this program.  If not, see <http://www.gnu.org/licenses/>.
22  //
23  //----------------------------------------------------------------------------------------------------
24  #include "LcsRuntimeLib.h"
25  #include "LcsRtLibInt.h"
26
27  //----------------------------------------------------------------------------------------------------
28  // External declaration to global structures defined in "LcsRtSetup".
29  //
30  //----------------------------------------------------------------------------------------------------
31  namespace LCS {
32
33      extern uint16_t           debugMask;
34      extern LcsCdcMap          cdcMap;
35      extern LcsNodeMap         nodeMap;
36      extern LcsPortMap         portMap;
37      extern LcsEventMap        eventMap;
38      extern LcsCallbackMap     callbackMap;
39      extern LcsTaskMap         taskMap;
40      extern LcsPendingReqMap   pendingReqMap;
41      extern LcsDrvFuncMap      drvFuncMap;
42      extern LcsDrvMap          drvMap;
43      extern LcsMsgBusCAN       *msgBus;
44  };
45
46  //----------------------------------------------------------------------------------------------------
47  // The LcsCoreLib implementation file local declarations and routines.
48  //
49  //----------------------------------------------------------------------------------------------------
50  namespace {
51
52  using namespace LCS;
53
54  //----------------------------------------------------------------------------------------------------
55  // Local constants and helper functions.
56  //
57  //----------------------------------------------------------------------------------------------------
58  const uint32_t  NODE_SETUP_RETRY_TIMER_VAL_MS   = 1000L;
59  uint32_t        timerVal                        = 0L;
60
61  bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
62
63    return (( val >= lower ) && ( val <= upper ));
64  }
65
66  uint16_t buildNpId( uint16_t nodeId, uint16_t portId ) {
67
68      return(( nodeId << 4 ) | ( portId & 0xF ));
69  }
70
71  uint16_t nodeId( uint16_t npId ) {
72
73      return( npId >> 4 );
74  }
75
76  uint16_t portId( uint16_t npId ) {
77
78      return( npId & 0xF );
79  }
80
81  } // namespace
82
83  //----------------------------------------------------------------------------------------------------
84  //  The LCS name space routines declared in this file.
85  //
86  //----------------------------------------------------------------------------------------------------
87  namespace LCS {
88
89  //----------------------------------------------------------------------------------------------------
90  // General callback registration functions. They just set the function Id field. Straightforward.
91  //
92  //----------------------------------------------------------------------------------------------------
93  void registerLcsMsgCallback( LcsMsgCallback functionId ) {
94
95    callbackMap.lcsMsgCallback = functionId;
96  }
97
98  void registerDccMsgCallback( LcsMsgCallback functionId ) {
```

```
99
100      callbackMap.dccMsgCallback = functionId;
101  }
102
103  void registerCmdCallback( LcsCmdCallback functionId ) {
104
105      callbackMap.cmdLineCallback = functionId;
106  }
107
108  void registerEventCallback( LcsEventCallback functionId ) {
109
110      callbackMap.eventCallback = functionId;
111  }
112
113  void registerInitCallback( LcsInitCallback functionId ) {
114
115        callbackMap.initCallback = functionId;
116  }
117
118  void registerResetCallback( LcsInitCallback functionId ) {
119
120        callbackMap.resetCallback = functionId;
121  }
122
123  void registerPfailCallback( LcsInitCallback functionId ) {
124
125        callbackMap.pfailCallback = functionId;
126  }
127
128  void registerReqCallback( LcsReqCallback functionId ) {
129
130        callbackMap.reqCallback = functionId;
131  }
132
133  void registerRepCallback( LcsRepCallback functionId ) {
134
135        callbackMap.repCallback = functionId;
136  }
137
138  //-------------------------------------------------------------------------------------------------------
139  // The core library features a very simple periodic task system. This routine adds a task callback to the
140  // pTaskMap. We only add entries, never remove them. A high water mark is used to record the highest entry
141  // used, so that processing will not run through empty entries.
142  //
143  // ??? perhaps this needs to be reworked to use HW driven timers.
144  //-------------------------------------------------------------------------------------------------------
145  uint8_t registerTaskCallback( LcsTaskCallback task, uint32_t interval ) {
146
147      if ( nodeMap.taskMapHwm < MAX_TASK_MAP_ENTRIES ) {
148
149          taskMap.map[ nodeMap.taskMapHwm ].task      = task;
150          taskMap.map[ nodeMap.taskMapHwm ].interval  = interval;
151          taskMap.map[ nodeMap.taskMapHwm ].timeStamp = CDC::getMillis( );
152          nodeMap.taskMapHwm ++;
153          return ( ALL_OK );
154
155      } else return ( ERR_TASK_MAP_SIZE_EXCEEDED );
156  }
157
158  //-------------------------------------------------------------------------------------------------------
159  // "handleNodePortEvents" will be called for processing inbound port events on each loop iteration. Note that
160  // it does not matter where the events came from, i.e. whether another node sends an event or the event was
161  // created by a firmware call on this node. The event callback can be delayed with a timer value.
162  //
163  //-------------------------------------------------------------------------------------------------------
164  void handleNodePortEvents( ) {
165
166      if ( callbackMap.eventCallback == nullptr ) return;
167
168      uint32_t ts = CDC::getMillis( );
169
170      for ( uint8_t i = 0; i < MAX_PORT_MAP_ENTRIES; i ++ ) {
171
172          LcsPortMapEntry *pPtr = & portMap.map[ i ];
173
174          if (( pPtr -> flags & PF_PORT_ENABLED                 ) &&
175              ( pPtr -> flags & PF_PORT_EVENT_HANDLING_ENABLED  ) &&
176              ( pPtr -> flags & PF_EVENT_PENDING                )) {
177
178              if ( ts > pPtr -> eventTimeStamp ) {
179
180                  callbackMap.eventCallback(  pPtr -> eventNodeId,
181                                              pPtr -> eventId,
182                                              pPtr -> eventAction,
183                                              pPtr -> eventValue );
184              }
185
186              pPtr -> flags &= ~ PF_EVENT_PENDING;
187          }
188      }
189  }
190
191  //-------------------------------------------------------------------------------------------------------
192  // "handlePeriodicTasks" is called from the core library main processing loop. The idea is that there is a
193  // lot of periodic processing that needs to be one by any firmware implementation. Instead of the firmware
194  // developer writing its own handler, there is a crude method that just samples the timestamps and interval
195  // and triggers the callback then the interval is reached. Note that this is not very accurate from a timing
196  // perspective but will do for simple periodic processing.
197  //
```

```
198    //---------------------------------------------------------------------------------------------------
199    void handlePeriodicTasks ( ) {
200
201        uint32_t ts = CDC::getMillis ( );
202
203        for ( int i = 0; i < nodeMap.taskMapHwm; i++ ) {
204
205            LcsPTaskMapEntry *thisEntry = &taskMap.map[ i ];
206
207            if ( ts > thisEntry -> timeStamp  ) {
208
209                if ( thisEntry -> task != nullptr ) thisEntry -> task( );
210                thisEntry -> timeStamp = ts + thisEntry -> interval;
211            }
212        }
213    }
214
215    //---------------------------------------------------------------------------------------------------
216    // "handleMsgRepNid" handles the message that the configuring node sends to our node in response to a nodeId
217    // setup request. If the UID matches, the message is for our node and we update our nodeId accordingly in
218    // MEM and NVM. The next node state is OPERATE.
219    //
220    //---------------------------------------------------------------------------------------------------
221    void handleMsgRepNid ( uint8_t *msg ) {
222
223        uint16_t nodeId  = ( msg[1] << 8 ) + msg[2];
224        uint32_t nodeUID = ((uint32_t) msg[3] << 24 ) +
225                           ((uint32_t) msg[4] << 16 ) +
226                           ((uint32_t) msg[5] << 8 ) +
227                           msg[6];
228
229        if ( nodeUID == nodeMap.nodeUID ) {
230
231            if ( nodeMap.nodeId != nodeId ) {
232
233                nodeMap.nodeId = nodeId;
234                uint8_t rStat = rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeId ), nodeId );
235            }
236
237            nodeMap.nodeState = NS_OPERATE;
238        }
239    }
240
241    //---------------------------------------------------------------------------------------------------
242    // LCS management deals with messages concerning the general LCS management. If there is a callback defined
243    // it will be invoked. Then the node state is changed accordingly. Most updates are just to the MEM nodeMap.
244    // In addition, the READY and ACTIVITY LEDs are set.
245    //
246    //---------------------------------------------------------------------------------------------------
247    void handleMsgLcsMgt ( uint8_t *msg ) {
248
249        switch ( msg[ 0 ] ) {
250
251            case LCS_OP_OPS: {
252
253                nodeMap.nodeState = NS_OPERATE;
254                if ( callbackMap.lcsMsgCallback != nullptr ) callbackMap.lcsMsgCallback( msg );
255
256            } break;
257
258            case LCS_OP_CFG: {
259
260                nodeMap.nodeState = NS_CONFIG;
261                if ( callbackMap.lcsMsgCallback != nullptr ) callbackMap.lcsMsgCallback( msg );
262
263            } break;
264
265            case LCS_OP_BON: {
266
267                CDC::writeDio ( cdcMap.cfg.READY_LED_PIN, true );
268                nodeMap.nodeState = NS_OPERATE;
269                if ( callbackMap.lcsMsgCallback != nullptr ) callbackMap.lcsMsgCallback( msg );
270
271            } break;
272
273            case LCS_OP_BOF: {
274
275                CDC::writeDio ( cdcMap.cfg.READY_LED_PIN, false );
276                nodeMap.nodeState = NS_HALTED;
277                if ( callbackMap.lcsMsgCallback != nullptr ) callbackMap.lcsMsgCallback( msg );
278
279            } break;
280
281            case LCS_OP_NCOL: {
282
283                CDC::writeDio ( cdcMap.cfg.READY_LED_PIN, false );
284                CDC::writeDio ( cdcMap.cfg.ACTIVE_LED_PIN, true );
285                nodeMap.nodeState = NS_COLLISION;
286                if ( callbackMap.lcsMsgCallback != nullptr ) callbackMap.lcsMsgCallback( msg );
287
288            } break;
289
290            case LCS_OP_RESET: {
291
292                uint16_t npId = (( msg[1] << 8 ) + msg[2] );
293                uint8_t rStat = resetNode( npId );
294
295                if ( rStat == ALL_OK ) LCS::sendAck( npId );
296                else                   LCS::sendErr( npId, rStat, 0, 0 );
```

APPENDIX A. LISTINGS TEST

```
297
298            } break;
299
300            case LCS_OP_SET_NID: {
301
302                uint16_t nodeId   = ( msg[1] << 8 ) + msg[2];
303                uint32_t nodeUID  = ((uint32_t) msg[3] << 24 ) + ((uint32_t) msg[4] << 16 ) +
304                                    ((uint32_t) msg[5] << 8 ) + msg[6];
305
306                if ( nodeUID == nodeMap.nodeUID ) {
307
308                    if ( nodeMap.nodeState == NS_CONFIG ) {
309
310                        if ( nodeId != nodeMap.nodeId ) nodeMap.nodeId = nodeId;
311                        uint8_t rStat = rtNvmPutWord( NVM_NODE_MAP_START + offsetof( LcsNodeMap, nodeId ), nodeId );
312
313                        sendAck( nodeId );
314                    }
315                    else sendErr( nodeId, ERR_NODE_NOT_CONFIG_STATE, 0, 0 );
316                }
317
318            } break;
319        }
320 }
321
322 //----------------------------------------------------------------------------------------------------
323 // "handleMsgGetNode" processes an incoming GET message for a node or port attribute. We construct the
324 // reply message with the requested data.
325 //
326 //----------------------------------------------------------------------------------------------------
327 void handleMsgGetNode( uint8_t *msg ) {
328
329     uint16_t npId =  (( msg[1] << 8 ) + msg[2] );
330
331     if ( nodeId( npId ) == nodeMap.nodeId ) {
332
333         uint8_t   item  = msg[3];
334         uint16_t  arg1  = ( msg[4] << 8 ) + msg[5];
335         uint16_t  arg2  = ( msg[6] << 8 ) + msg[7];
336         uint8_t   ret   = nodeGet( npId, item, &arg1, &arg2 );
337
338         if ( ret == ALL_OK )  sendRepNode( npId, item, arg1, arg2 );
339         else                  sendErr( npId, ret, 0, 0 );
340     }
341 }
342
343 //----------------------------------------------------------------------------------------------------
344 // "handleMsgPutNode" processes an incoming PUT message for a node or port attribute. We update the data
345 // and send a confirmation.
346 //
347 //----------------------------------------------------------------------------------------------------
348 void handleMsgPutNode( uint8_t *msg ) {
349
350     uint16_t npId =  (( msg[1] << 8 ) + msg[2] );
351
352     if ( nodeId( npId ) == nodeMap.nodeId ) {
353
354         uint8_t   item  = msg[3];
355         uint16_t  arg1  = ( msg[4] << 8 ) + msg[5];
356         uint16_t  arg2  = ( msg[6] << 8 ) + msg[7];
357         uint8_t   ret   = nodePut( npId, item, arg1, arg2 );
358
359         if ( ret == ALL_OK )  sendAck( npId );
360         else                  sendErr( npId, ret, 0, 0 );
361     }
362 }
363
364 //----------------------------------------------------------------------------------------------------
365 // "handleMsgRepNode" processes the answer to a previously sent node query. The incoming message will only
366 // result in an action when we have an outstanding request for that node. That is, this handler will only
367 // be called when the we passed the outstanding reply map check done before. All reply messages are routed
368 // to this one callback. It is up to the firmware programmer to analyze for what and whom the reply really
369 // is.
370 //
371 //----------------------------------------------------------------------------------------------------
372 void handleMsgRepNode( uint8_t *msg ) {
373
374     uint16_t  npId   = (( msg[1] << 8 ) + msg[2] );
375     uint8_t   item   = msg[3];
376     uint16_t  arg1   = ( msg[4] << 8 ) + msg[5];
377     uint16_t  arg2   = ( msg[6] << 8 ) + msg[7];
378
379     if ( callbackMap.repCallback != nullptr ) callbackMap.repCallback( npId, item, arg1, arg2, ALL_OK );
380 }
381
382 //----------------------------------------------------------------------------------------------------
383 // "handleMsgReqNode" processes an incoming request for a node or port. The REQ message request will result
384 // in invoking the register firmware callback. We send a confirmation message.
385 //
386 //----------------------------------------------------------------------------------------------------
387 void handleMsgReqNode( uint8_t *msg ) {
388
389     uint16_t npId = (( msg[1] << 8 ) + msg[2] );
390
391     if ( nodeId( npId ) == nodeMap.nodeId ) {
392
393         uint8_t   item  = msg[3];
394         uint16_t  arg1  = ( msg[4] << 8 ) + msg[5];
395         uint16_t  arg2  = ( msg[6] << 8 ) + msg[7];
```

```
396            uint8_t   ret    = nodeReq( npId, item, &arg1, &arg2 );
397
398            if ( ret == ALL_OK )  sendAck( npId );
399            else                  sendErr( npId, ret, 0, 0 );
400        }
401 }
402
403 //-------------------------------------------------------------------------------------------------------
404 // "handleMsgEvent" deals with the event messages for inbound ports. For all matching events in the eventMap,
405 // the respective port map entry fields are set. The searchEvent function will return us the first matching
406 // entry in the sorted event map, if any. From there, we just hop along the eventMap until the eventId does
407 // not match any longer. All we do in this routine is to record the event data and the optional future time
408 // stamp when the event should result in a callback. The actual event processing is done in the port event
409 // processing routine, which will manage the timely invocation of the event callbacks.
410 //
411 // Note that we also are called from the event sending routine because another port on our node could be
412 // interested in this event. It is up to the firmware programmer to ensure that a port does send itself an
413 // event and may trigger an infinite loop.
414 //
415 //-------------------------------------------------------------------------------------------------------
416 void handleMsgEvent( uint8_t *msg ) {
417
418     uint16_t  eventId = ( msg[3] * 256 ) + msg[4];
419     int       index   = searchEvent( eventId );
420
421     if ( index >= 0 ) {
422
423         uint8_t   opCode           = msg[0];
424         uint16_t  nodeId           = ( msg[1] * 256 ) + msg[2];
425         uint16_t  eventData        = ( msg[5] * 256 ) + msg[6];
426         uint8_t   eventAction      = PEA_EVENT_IDLE;
427         uint32_t  ts               = CDC::getMillis( );
428
429         switch ( opCode ) {
430
431             case LCS_OP_EVT_ON:   eventAction = PEA_EVENT_ON;   break;
432             case LCS_OP_EVT_OFF:  eventAction = PEA_EVENT_OFF;  break;
433             case LCS_OP_EVT:      eventAction = PEA_EVENT_EVT;  break;
434         }
435
436         while (( index < nodeMap.eventMapHwm ) && ( eventMap.map[ index ].eventId == eventId )) {
437
438             LcsPortMapEntry *pPtr = &portMap.map[ index ];
439
440             if (( pPtr -> flags & PF_PORT_ENABLED                 ) &&
441                 ( pPtr -> flags & PF_PORT_EVENT_HANDLING_ENABLED  )) {
442
443                 pPtr -> eventNodeId    = nodeId;
444                 pPtr -> eventId        = eventId;
445                 pPtr -> eventAction    = eventAction;
446                 pPtr -> eventValue     = eventData;
447                 pPtr -> eventTimeStamp = ts + ( pPtr -> eventDelayTime * EVENT_DELAY_TICK_MILLIS );
448                 pPtr -> flags          |= PF_EVENT_PENDING;
449             }
450
451             index++;
452         }
453     }
454 }
455
456 //-------------------------------------------------------------------------------------------------------
457 // We received a DCC subsystem message. These messages are handler solely by firmware, which is typically
458 // the base station, a handheld, or a decoder alike device. All we do is to pass the message to the call
459 // back routine. One day, we could decode the message a bit more and invoke more specialized callback.
460 //
461 //-------------------------------------------------------------------------------------------------------
462 void handleMsgDccMgt( uint8_t *msg ) {
463
464     if ( callbackMap.dccMsgCallback != NULL ) callbackMap.dccMsgCallback( msg );
465 }
466
467 //-------------------------------------------------------------------------------------------------------
468 // Node state INIT. This is the first state after the initial library setup. The runtime init call created
469 // all memory areas and initialized the data structures. After a successful init call, the state is INIT and
470 // the firmware programmer can register the necessary callback functions and do other firmware specific work.
471 // Eventually, the runtime loop method is called. If the "init" option is set, the node init and port init
472 // callback routine will be invoked. If the nodeId validation option is set, the node will request a nodeId
473 // and enter the state SETUP. Otherwise the next state is OPERATE.
474 //
475 // ??? idea: a port init call cold return a status that says "this port is not used". This way we could
476 // set a better HWM.
477 //-------------------------------------------------------------------------------------------------------
478 void handleNodeStateInit( ) {
479
480     if ( ! ( nodeMap.nodeOptions & NOPT_SKIP_NODE_INIT_STEP )) {
481
482         if ( callbackMap.initCallback != nullptr ) {
483
484             if ( callbackMap.initCallback ) callbackMap.initCallback( nodeMap.nodeId << 4 );
485         }
486
487         for ( uint8_t i = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
488
489             if ( callbackMap.initCallback ) callbackMap.initCallback(( nodeMap.nodeId << 4 ) | i + 1 );
490
491             portMap.map[ i ].flags |= PF_PORT_ENABLED;
492             portMap.map[ i ].flags |= PF_PORT_EVENT_HANDLING_ENABLED;
493         }
494     }
```

```
495
496        if ( ! ( nodeMap.nodeOptions & NOPT_SKIP_NODE_ID_CONFIG )) {
497
498            sendReqNodeId( nodeMap.nodeId, nodeMap.nodeUID, 0 );
499            timerVal  = CDC::getMillis( );
500
501            nodeMap.nodeState = NS_REGISTER;
502
503        } else nodeMap.nodeState = NS_OPERATE;
504 }
505
506 //---------------------------------------------------------------------------------------------------------
507 // Node State FAIL. This is the state after the node startup failed.
508 //
509 // ??? would we ever come here ? if the INIT failed, the firmware programmer should do what ?
510 //---------------------------------------------------------------------------------------------------------
511 void handleNodeStateFail( ) {
512
513        handleSerialCommand( );
514
515 }
516
517 //---------------------------------------------------------------------------------------------------------
518 // Node State Power FAIL. This is the state after when the node starts up after a power fail. We have this
519 // state so that the firmware programmer can take some recovery action before the power goes away. x
520 //
521 //---------------------------------------------------------------------------------------------------------
522 void handleNodeStatePfail( ) {
523
524        if ( callbackMap.pfailCallback != nullptr ) {
525
526            callbackMap.pfailCallback( nodeMap.nodeId << 4 );
527        }
528
529        for ( uint8_t i = 0; i < MAX_PORT_MAP_ENTRIES; i++ ) {
530
531            callbackMap.pfailCallback(( nodeMap.nodeId << 4 ) | i + 1 );
532        }
533
534        handleSerialCommand( );
535 }
536
537 //---------------------------------------------------------------------------------------------------------
538 // Node State REGISTER. This is the state after the INIT state when a nodeId setup was requested. We are
539 // waiting for a nodeId reply message. If there is a timely reply message, we will handle the message reply
540 // and the node state will advance. If there is no timely reply, we will resubmit the request.
541 //
542 //---------------------------------------------------------------------------------------------------------
543 void handleNodeStateRegister( ) {
544
545        uint8_t msg[ MAX_LCS_MSG_SIZE ];
546
547        switch ( msgBus -> receiveLcsMsg( msg )) {
548
549            case LCS_OP_REP_NID: handleMsgRepNid( msg );  break;
550            case LCS_OP_RESET:   handleMsgLcsMgt( msg );  break;
551
552            default: {
553
554                if (( CDC::getMillis( ) - timerVal ) > NODE_SETUP_RETRY_TIMER_VAL_MS ) {
555
556                    sendReqNodeId( nodeMap.nodeId, nodeMap.nodeUID, 0 );
557                    timerVal = CDC::getMillis( );
558                }
559            }
560        }
561
562        handleSerialCommand( );
563 }
564
565 //---------------------------------------------------------------------------------------------------------
566 // Node State COLLISION. This is the state after the node receiver routine detected a nodeId collision. We
567 // will stay in this state and only react to RESET and SET_NID messages.
568 //
569 //---------------------------------------------------------------------------------------------------------
570 void handleNodeStateCollision( ) {
571
572        uint8_t msg[ MAX_LCS_MSG_SIZE ];
573
574        switch ( msgBus -> receiveLcsMsg( msg )) {
575
576            case LCS_OP_RESET:
577            case LCS_OP_SET_NID:  handleMsgLcsMgt( msg ); break;
578        }
579
580        handleSerialCommand( );
581 }
582
583 //---------------------------------------------------------------------------------------------------------
584 // Node State HALTED. The LCS communication bus was halted for all nodes. Note that the bus is still there,
585 // just not active. We just listen to the BON or RESET message to get going again.
586 //
587 //---------------------------------------------------------------------------------------------------------
588 void handleNodeStateHalted( ) {
589
590        uint8_t msg[ MAX_LCS_MSG_SIZE ];
591
592        switch ( msgBus -> receiveLcsMsg( msg )) {
593
```

```
594            case LCS_OP_BON:
595            case LCS_OP_RESET: handleMsgLcsMgt( msg ); break;
596        }
597 }
598
599 //----------------------------------------------------------------------------------------------------
600 // Node State CONFIG. A node can be placed into configuration state. We process any LCS message, handle the
601 // periodic tasks registered and port events that may have been received. Note that we just listen to messages
602 // valid for that mode and invoke the respective handler. All other messages are ignored.
603 //
604 //----------------------------------------------------------------------------------------------------
605 void handleNodeStateConfig( ) {
606
607     uint8_t msg[ MAX_LCS_MSG_SIZE ];
608
609     switch ( msgBus -> receiveLcsMsg( msg )) {
610
611         case LCS_OP_OPS:
612         case LCS_OP_RESET:
613         case LCS_OP_BON:
614         case LCS_OP_BOF:
615         case LCS_OP_ACK:
616         case LCS_OP_ERR:
617         case LCS_OP_SET_NID:
618         case LCS_OP_NCOL:           handleMsgLcsMgt( msg );            break;
619
620         case LCS_OP_NODE_GET:       handleMsgGetNode( msg );           break;
621         case LCS_OP_NODE_REP:       handleMsgRepNode( msg );           break;
622         case LCS_OP_NODE_REQ:       handleMsgReqNode( msg );           break;
623     }
624
625     handlePeriodicTasks( );
626     handleNodePortEvents( );
627     handleSerialCommand( );
628 }
629
630 //----------------------------------------------------------------------------------------------------
631 // Node State OPERATIONS. Most of the time the node state is in operations mode. We process any LCS message,
632 // handle the periodic tasks registered and port events that may have been received. Note that we just listen
633 // to messages valid for that mode and invoke the respective handler. All other messages are ignored.
634 //
635 //----------------------------------------------------------------------------------------------------
636 void handleNodeStateOperations( ) {
637
638     uint8_t msg [ MAX_LCS_MSG_SIZE ];
639
640     switch ( msgBus -> receiveLcsMsg( msg )) {
641
642         case LCS_OP_CFG:
643         case LCS_OP_RESET:
644         case LCS_OP_BON:
645         case LCS_OP_BOF:
646         case LCS_OP_ACK:
647         case LCS_OP_ERR:
648         case LCS_OP_REQ_NID:
649         case LCS_OP_NCOL:           handleMsgLcsMgt( msg );            break;
650
651         case LCS_OP_NODE_GET:       handleMsgGetNode( msg );           break;
652         case LCS_OP_NODE_PUT:       handleMsgPutNode( msg );           break;
653         case LCS_OP_NODE_REQ:       handleMsgReqNode( msg );           break;
654         case LCS_OP_NODE_REP:       handleMsgRepNode( msg );           break;
655
656         case LCS_OP_EVT_ON:
657         case LCS_OP_EVT_OFF:
658         case LCS_OP_EVT:            handleMsgEvent( msg );             break;
659
660         case LCS_OP_REQ_LOC:
661         case LCS_OP_REL_LOC:
662         case LCS_OP_REP_LOC:
663         case LCS_OP_SET_LCON:
664         case LCS_OP_KEEP_LOC:
665         case LCS_OP_SET_LSPD:
666         case LCS_OP_SET_LMOD:
667         case LCS_OP_LOC_FON:
668         case LCS_OP_LOC_FOF:
669
670         case LCS_OP_SET_CVM:
671         case LCS_OP_REQ_CVS:
672         case LCS_OP_REP_CVS:
673         case LCS_OP_SET_CVS:
674
675         case LCS_OP_TON:
676         case LCS_OP_TOF:
677         case LCS_OP_ESTP:
678
679         case LCS_OP_SEND_DCC3:
680         case LCS_OP_SEND_DCC4:
681         case LCS_OP_SEND_DCC5:
682         case LCS_OP_SEND_DCC6:
683
684         case LCS_OP_DCC_ACK:
685         case LCS_OP_DCC_ERR:        handleMsgDccMgt( msg );            break;
686     }
687
688     handlePeriodicTasks( );
689     handleNodePortEvents( );
690     handleSerialCommand( );
691 }
692
```

```
693   //-------------------------------------------------------------------------------------------------------
694   // "handleNodeState" is the main routine of the node activity processing. It is the method called after all
695   // setup is done. Running in a loop, the primary function is to handle the activities according to the node
696   // state. The run loop also processes the serial commands. Note that this function will not return.
697   //
698   //-------------------------------------------------------------------------------------------------------
699   void handleNodeState( ) {
700
701       while ( true ) {
702
703           switch ( nodeMap.nodeState ) {
704
705               case NS_INIT:       handleNodeStateInit( );        break;
706               case NS_FAIL:       handleNodeStateFail( );        break;
707               case NS_REGISTER:   handleNodeStateRegister( );    break;
708               case NS_COLLISION:  handleNodeStateCollision( );   break;
709               case NS_HALTED:     handleNodeStateHalted( );      break;
710               case NS_CONFIG:     handleNodeStateConfig( );      break;
711               case NS_OPERATE:    handleNodeStateOperations( );  break;
712               default: ;
713           }
714       }
715   }
716
717   }; // namespace
```

A.3   Base Station

```
 1  //------------------------------------------------------------------------------------------------------------
 2  //
 3  // LCS Base Station - Include file
 4  //
 5  //------------------------------------------------------------------------------------------------------------
 6  //
 7  // LCS - Base Station
 8  // Copyright (C) 2019 - 2024  Helmut Fieres
 9  //
10  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
11  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
12  // option) any later version.
13  //
14  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
15  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
16  // for more details.
17  //
18  // You should have received a copy of the GNU General Public License along with this program. If not, see
19  // http://www.gnu.org/licenses
20  //
21  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
22  //
23  //------------------------------------------------------------------------------------------------------------
24  #ifndef LcsBaseStation_h
25  #define LcsBaseStation_h
26
27  #include "LcsCdcLib.h"
28  #include "LcsRuntimeLib.h"
29
30  //------------------------------------------------------------------------------------------------------------
31  // The base station maintains a set of debug flags. The overall concept is very similar to the LCS runtime
32  // library debug mask. Then following debug flags are defined:
33  //
34  //      DBG_BS_CONFIG                     -   DEBUG base station enabled
35  //      DBG_BS_SESSION                    -   show the session management actions
36  //      DBG_BS_LCS_MSG_INTERFACE          -   show the incoming LCS messages
37  //      DBG_BS_TRACK_POWER_MGMT           -   show the track power measurement data
38  //      DBG_BS_DCC_ACK_DETECT             -   display decoder ACK power measurements
39  //      DBG_BS_CHECK_ALIVE_SESSIONS       -   displays that a session seems no longer be alive
40  //      DBG_BS_RAILCOM                    -   show the RailCom activity
41  //
42  // The way to use these flags is for example:
43  //
44  //      if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_SESSION ))
45  //
46  // ??? should have a command to set the debug mask on the fly...
47  //------------------------------------------------------------------------------------------------------------
48  enum BaseStationDebugFlags : uint16_t {
49
50      DBG_BS_CONFIG                    = 1 << 15,       // DEBUG base station enabled
51
52      DBG_BS_SESSION                   = 1 << 0,        // show the session management actions
53      DBG_BS_LCS_MSG_INTERFACE         = 1 << 1,        // show the incoming LCS messages
54      DBG_BS_TRACK_POWER_MGMT          = 1 << 2,        // show the track power measurement data
55      DBG_BS_DCC_ACK_DETECT            = 1 << 3,        // display decoder ACK power measurements
56      DBG_BS_CHECK_ALIVE_SESSIONS      = 1 << 4,        // displays that a session seems no longer be alive
57      DBG_BS_RAILCOM                   = 1 << 5         // show the RailCom activity
58
59  };
60
61  //------------------------------------------------------------------------------------------------------------
62  // Base station errors. Note that they need to be in the assigned to the user number range of errors defined
63  // in the LCS runtime library.
64  //
65  //------------------------------------------------------------------------------------------------------------
66  enum BaseStationErrors : uint8_t {
67
68      BASE_STATION_ERR_BASE            = 128,
69
70      ERR_NO_SVC_MODE                  = BASE_STATION_ERR_BASE + 1,
71      ERR_CV_OP_FAILED                 = BASE_STATION_ERR_BASE + 2,
72
73      ERR_LOCO_NOT_FOUND               = BASE_STATION_ERR_BASE + 4,
74      ERR_SESSION_NOT_FOUND            = BASE_STATION_ERR_BASE + 5,
75      ERR_LOCO_SESSION_ALLOCATE        = BASE_STATION_ERR_BASE + 6,
76      ERR_LOCO_SESSION_CANCELLED       = BASE_STATION_ERR_BASE + 7,
77
78      ERR_SESSION_SETUP                = BASE_STATION_ERR_BASE + 9,
79      ERR_MSG_INTERFACE_SETUP          = BASE_STATION_ERR_BASE + 10,
80      ERR_DCC_TRACK_CONFIG             = BASE_STATION_ERR_BASE + 11,
81      ERR_DCC_PIN_CONFIG               = BASE_STATION_ERR_BASE + 12,
82
83      ERR_NVM_HW_SETUP                 = BASE_STATION_ERR_BASE + 15,
84      ERR_PIO_HW_SETUP                 = BASE_STATION_ERR_BASE + 16
85  };
86
87  //------------------------------------------------------------------------------------------------------------
88  // DCC packet definition. A DCC packet is the payload data without the checksum. Besides the length in bytes
89  // and the buffer, there is a repeat counter to specify how often this packet will be repeatedly transmitted
90  // after the first transmission. Currently, a DCC packet is at most 15 bytes long, excluding the checksum
91  // byte. This is true for XPOM and DCC-A support, otherwise it is historically a maximum of 6 bytes.
92  //
93  //------------------------------------------------------------------------------------------------------------
94  const uint8_t DCC_PACKET_SIZE = 16;
95
96  struct DccPacket {
97
98      uint8_t len;
```

```
 99        uint8_t repeat;
100        uint8_t buf[ DCC_PACKET_SIZE ];
101    };
102
103    //-------------------------------------------------------------------------------------------------------------
104    // DCC packet payload data definitions we need often, so these constants come in handy.
105    //
106    //-------------------------------------------------------------------------------------------------------------
107    const uint8_t   idleDccPacketData[ ]    = { 0xFF, 0x00 };
108    const uint8_t   resetDccPacketData[ ]   = { 0x00, 0x00 };
109    const uint8_t   eStopDccPacketData[ ]   = { 0x00, 0x01 };
110
111    //-------------------------------------------------------------------------------------------------------------
112    // Setup options to set for the DCC track. They are set when the track object is created.
113    //
114    //   DT_OPT_SERVICE_MODE_TRACK  - The track is a PROG track.
115    //   DT_OPT_CUTOUT              - The track is configured to emit a cutout during the DCC packet preamble.
116    //   DT_OPT_RAILCOM             - The track support Railcom detection.
117    //
118    //-------------------------------------------------------------------------------------------------------------
119    enum DccTrackOptions : uint16_t {
120
121        DT_OPT_DEFAULT_SETTING     = 0,
122        DT_OPT_SERVICE_MODE_TRACK  = 1 << 0,
123        DT_OPT_CUTOUT              = 1 << 1,
124        DT_OPT_RAILCOM             = 1 << 2
125    };
126
127    //-------------------------------------------------------------------------------------------------------------
128    // The DCC track object has a set of flags to indicate its current status.
129    //
130    //   DT_F_POWER_ON             - The track is under power.
131    //   DT_F_POWER_OVERLOAD       - An overload situation was detected.
132    //   DT_F_MEASUREMENT_ON       - The power measurement is enabled.
133    //   DT_F_SERVICE_MODE_ON      - The track is currently in service mode, i.e. is a PROG track.
134    //   DT_F_CUTOUT_MODE_ON       - The track has the cutout generation enabled.
135    //   DT_F_RAILCOM_MODE_ON      - The track has the railcom detect enabled.
136    //   DT_F_RAILCOM_MSG_PENDING  - If railcom is enabled, a received datagram is indicated.
137    //   DT_F_CONFIG_ERROR         - The passed configuration descriptor has invalid options configured.
138    //
139    //-------------------------------------------------------------------------------------------------------------
140    enum DccTrackFlags : uint16_t {
141
142        DT_F_DEFAULT_SETTING     = 0,
143        DT_F_POWER_ON            = 1 << 0,
144        DT_F_POWER_OVERLOAD      = 1 << 1,
145        DT_F_MEASUREMENT_ON      = 1 << 2,
146        DT_F_SERVICE_MODE_ON     = 1 << 3,
147        DT_F_CUTOUT_MODE_ON      = 1 << 4,
148        DT_F_RAILCOM_MODE_ON     = 1 << 5,
149        DT_F_DCC_PACKET_PENDING  = 1 << 6,
150        DT_F_RAILCOM_MSG_PENDING = 1 << 7,
151        DT_F_CONFIG_ERROR        = 1 << 15
152    };
153
154    //-------------------------------------------------------------------------------------------------------------
155    // The following constants are for the current consumption RMS measurement. The idea is to record the measured
156    // ADC values in a circular buffer, every time a certain amount of milliseconds has passed. This work is done
157    // by the DCC track state machine as part of the power on state.
158    //
159    //-------------------------------------------------------------------------------------------------------------
160    const uint8_t   PWR_SAMPLE_BUF_SIZE             = 64;
161    const uint32_t  PWR_SAMPLE_TIME_INTERVAL_MILLIS = 16;
162
163    //-------------------------------------------------------------------------------------------------------------
164    // The RailCom buffer size. During the cutout period up to eight bytes of raw data are sent by the decoder if
165    // the Railcom option is enabled.
166    //
167    //-------------------------------------------------------------------------------------------------------------
168    const uint8_t   RAILCOM_BUF_SIZE = 8;
169
170    //-------------------------------------------------------------------------------------------------------------
171    // The session map options. These are options initially set when the base station starts. They are used to
172    // set the flags, which are then used for processing the the actual settings.
173    //
174    //   SM_KEEP_ALIVE_CHECKING  - enable keep alive checking. When enabled, the locomotive session need to receive
175    //                             a keep alive LCS message periodically.
176    //   SM_ENABLE_REFRESH       - refresh the session data. This will send the locomotive speed and direction as
177    //                             well as the function flags periodically in a round robin processing of the
178    //
179    //-------------------------------------------------------------------------------------------------------------
180    enum SessionMapOptions : uint16_t {
181
182        SM_OPT_DEFAULT_SETTING      = 0,
183        SM_OPT_KEEP_ALIVE_CHECKING  = 1 << 0,
184        SM_OPT_ENABLE_REFRESH       = 1 << 1
185    };
186
187    //-------------------------------------------------------------------------------------------------------------
188    // The session map flags. The apply to all sessions in the session map. The initial values are copied from
189    // session option initial values.
190    //
191    //   SM_F_KEEP_ALIVE_CHECKING  - enable keep alive checking. When enabled, the locomotive session need to receive
192    //                               a keep alive LCS message periodically.
193    //   SM_F_ENABLE_REFRESH       - refresh the session data. This will send the locomotive speed and direction as
194    //                               well as the function flags periodically in a round robin processing of the
195    //
196    //-------------------------------------------------------------------------------------------------------------
197    enum SessionMapFlags : uint16_t {
```

```
198
199        SM_F_DEFAULT_SETTING        = 0,
200        SM_F_KEEP_ALIVE_CHECKING    = 1 << 0,
201        SM_F_ENABLE_REFRESH         = 1 << 1
202   };
203
204   //-------------------------------------------------------------------------------------------------------------
205   // Each session map entry has a set of flags.
206   //
207   //   SME_ALLOCATED            - the session is allocated, the entry valid.
208   //   SME_COMBINED_REFRESH     - locomotive speed/dir and functions are refreshed using the combined DCC packet.
209   //   SME_SPDIR_REFRESH        - locomotive speed/dir are refreshed.
210   //   SME_FUNC_REFRESH         - locomotive functions are refreshed.
211   //   SME_DISPATCHED           -
212   //   SME_SHARED               -
213   //
214   //
215   // ??? when the base station has a config value of using the DCC spdir/func command, these flags need to be
216   // named slightly different. Should we still have the option to enable or disable it even though the base
217   // station can do it ? A decoder might not support this packet type...
218   //-------------------------------------------------------------------------------------------------------------
219   enum SessionMapEntryFlags : uint16_t {
220
221        SME_DEFAULT_SETTING     = 0,
222        SME_ALLOCATED           = 1 << 0,
223        SME_COMBINED_REFRESH    = 1 << 1,
224        SME_SPDIR_ONLY_REFRESH  = 1 << 2, // ??? phase out...
225        SME_SPDIR_REFRESH       = 1 << 2,
226        SME_FUNC_REFRESH        = 1 << 3,
227        SME_DISPATCHED          = 1 << 4,
228        SME_SHARED              = 1 << 5
229   };
230
231   //-------------------------------------------------------------------------------------------------------------
232   // The base station items for nodeInfo and nodeControl calls .... tbd
233   //
234   // ??? the are mapped in the MEM / NVM range as well as in the USER range.
235   // ??? how to do it consistently and understandably ?
236   //-------------------------------------------------------------------------------------------------------------
237   enum BaseStationItems : uint8_t {
238
239        // or use GET in all constants
240
241        BS_ITEM_SESSION_MAP_OPTIONS   = 128,
242        BS_ITEM_SESSION_MAP_FLAGS     = 129,
243        BS_ITEM_MAX_SESSIONS          = 130,
244        BS_ITEM_ACTIVE_SESSIONS       = 131,
245
246        BS_ITEM_INIT_CURRENT_VAL      = 140,
247        BS_ITEM_LIMIT_CURRENT_VAL     = 140,
248        BS_ITEM_MAX_CURRENT_VAL       = 140,
249        BS_ITEM_ACTUAL_CURRENT_VAL    = 140,
250
251        // thresholds
252
253        // eventID to send for events ?
254
255   };
256
257   //-------------------------------------------------------------------------------------------------------------
258   //
259   //
260   //-------------------------------------------------------------------------------------------------------------
261   const uint32_t  MAIN_TRACK_STATE_TIME_INTERVAL  = 10;
262   const uint32_t  PROG_TRACK_STATE_TIME_INTERVAL  = 10;
263   const uint32_t  SESSION_REFRESH_TASK_INTERVAL   = 50;
264
265   const uint16_t  MAX_CAB_SESSIONS                = 64;
266
267   //-------------------------------------------------------------------------------------------------------------
268   // For creating the Loco Session object the session map object is described by the following descriptor.
269   //
270   //-------------------------------------------------------------------------------------------------------------
271   struct LcsBaseStationSessionMapDesc {
272
273        uint16_t    options      = SM_OPT_DEFAULT_SETTING;
274        uint16_t    maxSessions  = MAX_CAB_SESSIONS;
275   };
276
277   //-------------------------------------------------------------------------------------------------------------
278   // For creating the DCC track object, the track is described by the data structure below. In addition to the
279   // hardware pins enablePin, dcc1Pin1, dccPin2 and sensePin, there are the limits for current consumption
280   // values, all specified in milliAmps. The initial current sets the current consumption limit after the track
281   // is turned on. The limit current consumption specifies the actual configured value that is checked for a
282   // track current overload situation. The maximum current defines what current the power module should never
283   // exceed. For the measurements to work, the power module needs to deliver a voltage that corresponds to the
284   // current drawn on the track. The value is measured in milliVolt per Ampere drawn. Finally, there are
285   // threshold times for managing the track overload and restart capability.
286   //
287   //-------------------------------------------------------------------------------------------------------------
288   struct LcsBaseStationTrackDesc {
289
290        uint16_t  options                         = SM_OPT_DEFAULT_SETTING;
291
292        uint8_t   enablePin                       = CDC::UNDEFINED_PIN;
293        uint8_t   dccSigPin1                      = CDC::UNDEFINED_PIN;
294        uint8_t   dccSigPin2                      = CDC::UNDEFINED_PIN;
295        uint8_t   sensePin                        = CDC::UNDEFINED_PIN;
296        uint8_t   uartRxPin                       = CDC::UNDEFINED_PIN;
```

```
297
298        uint16_t  initCurrentMilliAmp           = 0;
299        uint16_t  limitCurrentMilliAmp          = 0;
300        uint16_t  maxCurrentMilliAmp            = 0;
301        uint16_t  milliVoltPerAmp               = 0;
302
303        uint16_t  startTimeThresholdMillis      = 0;
304        uint16_t  stopTimeThresholdMillis       = 0;
305        uint16_t  overloadTimeThresholdMillis   = 0;
306        uint16_t  overloadEventThreshold        = 0;
307        uint16_t  overloadRestartThreshold      = 0;
308 };
309
310 //----------------------------------------------------------------------------------------------------
311 // DCC track definition. The DCC track object is responsible for managing the track power as well as building
312 // and sending the DCC packet bit stream. A packet consists of the preamble bits, the postamble bit, the data
313 // bytes separated with a ZERO bit and a checksum byte. Creating the DCC bit stream is done with the signal
314 // generation routines. The signal state machine, running on a 29 microsecond tick, takes a DCC packet and
315 // gets it out to the track. The DCC signal state machine also invokes follow up actions that measure the
316 // actual power consumption, read in a railcom message and so on. There is also a DCC log facility which
317 // records internal events for testing and debugging.
318 //
319 // The other state machine will manage the actual track power. This machine is responsible for the periodic
320 // checking of power consumption and resulting power control. In contrast to the DCC signal state machine,
321 // this machine is not driven by a periodic interrupt but invoked periodically via the LCS runtime task
322 // manager.
323 //
324 // For a base station, there will be two track objects. One is the MAIN track and the other one is the PROG
325 // track. Each track has a DCC track object associated with it. In addition to the two track objects, there
326 // are class level static routines to manage the timer hardware functions, the analog signal read for current
327 // measurement and the serial IO for the optional RailCom message processing. The current version is AtMega
328 // specific.
329 //
330 //----------------------------------------------------------------------------------------------------
331 struct LcsBaseStationDccTrack {
332
333        public:
334
335        LcsBaseStationDccTrack( );
336
337        uint8_t                 setupDccTrack( LcsBaseStationTrackDesc* trackDesc );
338        void                    loadPacket( const uint8_t *packet, uint8_t len, uint8_t repeat = 0 );
339
340        uint16_t                getFlags( );
341        uint16_t                getOptions( );
342
343        bool                    isServiceModeOn( );
344        void                    serviceModeOn( );
345        void                    serviceModeOff( );
346
347        void                    runDccTrackStateMachine( );
348        void                    powerStart( );
349        void                    powerStop( );
350        bool                    isPowerOn( );
351        bool                    isPowerOverload( );
352
353        void                    cutoutOn( );
354        void                    cutoutOff( );
355        bool                    isCutoutOn( );
356
357        void                    railComOn( );
358        void                    railComOff( );
359        bool                    isRailComOn( );
360
361        void                    setLimitCurrent( uint16_t val );
362        uint16_t                getLimitCurrent( );
363        uint16_t                getActualCurrent( );
364        uint16_t                getInitCurrent( );
365        uint16_t                getMaxCurrent( );
366        uint16_t                getRMSCurrent( );
367
368        uint16_t                decoderAckBaseline( uint8_t resetPacketsToSend );
369        bool                    decoderAckDetect( uint16_t baseValue, uint8_t retries );
370        void                    checkOverload( );
371
372        void                    runDccSignalStateMachine( volatile uint8_t *timeToInterrupt, uint8_t *followUpAction );
373
374        void                    getNextBit( );
375        void                    getNextPacket( );
376        void                    powerMeasurement( );
377
378        void                    startRailComIO( );
379        void                    stopRailComIO( );
380        uint8_t                 handleRailComMsg( );
381        uint8_t                 getRailComMsg( uint8_t *buf, uint8_t bufLen );
382
383        uint32_t                getDccPacketsSend( );
384        uint32_t                getPwrSamplesTaken( );
385        uint16_t                getPwrSamplesPerSec( );
386
387        void                    printDccTrackConfig( );
388        void                    printDccTrackStatus( );
389
390        void                    enableLog( bool arg );
391        void                    beginLog( );
392        void                    endLog( );
393        void                    printLog( );
394
395        void                    writeLogData( uint8_t id, uint8_t *buf, uint8_t len );
```

```
396        void                      writeLogId( uint8_t id );
397        void                      writeLogTs( );
398        void                      writeLogVal( uint8_t valId, uint16_t val );
399
400        private:
401
402        uint16_t                  options                      = DT_OPT_DEFAULT_SETTING;
403        volatile uint16_t         flags                        = DT_F_DEFAULT_SETTING;
404
405        volatile uint8_t          trackState                   = 0;
406        volatile uint8_t          signalState                  = 0;
407
408        volatile uint32_t         trackTimeStamp               = 0;
409        volatile uint8_t          overloadEventCount           = 0;
410        volatile uint8_t          overloadRestartCount         = 0;
411
412        uint8_t                   enablePin                    = CDC::UNDEFINED_PIN;
413        uint8_t                   dccSigPin1                   = CDC::UNDEFINED_PIN;
414        uint8_t                   dccSigPin2                   = CDC::UNDEFINED_PIN;
415        uint8_t                   sensePin                     = CDC::UNDEFINED_PIN;
416        uint8_t                   uartRxPin                    = CDC::UNDEFINED_PIN;
417
418        uint16_t                  initCurrentMilliAmp          = 0;
419        uint16_t                  limitCurrentMilliAmp         = 0;
420        uint16_t                  maxCurrentMilliAmp           = 0;
421
422        uint16_t                  startTimeThreshold           = 0;
423        uint16_t                  stopTimeThreshold            = 0;
424        uint16_t                  overloadTimeThreshold        = 0;
425        uint16_t                  overloadEventThreshold       = 0;
426        uint16_t                  overloadRestartThreshold     = 0;
427
428        uint16_t                  milliVoltPerAmp              = 0;
429        uint16_t                  digitsPerAmp                 = 0;
430        volatile uint16_t         actualCurrentDigitValue      = 0;
431        volatile uint16_t         highWaterMarkDigitValue      = 0;
432        volatile uint16_t         limitCurrentDigitValue       = 0;
433        uint16_t                  ackThresholdDigitValue       = 0;
434
435        uint32_t                  totalPwrSamplesTaken         = 0;
436        uint32_t                  lastPwrSampleTimeStamp       = 0;
437
438        uint32_t                  lastPwrSamplePerSecTaken     = 0;
439        uint32_t                  lastPwrSamplePerSecTimeStamp = 0;
440        uint32_t                  pwrSamplesPerSec             = 0;
441
442        uint8_t                   preambleLen                  = 0;
443        uint8_t                   postambleLen                 = 0;
444        volatile bool             currentBit                   = false;
445        volatile uint8_t          bytesSent                    = 0;
446        volatile uint8_t          bitsSent                     = 0;
447        volatile uint8_t          preambleSent                 = 0;
448        volatile uint8_t          postambleSent                = 0;
449        uint32_t                  dccPacketsSend               = 0;
450
451        DccPacket                 dccBuf1;
452        DccPacket                 dccBuf2;
453        DccPacket                 *activeBufPtr   = nullptr;
454        DccPacket                 *pendingBufPtr  = nullptr;
455
456        // ??? to add....
457        // base station capabilities according to RCN200 - 4 16 bit words
458        // sample values per second for samples and dcc packets
459        // buffers for POM / XPOM data
460        // queue for POM / XPOM commands
461
462        uint8_t                   railComBufIndex              = 0;
463        uint8_t                   railComMsgBuf[ RAILCOM_BUF_SIZE ] = { 0 };
464
465        uint8_t                   pwrSampleBufIndex            = 0;
466        uint16_t                  pwrSampleBuf[ PWR_SAMPLE_BUF_SIZE ]      = { 0 };
467
468        public:
469
470        static void               startDccProcessing( );
471
472   };
473
474   //-------------------------------------------------------------------------------------------------------------
475   // Every allocated loco session is described by the sessionMap structure. There are the engine cab Id, speed,
476   // direction and function information. There is also a field that indicates when we received information for
477   // this session from a cab control handheld. The function flags are stored in an array, each byte representing
478   // a group. Most of the fields are actually used for a DCC type locomotive. When the locomotive is an analog
479   // engine, only a subset of the fields is actually used. Nevertheless, even for an analog engine we will
480   // have a session. The base station will however not generate packets for this engine.
481   //
482   //-------------------------------------------------------------------------------------------------------------
483   struct SessionMapEntry {
484
485     uint16_t        flags                = SME_DEFAULT_SETTING;
486     uint16_t        cabId                = LCS::NIL_CAB_ID;
487     uint8_t         speed                = 0;
488     uint8_t         speedSteps           = 128;
489     uint8_t         direction            = 0;
490     uint8_t         engineState          = 0;
491     uint8_t         nextRefreshStep      = 0;
492     unsigned long   lastKeepAliveTime    = 0;
493     uint8_t         functions[ LCS::MAX_DCC_FUNC_GROUP_ID ] = { 0 };
494
```

```
495  };
496
497  //--------------------------------------------------------------------------------------------------------------
498  // The loco session object is the central data structure for the base station locomotive management. For a
499  // DCC type engine it manages the loco sessions and assembles the DCC packets and drives the DCC track objects
500  // to send out the relevant DCC packages. For an analog engine it will just manage the session entry and
501  // communicate via the LCS bus with the block controller that actually owns the engine at the moment.
502  //
503  //--------------------------------------------------------------------------------------------------------------
504  struct LcsBaseStationLocoSession {
505
506    public:
507
508      LcsBaseStationLocoSession( );
509
510      uint8_t setupSessionMap(
511
512          LcsBaseStationSessionMapDesc  *sessionMapDesc,
513          LcsBaseStationDccTrack        *mainTrack,
514          LcsBaseStationDccTrack        *progTrack
515      );
516
517      uint8_t                 requestSession( uint16_t cabId, uint8_t mode, uint8_t *sId );
518      uint8_t                 releaseSession( uint8_t sId );
519      uint8_t                 updateSession( uint8_t sId, uint8_t flags );
520
521      uint8_t                 markSessionAlive( uint8_t sId );
522      void                    refreshActiveSessions( );
523      uint32_t                getSessionKeepAliveInterval( );
524
525      uint16_t                getOptions( );
526      uint16_t                getFlags( );
527      uint8_t                 getSessionMapHwm( );
528      uint8_t                 getActiveSessions( );
529      uint8_t                 getSessionIdByCabId( uint16_t cabId );
530      void                    emergencyStopAll( );
531
532      uint8_t                 setThrottle( uint8_t sId, uint8_t speed, uint8_t direction );
533      uint8_t                 setDccFunctionBit( uint8_t sId, uint8_t funcNum, uint8_t val );
534      uint8_t                 setDccFunctionGroup( uint8_t sId, uint8_t fGroup, uint8_t dccByte );
535
536      uint8_t                 writeCVMain( uint8_t sId, uint16_t cvId, uint8_t mode, uint8_t val );
537      uint8_t                 writeCVByteMain( uint8_t sId, uint16_t cvId, uint8_t val );
538      uint8_t                 writeCVBitMain( uint8_t sId, uint16_t cvId, uint8_t bitPos, uint8_t val );
539
540      uint8_t                 readCV( uint16_t cvId, uint8_t mode, uint8_t *val );
541      uint8_t                 readCVByte( uint16_t cvId, uint8_t *val );
542      uint8_t                 readCVBit( uint16_t cvId, uint8_t bitPos, uint8_t *val );
543
544      uint8_t                 writeCV( uint16_t cvId, uint8_t mode, uint8_t val );
545      uint8_t                 writeCVByte( uint16_t cvId, uint8_t val );
546      uint8_t                 writeCVBit( uint16_t cvId, uint8_t bitPos, uint8_t val );
547
548      uint8_t                 writeDccPacketMain( uint8_t *buf,  uint8_t len, uint8_t nRepeat );
549      uint8_t                 writeDccPacketProg( uint8_t *buf,  uint8_t len, uint8_t nRepeat );
550
551      void                    printSessionMapConfig( );
552      void                    printSessionMapInfo( );
553
554      SessionMapEntry         *lookupSessionEntry( uint16_t cabId );
555      SessionMapEntry         *getSessionMapEntryPtr( uint8_t sId );
556
557      private:
558
559      uint8_t                 setThrottle( SessionMapEntry *csptr, uint8_t speed, uint8_t direction );
560      uint8_t                 setDccFunctionGroup( SessionMapEntry *csPtr, uint8_t fGroup, uint8_t dccByte );
561
562      SessionMapEntry         *allocateSessionEntry( uint16_t cabId );
563      void                    deallocateSessionEntry( SessionMapEntry *csPtr );
564      void                    refreshSessionEntry( SessionMapEntry *csPtr );
565      void                    initSessionEntry( SessionMapEntry *csPtr );
566      void                    printSessionEntry( SessionMapEntry *csPtr );
567
568      private:
569
570      LcsBaseStationDccTrack   *mainTrack              = nullptr;
571      LcsBaseStationDccTrack   *progTrack              = nullptr;
572
573      uint16_t                 options                = DT_OPT_DEFAULT_SETTING;
574      uint16_t                 flags                  = DT_F_DEFAULT_SETTING;
575      uint32_t                 lastAliveCheckTime     = 0L;
576      uint32_t                 refreshAliveTimeOutVal = 2000L;  // ??? a constant name ...
577
578      SessionMapEntry          *sessionMap            = nullptr;
579      SessionMapEntry          *sessionMapNextRefresh = nullptr;
580      SessionMapEntry          *sessionMapHwm         = nullptr;
581      SessionMapEntry          *sessionMapLimit       = nullptr;
582
583  };
584
585  //--------------------------------------------------------------------------------------------------------------
586  // One of the key duties of the base station is to listen and react to DCC commands coming via the LCS bus.
587  // The interface works very closely with the session management and the two DCC track objects.
588  //
589  // ??? how about we make the handleLcsMsg handler a routine vs. an object ?
590  // ??? would make the any REQ/REP scheme easier ?
591  //--------------------------------------------------------------------------------------------------------------
592  struct LcsBaseStationMsgInterface {
593
```

109

```
594        public:
595
596        LcsBaseStationMsgInterface( );
597
598        uint8_t setupLcsMsgInterface( LcsBaseStationLocoSession   *locoSessions,
599                                      LcsBaseStationDccTrack       *mainTrack,
600                                      LcsBaseStationDccTrack       *progTrack
601                                    );
602
603        void handleLcsMsg( uint8_t *msg );
604
605        private:
606
607        LcsBaseStationLocoSession   *locoSessions   = nullptr;
608        LcsBaseStationDccTrack      *mainTrack      = nullptr;
609        LcsBaseStationDccTrack      *progTrack      = nullptr;
610
611 };
612
613 //----------------------------------------------------------------------------------------------------
614 // The base station implements a serial IO command interface. The command interface uses the DCC++ syntax of
615 // a command line and where it is a original DCC++ command it implements them in a compatible way. The idea
616 // is to one day connect to the programs of the JMRI world, which support the DCC++ style command interface.
617 //
618 //----------------------------------------------------------------------------------------------------
619 struct LcsBaseStationCommand {
620
621        public:
622
623        LcsBaseStationCommand( );
624
625        uint8_t setupSerialCommand( LcsBaseStationLocoSession   *locoSessions,
626                                    LcsBaseStationDccTrack       *mainTrack,
627                                    LcsBaseStationDccTrack       *progTrack );
628
629        void handleSerialCommand( char *s );
630
631        private:
632
633        void openSessionCmd( char *s );
634        void closeSessionCmd( char *s );
635
636        void setThrottleCmd( char *s );
637        void setFunctionBitCmd( char *s );
638        void setFunctionGroupCmd( char *s );
639        void emergencyStopCmd( );
640
641        void readCVCmd( char *s );
642        void writeCVByteCmd( char *s );
643        void writeCVBitCmd( char *s );
644        void writeCVByteMainCmd( char *s );
645        void writeCVBitMainCmd( char *s );
646
647        void writeDccPacketMainCmd( char *s );
648        void writeDccPacketProgCmd( char *s );
649
650        void setTrackOptionCmd( char *s );
651        void turnPowerOnAllCmd( );
652        void turnPowerOnMainCmd( );
653        void turnPowerOnProgCmd( );
654        void turnPowerOffAllCmd( );
655
656        void printStatusCmd( char *s );
657        void printTrackCurrentCmd( char *s );
658        void printBaseStationConfigCmd( );
659        void printHelpCmd( );
660        void printVersionInfo( );
661        void printConfiguration( );
662        void printSessionMap( );
663        void printTrackStatusMain( );
664        void printTrackStatusProg( );
665
666        void printDccLogCommand( char *s );
667
668        private:
669
670        LcsBaseStationLocoSession *locoSessions = nullptr;
671        LcsBaseStationDccTrack    *mainTrack    = nullptr;
672        LcsBaseStationDccTrack    *progTrack    = nullptr;
673 };
674
675 #endif
```

APPENDIX A. LISTINGS TEST

```
1   //-------------------------------------------------------------------------------------------------------------------
2   //
3   // LCS Base Station - Serial Command Interface - implementation file
4   //
5   //-------------------------------------------------------------------------------------------------------------------
6   // The serial command interface is used to directly send commands to the session and DCC track objects. The
7   // command syntax is patterned after the DCC++ command syntax. Available commands that have a DCC++ counter
8   // part are implemented exactly after the DCC++ command specification. The main motivation is to use this
9   // interface for testing and debugging as well as third party tools that also implement the DCC++ command set
10  // to send commands to this base station as well when calling the serial IO interface. For the layout control
11  // system, the approach would rather be to send LCS messages for all tasks.
12  //
13  //-------------------------------------------------------------------------------------------------------------------
14  //
15  // LCS - Base Station
16  // Copyright (C) 2019 - 2024  Helmut Fieres
17  //
18  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
19  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
20  // option) any later version.
21  //
22  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
23  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
24  // for more details.
25  //
26  // You should have received a copy of the GNU General Public License along with this program. If not, see
27  // http://www.gnu.org/licenses
28  //
29  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
30  //
31  //-------------------------------------------------------------------------------------------------------------------
32  #include "LcsBaseStation.h"
33
34  using namespace LCS;
35
36  //-------------------------------------------------------------------------------------------------------------------
37  // External global variables.
38  //
39  //-------------------------------------------------------------------------------------------------------------------
40  extern uint16_t debugMask;
41
42  //-------------------------------------------------------------------------------------------------------------------
43  // The object constructor. Nothing to do here.
44  //
45  //-------------------------------------------------------------------------------------------------------------------
46  LcsBaseStationCommand::LcsBaseStationCommand( ) { }
47
48  //-------------------------------------------------------------------------------------------------------------------
49  // The object setup command. We need to remember the other objects we use in handling the commands. For the
50  // serial IO itself nothing to do, it was already done in the LCS runtime setup.
51  //
52  //-------------------------------------------------------------------------------------------------------------------
53  uint8_t LcsBaseStationCommand::setupSerialCommand(
54
55      LcsBaseStationLocoSession *locoSessions,
56      LcsBaseStationDccTrack    *mainTrack,
57      LcsBaseStationDccTrack    *progTrack ) {
58
59      this -> locoSessions  = locoSessions;
60      this -> mainTrack     = mainTrack;
61      this -> progTrack     = progTrack;
62
63      return ( ALL_OK );
64  }
65
66  //-------------------------------------------------------------------------------------------------------------------
67  // "handleSerialCommand" analyzes the command line and invokes the respective command handler. The first
68  // character in a command is the command letter. The command is followed by the arguments. For compatibility
69  // with the DCC++ original command set, each command that is also a DCC++ command is implemented exactly as
70  // the original. This allows external tools, such as the JMRI Decoder Pro configuration tool to be used. The
71  // command handler supports command sequences "<" ... ">" in one line which are processed once the carriage
72  // return is hit.
73  //
74  //-------------------------------------------------------------------------------------------------------------------
75  void LcsBaseStationCommand::handleSerialCommand( char *s ) {
76
77      int     charIndex      = 0;
78      char    cmdStr[ 256 ]  = { 0 };
79
80      while ( s[ charIndex ] != '\0' ) {
81
82          switch ( s[ charIndex ] ) {
83
84              case '<': {
85
86                  cmdStr[ 0 ] = '\0';
87                  charIndex ++;
88
89              } break;
90
91              case '>': {
92
93                  switch ( cmdStr[ 0 ] ) {
94
95                      case 'O': openSessionCmd( cmdStr + 1 ); break;
96                      case 'K': closeSessionCmd( cmdStr + 1 ); break;
97
98                      case 't': setThrottleCmd( cmdStr + 1 );  break;
```

```
 99                     case 'f': setFunctionGroupCmd( cmdStr + 1 ); break;
100                     case 'v': setFunctionBitCmd( cmdStr + 1 ); break;
101
102                     case 'R': readCVCmd( cmdStr + 1 ); break;
103                     case 'W': writeCVByteCmd( cmdStr + 1 ); break;
104                     case 'B': writeCVBitCmd( cmdStr + 1 ); break;
105                     case 'w': writeCVByteMainCmd( cmdStr + 1 ); break;
106                     case 'b': writeCVBitMainCmd( cmdStr + 1 ); break;
107
108                     case 'M': writeDccPacketMainCmd( cmdStr + 1 ); break;
109                     case 'P': writeDccPacketProgCmd( cmdStr + 1 ); break;
110
111                     case 'C': setTrackOptionCmd( cmdStr + 1 ); break;
112                     case 'Y': printDccLogCommand( cmdStr + 1 ); break;
113
114                     case 'X': emergencyStopCmd( ); break;
115                     case '0': turnPowerOffAllCmd( ); break;
116                     case '1': turnPowerOnAllCmd( ); break;
117                     case '2': turnPowerOnMainCmd( ); break;
118                     case '3': turnPowerOnProgCmd( ); break;
119
120                     case 's': printStatusCmd( cmdStr + 1 ); break;
121                     case 'S': printBaseStationConfigCmd( ); break;
122                     case 'L': printSessionMap( ); break;
123
124                     case 'a': printTrackCurrentCmd( cmdStr + 1 ); break;
125
126                     case '?': printHelpCmd( ); break;
127
128                     case ' ': printf( "\n" ); break;
129
130                     case 'e':
131                     case 'E':
132                     case 'D':
133                     case 'T':
134                     case 'Z':
135                     case 'Q':
136                     case 'F': printf( "<Not implemented>\n" ); break;
137
138                     default: printf( "<Unknown command, use '?' for help>\n" );
139                 }
140
141                 charIndex ++;
142
143             } break;
144
145             default: {
146
147                 if ( strlen( cmdStr ) < sizeof( cmdStr ) ) strncat( cmdStr, &s[ charIndex ], 1 );
148                 charIndex ++;
149             }
150         }
151     }
152 }
153
154 //------------------------------------------------------------------------------------------------------------------
155 // "openSessionCmd" handles the session creation command. This command is used to allocate a loco session.
156 // We are passed the cab ID and return a session Id.
157 //
158 //    <O cabId>
159 //
160 //    cabId     -  the requesting cab number, from 1 to MAX_CAB_ID.
161 //
162 //    returns: <O sId>
163 //
164 //------------------------------------------------------------------------------------------------------------------
165 void LcsBaseStationCommand::openSessionCmd( char *s ) {
166
167     uint16_t  cabId = NIL_CAB_ID;
168     uint8_t   sId   = 0;
169
170     if ( sscanf( s, "%hu", &cabId ) != 1 ) return;
171
172     int ret = locoSessions -> requestSession( cabId, LSM_NORMAL, &sId );
173
174     printf( "<O %d>", (( ret == ALL_OK ) ? sId : -1 ));
175 }
176
177 //------------------------------------------------------------------------------------------------------------------
178 // "closeSessionCmd" handles the session release command. The return code is the CabSession error code. A zero
179 // indicates a successful execution.
180 //
181 //    <K sId>
182 //
183 //    sId       -  the session number.
184 //
185 //    returns: <K status>
186 //
187 //------------------------------------------------------------------------------------------------------------------
188 void LcsBaseStationCommand::closeSessionCmd( char *s ) {
189
190     uint8_t sId = NIL_LOCO_SESSION_ID;
191
192     if ( sscanf( s, "%hhu", &sId ) != 1 ) return;
193
194     int ret = locoSessions -> releaseSession( sId );
195
196     printf( "<K %d>", ret );
197 }
```

```
198
199    //-------------------------------------------------------------------------------------------------------
200    // "setThrottleCmd" handles the throttle command. The original DCC++ interface uses both the register Id and
201    // the cabId. In the new version the sId is sufficient. But just to be compatible with the original
202    // DCC++ command, we also pass the cabId. It should be either zero or match the cabId in the allocated session.
203    //
204    //     <t sId cabId speed direction>
205    //
206    //     sId         - the allocated session number.
207    //     cabId       - the Cab Id. The number must match the can number in the session or be zero.
208    //     speed       - throttle speed from 0-126, or -1 for emergency stop (resets SPEED to 0)
209    //     direction   - the direction: 1=forward, 0=reverse. Setting direction when speed=0 only effects
210    //                   direction of cab lighting for a stopped train.
211    //
212    //     returns: <t sId speed direction >
213    //
214    //-------------------------------------------------------------------------------------------------------
215    void LcsBaseStationCommand::setThrottleCmd( char *s ) {
216
217      uint8_t   sId         = NIL_LOCO_SESSION_ID;
218      uint16_t  cabId       = NIL_CAB_ID;
219      uint8_t   speed       = 0;
220      uint8_t   direction   = 0;
221
222      if ( sscanf( s, "%hhu %hu %hhu %hhu", &sId, &cabId, &speed, &direction ) != 4 ) return;
223      if (( cabId != NIL_CAB_ID ) && ( locoSessions -> getSessionIdByCabId( cabId ) != sId )) return;
224
225      locoSessions -> setThrottle( sId, speed, direction );
226
227      printf( "<t %d %d %d>", sId, speed, direction );
228    }
229
230    //-------------------------------------------------------------------------------------------------------
231    // "setFunctionBitCmd" turns on and off the engine decoder functions F0-F68 (F0 is sometimes called FL). This
232    // new command directly transmits the function setting to the engine decoder. The command interface is
233    // handling one function number at a time. The base station will handle the DCC byte generation.
234    //
235    //     <v sId funcId val >
236    //
237    //     sId     - the allocated session number, from 1 to MAX_MAIN_REGISTERS.
238    //     funcId  - the function number, currently implemented for F0 - F68.
239    //     val     - the value to set, 1 or 0.
240    //
241    //     returns: NONE.
242    //
243    //-------------------------------------------------------------------------------------------------------
244    void LcsBaseStationCommand::setFunctionBitCmd( char *s ) {
245
246        uint8_t sId = NIL_LOCO_SESSION_ID;
247        uint8_t funcNum   = 0;
248        uint8_t val       = 0;
249
250        if ( sscanf( s, "%hhu %hhu %hhu", &sId, &funcNum, &val ) != 3 ) return;
251
252        locoSessions -> setDccFunctionBit( sId, funcNum, val );
253    }
254
255    //-------------------------------------------------------------------------------------------------------
256    // "setFunctionGroupCmd" sets the engine decoder functions F0-F68 by group byte using the DCC byte instruction
257    // format. The user needs to do the calculation as shown in the list below. This command directly transmits
258    // the command to the engine decoder. This function requires some user math, and is only there for the DCC++
259    // command interface compatibility.
260    //
261    //     <f cabId byte1 [ byte2 ] >
262    //
263    //     cabId         - the cab number
264    //     byte1         - see below for encoding
265    //     byte2         - see below for encoding
266    //
267    //     returns: NONE
268    //
269    //     The DCC packet data for setting function groups is defined as follows:
270    //
271    //       Group 1:  F0, F4, F3, F2, F1      DCC Command Format: 100DDDDD
272    //       Group 2:  F8, F7, F6, F5          DCC Command Format: 1011DDDD
273    //       Group 3:  F12, F11, F10, F9       DCC Command Format: 1010DDDD
274    //       Group 4:  F20 .. F13              DCC Command Format: 0xDE DDDDDDDD
275    //       Group 5:  F28 .. F21              DCC Command Format: 0xDF DDDDDDDD
276    //       Group 6:  F36 .. F29              DCC Command Format: 0xD8 DDDDDDDD
277    //       Group 7:  F44 .. F37              DCC Command Format: 0xD9 DDDDDDDD
278    //       Group 8:  F52 .. F45              DCC Command Format: 0xDA DDDDDDDD
279    //       Group 9:  F60 .. F53              DCC Command Format: 0xDB DDDDDDDD
280    //       Group 10: F68 .. F61              DCC Command Format: 0xDC DDDDDDDD
281    //
282    //     To set functions F0-F4 on (=1) or off (=0):
283    //
284    //       BYTE1:  128 + F1*1 + F2*2 + F3*4 + F4*8 + F0*16
285    //       BYTE2:  omitted
286    //
287    //     To set functions F5-F8 on (=1) or off (=0):
288    //
289    //       BYTE1:  176 + F5*1 + F6*2 + F7*4 + F8*8
290    //       BYTE2:  omitted
291    //
292    //     To set functions F9-F12 on (=1) or off (=0):
293    //
294    //       BYTE1:  160 + F9*1 +F10*2 + F11*4 + F12*8
295    //       BYTE2:  omitted
296    //
```

```
297  //      For the remaining groups , the two byte format is used . Byte one is:
298  //
299  //          0xde ( 222 ) -> F13-F20
300  //          0xdf ( 223 ) -> F21-F28
301  //          0xd8 ( 216 ) -> F29-F36
302  //          0xd9 ( 217 ) -> F37-F44
303  //          0xda ( 218 ) -> F45-F52
304  //          0xdb ( 219 ) -> F53-F60
305  //          0xdc ( 220 ) -> F61-F68
306  //
307  //      Byte two with N being the starting group index is always:
308  //
309  //        BYTE2: (FN)*1 + (FN+1)*2 + (FN+2)*4 + (FN+3)*8 + (FN+4)*16 + (FN+5)*32 + (FN+6)*64 + (FN+7)*128
310  //
311  //----------------------------------------------------------------------------------------------------------
312  void LcsBaseStationCommand::setFunctionGroupCmd( char *s ) {
313
314    uint16_t  cabId    = NIL_CAB_ID;
315    uint8_t   byte1    = 0;
316    uint8_t   byte2    = 0;
317
318      if ( sscanf( s, "%hu %hhu %hhu", &cabId, &byte1, &byte2 ) < 2 ) return;
319
320      uint8_t sId = locoSessions -> getSessionIdByCabId( cabId );
321
322      if ( sId == NIL_LOCO_SESSION_ID ) return;
323
324      if (( byte2 == 0 ) && ( byte1 >= 128 ) && ( byte1 < 160 )) {
325
326          locoSessions -> setDccFunctionGroup( sId, 1, byte1 );
327      }
328      else if (( byte2 == 0 ) && ( byte1 >= 160 ) && ( byte1 < 176 )) {
329
330          locoSessions -> setDccFunctionGroup( sId, 3, byte1 );
331      }
332      else if (( byte2 == 0 ) && ( byte1 >= 176 ) && ( byte1 < 192 )) {
333
334          locoSessions -> setDccFunctionGroup( sId, 2, byte1 );
335      }
336      else if ( byte1 == 0xde ) locoSessions -> setDccFunctionGroup( sId, 4, byte2 );
337      else if ( byte1 == 0xdf ) locoSessions -> setDccFunctionGroup( sId, 5, byte2 );
338      else if ( byte1 == 0xd8 ) locoSessions -> setDccFunctionGroup( sId, 6, byte2 );
339      else if ( byte1 == 0xd9 ) locoSessions -> setDccFunctionGroup( sId, 7, byte2 );
340      else if ( byte1 == 0xda ) locoSessions -> setDccFunctionGroup( sId, 8, byte2 );
341      else if ( byte1 == 0xdb ) locoSessions -> setDccFunctionGroup( sId, 9, byte2 );
342      else if ( byte1 == 0xdc ) locoSessions -> setDccFunctionGroup( sId, 10, byte2 );
343  }
344
345  //----------------------------------------------------------------------------------------------------------
346  // "readCVCmd" reads a configuration variable from the engine decoder on the programming track. The
347  // callbacknum and callbacksub parameter are ignored by the base station and just passed back to the caller
348  // for identification purposes.
349  //
350  //    <R cvId [ callbacknum callbacksub ]>
351  //
352  //    cvId          -  the configuration variable ID, 1 ... 1024.
353  //    callbacknum   -  a number echoed back, ignored by the base station
354  //    callbacksub   -  a number echoed back, ignored by the base station
355  //
356  //    returns: <R callbacknum|callbacksub|cvId value>
357  //
358  //    where value is 0 - 255 of the CV variable or -1 if the value could not be verified.
359  //
360  //----------------------------------------------------------------------------------------------------------
361  void LcsBaseStationCommand::readCVCmd( char *s ) {
362
363      uint16_t  cvId          = NIL_DCC_CV_ID;
364      uint8_t   val           = 0;
365      int       callbacknum   = 0;
366      int       callbacksub   = 0;
367      int       ret           = 0;
368
369      if ( sscanf( s, "%hu %d %d", &cvId, &callbacknum, &callbacksub )  < 1 ) return;
370
371      ret = locoSessions -> readCV( cvId, 0, &val );
372
373      printf( "<R %d|%d|%d %d>", callbacknum, callbacksub, cvId, (( ret == ALL_OK ) ? val : -1 ));
374  }
375
376  //----------------------------------------------------------------------------------------------------------
377  // "writeCVByteCmd" writes a data byte to the engine decoder on the programming track and then verifies it.
378  // The callbacknum and callbacksub parameter are ignored by the base station and just passed back to the
379  // caller for identification purposes.
380  //
381  //    <W cvId val [ callbacknum callbacksub ]>
382  //
383  //    cvId          -  the configuration variable ID, 1 ... 1024.
384  //    val           -  the data byte.
385  //    callbacknum   -  a number echoed back, ignored by the base station
386  //    callbacksub   -  a number echoed back, ignored by the base station
387  //
388  //    returns: <W callbacknum|callbacksub|cvId Value>
389  //
390  //    where Value is 0 - 255 of the CV variable or -1 if the verification failed.
391  //
392  //----------------------------------------------------------------------------------------------------------
393  void LcsBaseStationCommand::writeCVByteCmd( char *s ) {
394
395      uint16_t  cvId          = NIL_DCC_CV_ID;
```

```
396       uint8_t    val            = 0;
397       int        callbacknum    = 0;
398       int        callbacksub    = 0;
399       int        ret            = 0;
400
401       if ( sscanf( s, "%hu %hhu %d %d", &cvId, &val, &callbacknum, &callbacksub ) < 2 ) return;
402
403       ret = locoSessions -> writeCVByte( cvId, val );
404
405       printf( "<W %d|%d|%d %d>", callbacknum, callbacksub, cvId, (( ret == ALL_OK ) ? val : -1 ));
406   }
407
408   //-------------------------------------------------------------------------------------------------------------
409   // "writeCVBitCmd" writes a bit to the engine decoder on the programming track and then verifies the
410   // operation. The callbacknum and callbacksub parameter are ignored by the base station and just passed back
411   // to the caller for identification purposes.
412   //
413   //     <B cvId bitPos bitVal callbacknum callbacksub>
414   //
415   //     cvId          -  the configuration variable ID, 1 ... 1024.
416   //     bitPos        -  the bit position of the bit, 0 .. 7.
417   //     bitVal        -  the data bit.
418   //     callbacknum   -  a number echoed back, ignored by the base station
419   //     callbacksub   -  a number echoed back, ignored by the base station
420   //
421   //     returns: <B callbacknum|callbacksub|cvId bitPos Value>
422   //
423   //     where Value is 0 or 1 of the bit or -1 if the verification failed.
424   //
425   //-------------------------------------------------------------------------------------------------------------
426   void LcsBaseStationCommand::writeCVBitCmd( char *s ) {
427
428       uint16_t  cvId          = NIL_DCC_CV_ID;
429       uint8_t   bitPos        = 0;
430       uint8_t   bitVal        = 0;
431       int       callbacknum   = 0;
432       int       callbacksub   = 0;
433       int       ret           = 0;
434
435       if ( sscanf( s, "%hu %hhu %hhu %d %d", &cvId, &bitPos, &bitVal, &callbacknum, &callbacksub ) != 5 ) return;
436
437       ret = locoSessions -> writeCVBit( cvId, bitPos, bitVal );
438
439       printf( "<B %d|%d|%d|%d %d>", callbacknum, callbacksub, cvId, bitPos, (( ret == ALL_OK ) ? bitVal : -1 ));
440   }
441
442   //-------------------------------------------------------------------------------------------------------------
443   // "writeCVByteMainCmd" writes a data byte to the engine decoder on the main track, without any verification.
444   // To be compatible with the DCC++ command set, the command is using the cabId to identify the loco we talk
445   // about.
446   //
447   //     <w cabId cvId val >
448   //
449   //     cabId        -  the cabId number.
450   //     cvId         -  the configuration variable ID, 1 ... 1024.
451   //     val          -  the data byte.
452   //
453   //     returns: NONE
454   //
455   //-------------------------------------------------------------------------------------------------------------
456   void LcsBaseStationCommand::writeCVByteMainCmd( char *s ) {
457
458       uint16_t  cabId = NIL_CAB_ID;
459       uint16_t  cvId  = NIL_DCC_CV_ID;
460       uint8_t   val   = 0;
461
462       if ( sscanf( s, "%hu %hu %hhu", &cabId, &cvId, &val ) != 3 ) return;
463
464       locoSessions -> writeCVByteMain( locoSessions -> getSessionIdByCabId( cabId ), cvId, val );
465   }
466
467   //-------------------------------------------------------------------------------------------------------------
468   // "writeCVBitMainCmd" writes a data byte to the engine decoder on the main track, without any verification.
469   // To be compatible with the DCC++ command set, the command is using the cabId to identify the loco we talk
470   // about.
471   //
472   //     <b cabId cvId bitPos bitVal >
473   //
474   //     cabId        -  the cabId number.
475   //     cvId         -  the configuration variable ID, 1 ... 1024.
476   //     bitPos       -  the bit position of the bit, 0 .. 7.
477   //     bitVal       -  the data bit.
478   //
479   //     returns: NONE
480   //
481   //-------------------------------------------------------------------------------------------------------------
482   void LcsBaseStationCommand::writeCVBitMainCmd( char *s ) {
483
484       uint16_t  cabId = NIL_CAB_ID;
485       uint16_t  cvId    = NIL_DCC_CV_ID;
486       uint8_t   bitPos = 0;
487       uint8_t   bitVal = 0;
488
489       if ( sscanf(s, "%hu %hu %hhu %hhu", &cabId, &cvId, &bitPos, &bitVal ) != 4 ) return;
490
491       locoSessions -> writeCVBitMain( locoSessions -> getSessionIdByCabId( cabId ), cvId, bitPos, bitVal );
492   }
493
494   //-------------------------------------------------------------------------------------------------------------
```

```
495  // "writeDccPacketMainCmd" writes a DCC packet to the main operations track. This is for testing and debugging
496  // and you better know the DCC packet standard by heart :-). The DCC standards define packets up to 15 data
497  // bytes payload.
498  //
499  //    <M byte1 byte2 [ byte3 ... byte10 ]>
500  //
501  //    byte1 .. byte10   - the packet data in hexadecimal
502  //
503  //    returns: NONE
504  //
505  //---------------------------------------------------------------------------------------------------------------
506  void LcsBaseStationCommand::writeDccPacketMainCmd( char *s ) {
507
508      uint8_t b[ 16 ] = { 0 };
509      uint8_t nBytes  = sscanf( s,
510                                "%hhu %hhu %hhu %hhu %hhu %hhu %hhu %hhu"
511                                "%hhu %hhu %hhu %hhu %hhu %hhu %hhu %hhu",
512                                b, b + 1, b + 2, b + 3, b + 4, b + 5, b + 6, b + 7,
513                                b + 8, b + 9, b + 10, b + 11, b + 12, b + 13, b + 14, b + 15 );
514
515      if ( nBytes >= 3 && nBytes <= 10 ) locoSessions -> writeDccPacketMain( b, nBytes, 0 );
516  }
517
518  //---------------------------------------------------------------------------------------------------------------
519  // "writeDccPacketProgCmd" writes a DCC packet to the programming track. This is for testing and debugging and
520  // you better know the DCC packet standard by heart :-). The DCC standards define packets up to 15 data
521  // bytes payload.
522  //
523  ///    <P byte1 byte2 [ byte3 ... byte10 ]>
524  //
525  //    byte1 .. byte10   - the packet data in hexadecimal
526  //
527  //    returns: NONE
528  //
529  //---------------------------------------------------------------------------------------------------------------
530  void LcsBaseStationCommand::writeDccPacketProgCmd( char *s ) {
531
532      uint8_t b[ 16 ] = { 0 };
533      uint8_t nBytes  = sscanf( s,
534                                "%hhu %hhu %hhu %hhu %hhu %hhu %hhu %hhu"
535                                "%hhu %hhu %hhu %hhu %hhu %hhu %hhu %hhu",
536                                b, b + 1, b + 2, b + 3, b + 4, b + 5, b + 6, b + 7,
537                                b + 8, b + 9, b + 10, b + 11, b + 12, b + 13, b + 14, b + 15 );
538
539      if ( nBytes >= 3 && nBytes <= 10 ) locoSessions -> writeDccPacketProg( b, nBytes, 0 );
540  }
541
542  //---------------------------------------------------------------------------------------------------------------
543  // "emergencyStopCmd" handles the emergencyStop command. This new command causes the base station to send out
544  // the emergency stop broadcast DCC command.
545  //
546  //    <X>
547  //
548  //    returns: <X>
549  //
550  //---------------------------------------------------------------------------------------------------------------
551  void LcsBaseStationCommand::emergencyStopCmd( ) {
552
553      locoSessions -> emergencyStopAll( );
554      printf( "<X>" );
555  }
556
557  //---------------------------------------------------------------------------------------------------------------
558  // "turnPowerOnXXX" and "turnPowerOff" enables/disables the main and/or the programming track.
559  //
560  //    <0> - turn operations and programming track power off
561  //    <1> - turn operations and programming track power on
562  //    <2> - turn operations track power on
563  //    <3> - turn programming track power on
564  //
565  //---------------------------------------------------------------------------------------------------------------
566  void LcsBaseStationCommand::turnPowerOnAllCmd( ) {
567
568      mainTrack -> powerStart( );
569      progTrack -> powerStart( );
570      printf( "<p1>" );
571  }
572
573  void LcsBaseStationCommand::turnPowerOffAllCmd( ) {
574
575      mainTrack -> powerStop( );
576      progTrack -> powerStop( );
577      printf( "<p0>" );
578  }
579
580  void LcsBaseStationCommand::turnPowerOnMainCmd( ) {
581
582      mainTrack -> powerStart( );
583      printf( "<p1 MAIN>" );
584  }
585
586  void LcsBaseStationCommand::turnPowerOnProgCmd( ) {
587
588      progTrack -> powerStart( );
589      printf( "<p1 PROG>" );
590  }
591
592  //---------------------------------------------------------------------------------------------------------------
593  // "setTrackOptionCmd" turns on and off capabilities of the operations or service track.
```

```
594  //
595  //    <C option>
596  //
597  //    option   - the option value.
598  //
599  //        1 -> set main track Cutout mode on.
600  //        2 -> set main track Cutout mode off.
601  //        3 -> set main track Railcom mode on.
602  //        4 -> set main track Railcom mode off.
603  //
604  //       10 -> set service track into operations mode.
605  //       11 -> set service track into service mode.
606  //
607  //    returns: NONE
608  //
609  //---------------------------------------------------------------------------------------------------------
610  void LcsBaseStationCommand::setTrackOptionCmd( char *s ) {
611
612      uint8_t option = 0;
613
614      if ( sscanf( s, "%hhu", &option ) == 1 ) {
615
616          switch ( option ) {
617
618              case 1: mainTrack -> cutoutOn( );   break;
619              case 2: mainTrack -> cutoutOff( );  break;
620              case 3: mainTrack -> railComOn( );  break;
621              case 4: mainTrack -> railComOff( ); break;
622
623              case 10: progTrack -> serviceModeOff( );  break;
624              case 11: progTrack -> serviceModeOn( ); break;
625          }
626      }
627  }
628
629  //---------------------------------------------------------------------------------------------------------
630  // "printStatusCmd" list information about the base station. Using just a "s" for a summary status is always
631  // a good idea to do this just as a first basic test if things are running at all. The level is a positive
632  // integer that specifies the information items to be listed.
633  //
634  //    <s [ opt ]> - the kind of status to display.
635  //
636  //    returns:  series of status information that can be read by an interface to determine status of the base
637  //              station and important settings
638  //
639  //---------------------------------------------------------------------------------------------------------
640  void LcsBaseStationCommand::printStatusCmd( char *s ) {
641
642      uint8_t opt = 0;
643
644      if ( sscanf( s, "%hhu", &opt ) > 0 ) {
645
646          switch ( opt ) {
647
648              case 0: printVersionInfo( );      break;
649              case 1: printConfiguration( );    break;
650              case 2: printSessionMap( );       break;
651              case 3: printTrackStatusMain( );  break;
652              case 4: printTrackStatusProg( );  break;
653
654              case 9: {
655
656                  printConfiguration( );
657                  printSessionMap( );
658                  printTrackStatusMain( );
659                  printTrackStatusProg( );
660
661              } break;
662
663              default: printVersionInfo( );
664          }
665      } else printVersionInfo( );
666  }
667
668  //---------------------------------------------------------------------------------------------------------
669  // "printBaseStationConfigCmd" list information about the base in a DCC++ compatible way.
670  //
671  //    <S> - the basestation configuration.
672  //
673  //    returns:  series of status information that can be read by an interface to determine status of the base
674  //              station and important settings
675  //
676  //---------------------------------------------------------------------------------------------------------
677  void LcsBaseStationCommand::printBaseStationConfigCmd( ) {
678
679      printConfiguration( );
680  }
681
682  //---------------------------------------------------------------------------------------------------------
683  // "printConfiguration" lists out the key hardware and software settings. Also very useful as the first
684  // trouble shooting task.
685  //
686  //---------------------------------------------------------------------------------------------------------
687  void LcsBaseStationCommand::printConfiguration( ) {
688
689      printVersionInfo( );
690      locoSessions -> printSessionMapConfig( );
691      mainTrack -> printDccTrackConfig( );
692      progTrack -> printDccTrackConfig( );
```

```
693 | }
694 |
695 | //-----------------------------------------------------------------------------------------------------------------
696 | // "printVersionInfo" list out the Arduino type and software version of this program.
697 | //
698 | //-----------------------------------------------------------------------------------------------------------------
699 | void LcsBaseStationCommand::printVersionInfo( ) {
700 |
701 |     printf( "<\nLCS Base Station / Version: tbd / %s %s >\n", __DATE__, __TIME__  );
702 | }
703 |
704 | //-----------------------------------------------------------------------------------------------------------------
705 | // "printSessionMap" list out the active session table content.
706 | //
707 | //-----------------------------------------------------------------------------------------------------------------
708 | void LcsBaseStationCommand::printSessionMap( ) {
709 |
710 |     locoSessions -> printSessionMapInfo( );
711 | }
712 |
713 | //-----------------------------------------------------------------------------------------------------------------
714 | // "printTrackStatusMain" lists out the current MAIN track status
715 | //
716 | //-----------------------------------------------------------------------------------------------------------------
717 | void LcsBaseStationCommand::printTrackStatusMain( ) {
718 |
719 |     mainTrack -> printDccTrackStatus( );
720 | }
721 |
722 | //-----------------------------------------------------------------------------------------------------------------
723 | // "printTrackStatusProg" lists out the current PROG track status
724 | //
725 | //-----------------------------------------------------------------------------------------------------------------
726 | void LcsBaseStationCommand::printTrackStatusProg( ) {
727 |
728 |     progTrack -> printDccTrackStatus( );
729 | }
730 |
731 | //-----------------------------------------------------------------------------------------------------------------
732 | // "printTrackCurrentCmd" reads the actual current being drawn on the main operations track.
733 | //
734 | //    <a [ track ]>
735 | //
736 | // where "track" == 0 or omitted is the MAIN track, "track" == 1 is the PROG track.
737 | //
738 | //    returns: <a current>, where current is the actual power consumption in milliAmps.
739 | //
740 | //-----------------------------------------------------------------------------------------------------------------
741 | void LcsBaseStationCommand::printTrackCurrentCmd( char *s ) {
742 |
743 |     int opt = -1;
744 |
745 |     sscanf( s, "%d", &opt );
746 |
747 |     printf( "<a " );
748 |
749 |     switch ( opt ) {
750 |
751 |         case 0: printf( "%d", mainTrack -> getActualCurrent( )); break;
752 |         case 1: printf( "%d", progTrack -> getActualCurrent( )); break;
753 |         case 2: printf( "%d %d", mainTrack -> getActualCurrent( ), progTrack -> getActualCurrent( )); break;
754 |
755 |         case 10: printf( "%d", mainTrack -> getRMSCurrent( )); break;
756 |         case 11: printf( "%d", progTrack -> getRMSCurrent( )); break;
757 |         case 12: printf( "%d %d", mainTrack -> getRMSCurrent( ), progTrack -> getRMSCurrent( )); break;
758 |
759 |         default: printf( "%d", mainTrack -> getRMSCurrent( ));
760 |     }
761 |
762 |     printf( ">" );
763 | }
764 |
765 | //-----------------------------------------------------------------------------------------------------------------
766 | // "printDccLogCommandCommand" is the command to manage the DCC log for tracing and debugging purposes.
767 | //
768 | //    <Y [ opt ]> where "opt" is the command to execute from the DCC Log function.
769 | //
770 | //      Main track:
771 | //
772 | //      0 - disable DCC logging
773 | //      1 - enable DCC logging
774 | //      2 - start DCC logging
775 | //      3 - stop DCC logging
776 | //      4 - list log entries
777 | //
778 | //      Prog track:
779 | //
780 | //      10 - disable DCC logging
781 | //      11 - enable DCC logging
782 | //      12 - start DCC logging
783 | //      13 - stop DCC logging
784 | //      14 - list log entries
785 | //
786 | //      RailCom:
787 | //
788 | //      20 - show real time RailCom buffer, experimental
789 | //
790 | //-----------------------------------------------------------------------------------------------------------------
791 | void LcsBaseStationCommand::printDccLogCommand( char *s ) {
```

```cpp
792
793        int opt = -1;
794
795        sscanf( s, "%d", &opt );
796
797        printf( "<Y %d ", opt );
798
799        switch ( opt ) {
800
801            case 0:     mainTrack -> enableLog( false );  break;
802            case 1:     mainTrack -> enableLog( true );   break;
803            case 2:     mainTrack -> beginLog( );         break;
804            case 3:     mainTrack -> endLog( );           break;
805            case 4:     mainTrack -> printLog( );         break;
806
807            case 10:    progTrack -> enableLog( false );  break;
808            case 11:    progTrack -> enableLog( true );   break;
809            case 12:    progTrack -> beginLog( );         break;
810            case 13:    progTrack -> endLog( );           break;
811            case 14:    progTrack -> printLog( );         break;
812
813            case 20: {
814
815                uint8_t buf[ 16 ];
816
817                mainTrack -> getRailComMsg( buf, sizeof( buf ));
818
819                printf( "RC: " );
820                for ( uint8_t i = 0; i < 8; i++ ) printf( "0x%x ", buf[ i ]);
821
822            } break;
823
824            default: ;
825        }
826
827        printf( ">" );
828   }
829
830   //-------------------------------------------------------------------------------------------------------------------
831   // "printHelp" lists a short version of all the command.
832   //
833   //-------------------------------------------------------------------------------------------------------------------
834   void LcsBaseStationCommand::printHelpCmd( ) {
835
836        printf( "\nCommands:\n" );
837
838        printf( "<O cabId>                            - allocate a session for the cab\n" );
839        printf( "<K sId>                              - release a session\n" );
840        printf( "<t sId cabId speed dir>              - set cab speed / direction\n" );
841        printf( "<f cabId funcId val >                - set cab function value, group DCC format\n" );
842        printf( "<v sId funcId val >                  - set cab function value, individual\n" );
843        printf( "<R cvId callbacknum callbacksub >    - read CV byte\n" );
844        printf( "<W cvId val callbacknum callbacksub> - write CV byte on programming track\n" );
845        printf( "<B cvId bitPos bitVal callbacknum callbacksub> - write CV bit on programming track\n" );
846        printf( "<w cabId cvId val > - write CV byte on operations track\n" );
847        printf( "<b cabId cvId bitPos bitVal > - write CV bit on operations track\n" );
848        printf( "<M sId byte1 byte2 [ byte3 ... byte10 ]> - send DCC packet on operations track to Reg n\n" );
849        printf( "<P sId byte1 byte2 [ byte3 ... byte10 ]> - send DCC packet on programming track to Reg n\n" );
850
851        printf( "<C track [option] - set track option, track = 0 -> MAIN, track = 1 -> PROG\n" );
852        printf( "              " " - 1  - set main track cutout on\n" );
853        printf( "              " " - 2  - set main track cutout off\n" );
854        printf( "              " " - 3  - set main track RailCom on\n" );
855        printf( "              " " - 4  - set main track RailCom off\n" );
856        printf( "              " " - 10 - set prog track in operations mode\n" );
857        printf( "              " " - 11 - set prog track in service mode\n" );
858
859        printf( "<X>  - emergency stop all\n" );
860
861        printf( "<0> - turn operations and programming track power off\n" );
862        printf( "<1> - turn operations and programming track power on\n" );
863        printf( "<2> - turn operations track power on\n" );
864        printf( "<3> - turn programming track power on\n" );
865
866        printf( "<a [ opt ]>  " " - list current consumption, default is RMS for MAIN\n" );
867        printf( "              " "   - opt 0  - actual - MAIN\n" );
868        printf( "              " "   - opt 1  - actual - PROG\n" );
869        printf( "              " "   - opt 2  - actual - both\n" );
870        printf( "              " "   - opt 10 - RMS - MAIN\n" );
871        printf( "              " "   - opt 11 - RMS - PROG\n" );
872        printf( "              " "   - opt 12 - RMS - both\n" );
873
874        printf( "<C <option>> - turn on/off the Railcom option on the main track( 0 - off, 1 - on)\n" );
875
876        printf( "<s [ level ]>" " - list status at detail level, default is summary\n" );
877        printf( "              " "   - level 0 - summary\n" );
878        printf( "              " "   - level 1 - configuration\n" );
879        printf( "              " "   - level 2 - session map\n" );
880        printf( "              " "   - level 3 - main track current\n" );
881        printf( "              " "   - level 4 - prog track current\n" );
882        printf( "              " "   - level 9 - all of the above\n" );
883
884        printf( "<S> - list base station configuration\n" );
885        printf( "<L> - list base station session table" );
886
887        printf( "<Y [ opt ]> - DCC log options ( used for debugging and tracing )\n" );
888        printf( "              " "   - 0  - disable main track logging\n" );
889        printf( "              " "   - 1  - enable main track logging\n" );
890        printf( "              " "   - 2  - begin main track logging\n" );
```

```
891        printf( "                  " "   - 3  - end main track logging\n" );
892        printf( "                  " "   - 4  - print main track logging data\n" );
893        printf( "                  " "   - 10 - disable prog track logging\n" );
894        printf( "                  " "   - 11 - enable prog track logging\n" );
895        printf( "                  " "   - 12 - begin prog track logging\n" );
896        printf( "                  " "   - 13 - end prog track logging\n" );
897        printf( "                  " "   - 14 - print prog track logging data\n" );
898
899        printf( "<?> - list this help\n" );
900
901        printf( "\n" );
902  }
```

```
1  //------------------------------------------------------------------------------------------------------------
2  //
3  // LCS Base Station - DCC Track - implementation file
4  //
5  //------------------------------------------------------------------------------------------------------------
6  // The DCC track object is one of the the key objects for the DCC subsystem. It is responsible for the DCC
7  // track signal generation and the power management functions. There will be exactly two objects of this kind,
8  // one for the MAIN track and the other for the PROG track. The DCC track object has two major functional
9  // parts. The first is to transmit a DCC packet to the track. This is the most important task, as with no
10 // packets no power is on the tracks and the locomotive will not work. The second task is to continuously
11 // monitor the current consumption. Finally, for the RailCOm option, the cutout generation and receiving
12 // of the RailCOm packets is handled.
13 //
14 //------------------------------------------------------------------------------------------------------------
15 //
16 // LCS - Base Station DCC Track implementation file
17 // Copyright (C) 2019 - 2024  Helmut Fieres
18 //
19 // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
20 // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
21 // option) any later version.
22 //
23 // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
24 // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
25 // for more details.
26 //
27 // You should have received a copy of the GNU General Public License along with this program. If not, see
28 // http://www.gnu.org/licenses
29 //
30 //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
31 //
32 //------------------------------------------------------------------------------------------------------------
33 #include "LcsBaseStation.h"
34 #include <math.h>
35
36 //------------------------------------------------------------------------------------------------------------
37 // External global variables.
38 //
39 //------------------------------------------------------------------------------------------------------------
40 extern uint16_t debugMask;
41
42 //------------------------------------------------------------------------------------------------------------
43 // DCC Signal debugging. A tick is defined to last 29 microseconds. There is a debugging option to set the
44 // clock much slower so that the waveform can be seen.
45 //
46 // ??? take out, we are past that ...... since a long time. -> one last check than out ...
47 //------------------------------------------------------------------------------------------------------------
48
49 #define DEBUG_WAVE_FORM 0
50
51 #if DEBUG_WAVE_FORM == 1
52 #define TICK_IN_MICROSECONDS  400000
53 #else
54 #define TICK_IN_MICROSECONDS  29
55 #endif
56
57 //------------------------------------------------------------------------------------------------------------
58 // The DccTrack Object local definitions. The DCC track object is a bit special. There are exactly two object
59 // instances created, MAIN and PROG. Both however share the global mechanism for generating the DCC hardware
60 // signals. There are callback functions for the DCC timer and the serial I/O capability for the RailCom
61 // feature. The hardware lower layers can be found in controller dependent code (CDC) layer.
62 //
63 //------------------------------------------------------------------------------------------------------------
64 namespace {
65
66 using namespace LCS;
67
68 //------------------------------------------------------------------------------------------------------------
69 // The DCC Track will allocate two DCC Track Objects. For the interrupt system to work, references to the
70 // objects must be static variables. The initialization sequence outside of this class will allocate the two
71 // objects and we keep a copy of the respective DCC track object created right here.
72 //
73 // ??? when we use the global variables in the "main" file, can this go away ?
74 //------------------------------------------------------------------------------------------------------------
75 LcsBaseStationDccTrack  *mainTrack  = nullptr;
76 LcsBaseStationDccTrack  *progTrack  = nullptr;
77
78 //------------------------------------------------------------------------------------------------------------
79 // DCC packet definitions. A DCC packet payload is at most 15 bytes long, excluding the checksum byte. This
80 // is true for XPOM and DCC-A support, otherwise it is according to NMRA up to 6 bytes. The preamble is a
81 // series of "ONE" bits, which helps the decoders to sync to the bit stream. The standard specifies a
82 // minimum of 16 ONE bits for the MAIN track and 22 ONE bits for the PROG track. The postamble is exactly
83 // one "ONE" bit. If the cutout period option is enabled, the cutout overlays the first ONE bits the
84 // preamble.
85 //
86 //------------------------------------------------------------------------------------------------------------
87 const uint8_t   MAIN_PACKET_PREAMBLE_LEN   = 17;
88 const uint8_t   MAIN_PACKET_POSTAMBLE_LEN  = 1;
89 const uint8_t   PROG_PACKET_PREAMBLE_LEN   = 22;
90 const uint8_t   PROG_PACKET_POSTAMBLE_LEN  = 1;
91 const uint8_t   DCC_PACKET_CUTOUT_LEN      = 4;
92 const uint8_t   MIN_DCC_PACKET_SIZE        = 2;
93 const uint8_t   MAX_DCC_PACKET_SIZE        = 16;
94 const uint8_t   MIN_DCC_PACKET_REPEATS     = 0;
95 const uint8_t   MAX_DCC_PACKET_REPEATS     = 8;
96 const uint8_t   RAILCOM_BUFFER_SIZE        = 8;
97
98 //------------------------------------------------------------------------------------------------------------
```

```
 99   // Constant values definition. We need the RESET and IDLE packet as well as a bit mask for a quick bit
100   // select in the data byte.
101   //
102   //-------------------------------------------------------------------------------------------------------
103   DccPacket       idleDccPacket       = { 3, 0, { 0xFF, 0x00, 0xFF }};
104   DccPacket       resetDccPacket      = { 3, 0, { 0x00, 0x00, 0x00 }};
105   const uint8_t   bitMask9[ ]          = { 0x00, 0x80, 0x40, 0x20, 0x10, 0x08, 0x04, 0x02, 0x01 };
106
107   //-------------------------------------------------------------------------------------------------------
108   // Programming decoders require to detect a short rise in power consumption. The value is at least 60mA,
109   // but decoders can raise anything from 100mA to 250mA. This is a bit touchy and the value set to 100mA
110   // was done after testing several decoders. Still, a bit flaky ...
111   //
112   //-------------------------------------------------------------------------------------------------------
113   const uint8_t ACK_TRESHOLD_VAL      = 100;
114
115   //-------------------------------------------------------------------------------------------------------
116   // The DCC signal generator thinks in ticks. With a DCC ONE based on 58 microseconds and a DCC ZERO based
117   // on 116 microseconds half period, we define a tick as a 29 microsecond interval. Although, ONE and ZERO
118   // bit signals could be implemented using a multiple of 58 microseconds, the cutout function requires a
119   // signal length of 29 microseconds at the beginning of the period, right after the packet end bit of the
120   // previous packet. Luckily 2 * 29 is 58, 2 * 58 is 116. Perfect for DCC packets.
121   //
122   // ??? think directly in microseconds ?
123   //-------------------------------------------------------------------------------------------------------
124   const uint32_t TICKS_29_MICROS            =  1;
125   const uint32_t TICKS_58_MICROS            =  TICKS_29_MICROS * 2;
126   const uint32_t TICKS_116_MICROS           =  TICKS_29_MICROS * 4;
127   const uint32_t TICKS_CUTOUT_MICROS        =  TICKS_29_MICROS * 16;
128
129   //-------------------------------------------------------------------------------------------------------
130   // Base Station global limits. Perhaps to move to a configurable place...
131   //
132   //-------------------------------------------------------------------------------------------------------
133   const uint16_t MILLI_VOLT_PER_DIGIT       = 5;
134   const uint16_t MILLI_VOLT_PER_AMP         = 1500;
135
136   //-------------------------------------------------------------------------------------------------------
137   // DCC track power management is also a a state machine managing the state of the power track. Maximum values
138   // for the DCC track power start and stop sequence as well as limits for power overload events are defined.
139   // We also define reasonable default values.
140   //
141   //-------------------------------------------------------------------------------------------------------
142   const uint16_t MAX_START_TIME_THRESHOLD_MILLIS    = 2000;
143   const uint16_t MAX_STOP_TIME_THRESHOLD_MILLIS     = 1000;
144   const uint16_t MAX_OVERLOAD_TIME_THRESHOLD_MILLIS = 500;
145   const uint16_t MAX_OVERLOAD_EVENT_COUNT           = 10;
146   const uint16_t MAX_OVERLOAD_RESTART_COUNT         = 10;
147
148   const uint16_t DEF_START_TIME_THRESHOLD_MILLIS    = 1000;
149   const uint16_t DEF_STOP_TIME_THRESHOLD_MILLIS     = 500;
150   const uint16_t DEF_OVERLOAD_TIME_THRESHOLD_MILLIS = 300;
151   const uint16_t DEF_OVERLOAD_EVENT_COUNT           = 10;
152   const uint16_t DEF_OVERLOAD_RESTART_COUNT         = 10;
153
154   //-------------------------------------------------------------------------------------------------------
155   // Track state machine state definitions. See the track state machine routine for an explanation of the
156   // individual states.
157   //
158   //-------------------------------------------------------------------------------------------------------
159   enum DccTrackState : uint8_t {
160
161       DCC_TRACK_POWER_OFF       = 0,
162       DCC_TRACK_POWER_ON        = 1,
163       DCC_TRACK_POWER_OVERLOAD  = 2,
164       DCC_TRACK_POWER_START1    = 3,
165       DCC_TRACK_POWER_START2    = 4,
166       DCC_TRACK_POWER_STOP1     = 5,
167       DCC_TRACK_POWER_STOP2     = 6
168   };
169
170   //-------------------------------------------------------------------------------------------------------
171   // DCC Track signal state machine states. See the DCC signal state machine routine for an explanation of
172   // the states.
173   //
174   //-------------------------------------------------------------------------------------------------------
175   enum DccSignalState : uint8_t {
176
177       DCC_SIG_CUTOUT_START      = 0,
178       DCC_SIG_CUTOUT_1          = 1,
179       DCC_SIG_CUTOUT_2          = 2,
180       DCC_SIG_CUTOUT_3          = 3,
181       DCC_SIG_CUTOUT_END        = 4,
182       DCC_SIG_START_BIT         = 5,
183       DCC_SIG_TEST_BIT          = 6,
184       DCC_SIG_ZERO_SECOND_HALF  = 7
185   };
186
187   // ??? idea: each state has a number of ticks it will set. Have an array where to get this value and just
188   // set it from the table...
189   //
190   uint8_t ticksForState[ ] = {
191
192       TICKS_29_MICROS,        // DCC_SIG_CUTOUT_START
193       TICKS_CUTOUT_MICROS,    // DCC_SIG_CUTOUT_1
194       TICKS_29_MICROS,        // DCC_SIG_CUTOUT_2
195       TICKS_58_MICROS,        // DCC_SIG_CUTOUT_3
196       TICKS_58_MICROS,        // DCC_SIG_CUTOUT_END
197       TICKS_58_MICROS,        // DCC_SIG_START_BIT
```

```
198        TICKS_58_MICROS,          // DCC_TEST_BIT,
199        TICKS_116_MICROS          // DCC_SIG_ZERO_SECOND_HALF
200  };
201
202  //------------------------------------------------------------------------------------------------------------
203  // DCC Track signal state machine follow up request items. The signal state machine first sets the hardware
204  // signal for both tracks and then determines whether a follow up action is required. See the track state
205  // machine routine for an explanation of the individual follow up actions.
206  //
207  //------------------------------------------------------------------------------------------------------------
208  enum DccSignalStateFollowup : uint8_t {
209
210      DCC_SIG_FOLLOW_UP_NONE                = 0,
211      DCC_SIG_FOLLOW_UP_GET_BIT             = 1,
212      DCC_SIG_FOLLOW_UP_GET_PACKET          = 2,
213      DCC_SIG_FOLLOW_UP_MEASURE_CURRENT     = 3,
214      DCC_SIG_FOLLOW_UP_START_RAILCOM_IO    = 4,
215      DCC_SIG_FOLLOW_UP_STOP_RAILCOM_IO     = 5,
216      DCC_SIG_FOLLOW_UP_RAILCOM_MSG         = 6,
217  };
218
219  //------------------------------------------------------------------------------------------------------------
220  // The hardware timer needs to be set to the ticks we want to pass before interrupting again. There are
221  // three things to remember between interrupts. First, the current time interval, which tells us how many
222  // ticks will have passed when the timer interrupts again. Next, for each DCC track signal state we need to
223  // remember how many ticks are left before the state machine needs to run again. Each time the timer will
224  // interrupt, the passed ticks are subtracted from the ticks left counters. When the counter becomes zero,
225  // the state machine for the track will run.
226  //
227  //------------------------------------------------------------------------------------------------------------
228  volatile uint8_t timeToInterrupt    = 0;
229  volatile uint8_t timeLeftMainTrack  = 0;
230  volatile uint8_t timeLeftProgTrack  = 0;
231
232  //------------------------------------------------------------------------------------------------------------
233  // The DCC track object maintains an internal log facility for test and debugging purposes. During operation
234  // a set of log entries can be recorded to a log buffer. A log entry consist of the header byte, which
235  // contains in the first byte the 4-bit log id and the 4-bit length of the log data. A log entry can therefore
236  // record up to 16 bytes of payload.
237  //
238  //------------------------------------------------------------------------------------------------------------
239  enum LogId : uint8_t {
240
241      LOG_NIL        = 0,
242      LOG_BEGIN      = 1,
243      LOG_END        = 2,
244      LOG_TSTAMP     = 3,
245      LOG_DCC_IDL    = 4,
246      LOG_DCC_RST    = 5,
247      LOG_DCC_PKT    = 6,
248      LOG_DCC_RCM    = 7,
249      LOG_VAL        = 8,
250      LOG_INV        = 15
251  };
252
253  //------------------------------------------------------------------------------------------------------------
254  // The log buffer and the log index. When writing to the log buffer, the index will always point to the
255  // next available position. Once the buffer is full, no further data can be added.
256  //
257  //------------------------------------------------------------------------------------------------------------
258  const uint16_t  LOG_BUF_SIZE            = 4096;
259
260  bool            logEnabled             = false;
261  bool            logActive              = false;
262  uint16_t        logBufIndex            = 0;
263  uint8_t         logBuf[ LOG_BUF_SIZE ] = { 0 };
264
265  //------------------------------------------------------------------------------------------------------------
266  // RailCom decoder table. The Railcom communication will send raw bytes where only four bits are "one" in
267  // a byte ( hamming weight 4 ). The first two bytes are labelled "channel1" and the remaining six bytes
268  // are labelled "channel2". The actual data is then encode using the table below. Each raw byte will be
269  // translated to a 6 bits of data for the datagram to assemble. In total there are therefore a maximum
270  // of 48bits that are transmitted in a railcom message.
271  //
272  //------------------------------------------------------------------------------------------------------------
273  enum RailComDataBytes : uint8_t {
274
275      INV   = 0xff,
276      BUSY  = 0xfe,
277      ACK   = 0xfd,
278      NACK  = 0xfc,
279      RSV1  = 0xfa,
280      RSV2  = 0xf9,
281      RSV3  = 0xf8
282  };
283
284  const uint8_t railComDecode[256] = {
285
286      INV,    INV,    INV,    INV,    INV,    INV,    INV,    INV,    // 0
287      INV,    INV,    INV,    INV,    INV,    INV,    INV,    ACK,
288
289      INV,    INV,    INV,    INV,    INV,    INV,    INV,    0x33,   // 1
290      INV,    INV,    INV,    0x34,   INV,    0x35,   0x36,   INV,
291
292      INV,    INV,    INV,    INV,    INV,    INV,    INV,    0x3A,   // 2
293      INV,    INV,    INV,    0x3B,   INV,    0x3C,   0x37,   INV,
294
295      INV,    INV,    INV,    0x3F,   INV,    0x3D,   0x38,   INV,    // 3
296      INV,    0x3E,   0x39,   INV,    NACK,   INV,    INV,    INV,
```

```
297
298        INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     0x24 ,   // 4
299        INV ,     INV ,     INV ,     0x23 ,    INV ,     0x22 ,    0x21 ,    INV ,
300
301        INV ,     INV ,     INV ,     0x1F ,    INV ,     0x1E ,    0x20 ,    INV ,    // 5
302        INV ,     0x1D ,    0x1C ,    INV ,     0x1B ,    INV ,     INV ,     INV ,
303
304        INV ,     INV ,     INV ,     0x19 ,    INV ,     0x18 ,    0x1A ,    INV ,    // 6
305        INV ,     0x17 ,    0x16 ,    INV ,     0x15 ,    INV ,     INV ,     INV ,
306
307        INV ,     0x25 ,    0x14 ,    INV ,     0x13 ,    INV ,     INV ,     INV ,    // 7
308        0x32 ,    INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,
309
310        INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     RSV2 ,   // 8
311        INV ,     INV ,     INV ,     0x0E ,    INV ,     0x0D ,    0x0C ,    INV ,
312
313        INV ,     INV ,     INV ,     0x0A ,    INV ,     0x09 ,    0x0B ,    INV ,    // 9
314        INV ,     0x08 ,    0x07 ,    INV ,     0x06 ,    INV ,     INV ,     INV ,
315
316        INV ,     INV ,     INV ,     0x04 ,    INV ,     0x03 ,    0x05 ,    INV ,    // a
317        INV ,     0x02 ,    0x01 ,    INV ,     0x00 ,    INV ,     INV ,     INV ,
318
319        INV ,     0x0F ,    0x10 ,    INV ,     0x11 ,    INV ,     INV ,     INV ,    // b
320        0x12 ,    INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,
321
322        INV ,     INV ,     INV ,     RSV1 ,    INV ,     0x2B ,    0x30 ,    INV ,    // c
323        INV ,     0x2A ,    0x2F ,    INV ,     0x31 ,    INV ,     INV ,     INV ,
324
325        INV ,     0x29 ,    0x2E ,    INV ,     0x2D ,    INV ,     INV ,     INV ,    // d
326        0x2C ,    INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,
327
328        INV ,     RSV3 ,    0x28 ,    INV ,     0x27 ,    INV ,     INV ,     INV ,    // e
329        0x26 ,    INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,
330
331        ACK ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,    // f
332        INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,     INV ,
333    };
334
335    //-------------------------------------------------------------------------------------------------------------
336    // Railcom datagrams are sent from a mobile or a stationary decoder.
337    //
338    //-------------------------------------------------------------------------------------------------------------
339    enum railComDatagramType : uint8_t {
340
341        RX_DG_TYPE_UNDEFINED  = 0,
342        RC_DG_TYPE_MOB        = 1,
343        RC_DG_TYPE_STAT       = 2
344    };
345
346    //-------------------------------------------------------------------------------------------------------------
347    // Each mobile decoder railcom datagram will start with an ID field of four bits. Channel one will use only
348    // the ADR_HIG and ADR_LOW Ids. All IDs can be used for channel 2. Since decoders answer on channel one
349    // for each DCC packet they receive, here is a good chance that channel 1 will contains nonsense data. This
350    // is different for channel two, where only the addressed decoder explicitly answers. To decide whether
351    // a railcom message is valid, you should perhaps ignore channel 1 data and just check channel 2 for this
352    // purpose. A RC datagram starts with the 4-bit ID and an 8 to 32bit payload.
353    //
354    //      RC_DG_MOB_ID_POM       ( 0  )  - 12bit
355    //      RC_DG_MOB_ID_ADR_HIGH  ( 1  )  - 12bit
356    //      RC_DG_MOB_ID_ADR_LOW   ( 2  )  - 12bit
357    //      RC_DG_MOB_ID_APP_EXT   ( 3  )  - 18bit
358    //      RC_DG_MOB_ID_APP_DYN   ( 7  )  - 18bit
359    //      RC_DG_MOB_ID_XPOM_1    ( 8  )  - 36bit
360    //      RC_DG_MOB_ID_XPOM_2    ( 9  )  - 36bit
361    //      RC_DG_MOB_ID_XPOM_3    ( 10 )  - 36bit
362    //      RC_DG_MOB_ID_XPOM_4    ( 11 )  - 36bit
363    //      RC_DG_MOB_ID_TEST      ( 12 )  - ignore
364    //      RC_DG_MOB_ID_SEARCH    ( 14 )  - 48bit
365    //
366    // A datagram with the ID 14 is a DDC-A datagram and all 8 datagram bytes are combined to an 48bit datagram.
367    // A datagram packet can also contain more than one datagram. For example there could be two 18-bit length
368    // datagram in one packet or 3 12-bit packets and so on. Finally, unused bytes in channel two could contain
369    // an ACK to fill them up.
370    //
371    //-------------------------------------------------------------------------------------------------------------
372    enum railComDatagramMobId : uint8_t {
373
374        RC_DG_MOB_ID_POM        = 0,
375        RC_DG_MOB_ID_ADR_HIGH   = 1,
376        RC_DG_MOB_ID_ADR_LOW    = 2,
377        RC_DG_MOB_ID_APP_EXT    = 3,
378        RC_DG_MOB__IDAPP_DYN    = 7,
379        RC_DG_MOB_ID_XPOM_1     = 8,
380        RC_DG_MOB_ID_XPOM_2     = 9,
381        RC_DG_MOB_ID_XPOM_3     = 10,
382        RC_DG_MOB_ID_XPOM_4     = 11,
383        RC_DG_MOB_ID_TEST       = 12,
384        RC_DG_MOB_ID_SEARCH     = 14
385    };
386
387    //-------------------------------------------------------------------------------------------------------------
388    // Similar to the mobile decode, a stationary decoder datagram will start an ID field of four bits. Stationary
389    // decoders also define a datagram with "SRQ" and no ID field to request service from the base station.
390    //
391    // ??? to fill in ...
392    //
393    //      RC_DG_STAT_ID_SRQ      ( 0  )  - 12bit
394    //      RC_DG_STAT_ID_POM      ( 1  )  - 12bit
395    //      RC_DG_STAT_ID_STAT1    ( 4  )  - 12bit
```

```
396   //        RC_DG_STAT_ID_TIME       ( 5  )  - xxbit
397   //        RC_DG_STAT_ID_ERR        ( 6  )  - xxbit
398   //        RC_DG_STAT_ID_XPOM_1     ( 8  )  - 36bit
399   //        RC_DG_STAT_ID_XPOM_2     ( 9  )  - 36bit
400   //        RC_DG_STAT_ID_XPOM_3     ( 10 )  - 36bit
401   //        RC_DG_STAT_ID_XPOM_4     ( 11 )  - 36bit
402   //        RC_DG_STAT_ID_TEST       ( 12 )  - ignore
403   //
404   //-------------------------------------------------------------------------------------------------------
405   enum railComDatagramStatId : uint8_t {
406
407       RC_DG_STAT_ID_SRQ        = 0,
408       RC_DG_STAT_ID_POM        = 1,
409       RC_DG_STAT_ID_STAT1      = 4,
410       RC_DG_STAT_ID_TIME       = 5,
411       RC_DG_STAT_ID_ERR        = 6,
412       RC_DG_STAT_ID_DYN        = 7,
413       RC_DG_STAT_ID_XPOM_1     = 8,
414       RC_DG_STAT_ID_XPOM_2     = 9,
415       RC_DG_STAT_ID_XPOM_3     = 10,
416       RC_DG_STAT_ID_XPOM_4     = 11,
417       RC_DG_STAT_ID_TEST       = 12
418   };
419
420   //-------------------------------------------------------------------------------------------------------
421   // Utility routine for number range checks.
422   //
423   //-------------------------------------------------------------------------------------------------------
424   bool isInRangeU( uint8_t val, uint8_t lower, uint8_t upper ) {
425
426       return (( val >= lower ) && ( val <= upper ));
427   }
428
429   //-------------------------------------------------------------------------------------------------------
430   // Utility function to map a DCC address to a railcom decoder type.
431   //
432   //-------------------------------------------------------------------------------------------------------
433   inline uint8_t mapDccAdrToRailComDatagramType( uint16_t adr ) {
434
435       if      (( adr >= 1 )   && ( adr <= 127 ))  return ( RC_DG_TYPE_MOB );
436       else if (( adr >= 128 ) && ( adr <= 191 ))  return ( RC_DG_TYPE_STAT );
437       else if (( adr >= 192 ) && ( adr <= 231 ))  return ( RC_DG_TYPE_MOB );
438       else                                        return ( RX_DG_TYPE_UNDEFINED );
439   }
440
441   //-------------------------------------------------------------------------------------------------------
442   // Conversion functions between milliAmps and digit values as report4de by the analog to digital converter
443   // hardware. For a better precision, the formula uses 32 bit computation and stores the result back in a
444   // 16 bit quantity.
445   //
446   //-------------------------------------------------------------------------------------------------------
447   uint16_t milliAmpToDigitValue( uint16_t milliAmp, uint16_t digitsPerAmp ) {
448
449       #if 0
450       uint32_t mA = milliAmp;
451       uint32_t dPA = digitsPerAmp;
452       return (( uint16_t ) ( mA * dPA / 1000 ));
453       #endif
454
455       return ((uint16_t) ((((uint32_t) milliAmp ) * ((uint32_t) digitsPerAmp )) / 1000 ));
456   }
457
458   uint16_t digitValueToMilliAmp( uint16_t digitValue, uint16_t digitsPerAmp ) {
459
460       #if 0
461       uint32_t dV = digitValue;
462       uint32_t dPA = digitsPerAmp;
463       return ((uint16_t)( dV * 1000 / dPA ));
464       #endif
465
466       return ((uint16_t) ((((uint32_t) digitValue ) * 1000 ) / ((uint32_t) digitsPerAmp )));
467   }
468
469   //-------------------------------------------------------------------------------------------------------
470   // The DccTrack timer interrupt handler routine implements the heartbeat of the DCC system. The two DCC
471   // track signal generators state machines MAIN and PROG use the same timer interrupt handler. Upon the timer
472   // interrupt, we first will update the time left counters. If a counter falls to zero, the signal state
473   // machine for that track will run and set the DCC signal levels. The state machine returns the next time
474   // interval it expects to be called again and a possible follow up action code. After handling both state
475   // machines, the timer is set to the smaller new remaining minimum time interval of both state machines.
476   // This is the time when the next state machine in one of the  signal generators needs to run. It is
477   // important to always have the timer running, so we keep decrementing the ticks to interrupt values.
478   //
479   // If a state machine determined that it needs to do some more elaborate action, the interrupt handler runs
480   // part two of its work. This split allows to run the time sensitive signal level settings first and any
481   // actions, such as getting the next packet, after both signal generator signal settings have been processed.
482   // Follow up actions are getting the next bit value to transmit, the next packet to send, a power consumption
483   // measurement and Railcom message processing. As we do not have all time in the world, these follow up
484   // actions still should be brief. The state machine carefully selects the spot for requesting such follow up
485   // actions in the DCC bit stream.
486   //
487   // The timer interrupt routine and all it calls runs with interrupts disabled. As said, better be quick.
488   // Top priority is to fetch the next bit and the next packet. Next is the Railcom processing if enabled. If
489   // there are power consumption measurement follow up actions, they are run last. Since the ADC converter
490   // hardware serializes the analog measurements, we will only do one measurement and drop the other. MAIN
491   // always has the higher priority.
492   //
493   // For the MAIN track with cutout enabled, the entry and exit of that cutout is a 29us timer call. That is
494   // awfully short and no follow-up action is scheduled there. All other intervals are either 58us or 116us
```

```
495   // or even longer for the cutout itself and give us some more room.
496   //
497   // ??? we could use timerVal, but this is in microseconds, not ticks. Convert one day...
498   //-------------------------------------------------------------------------------------------------------------
499   void timerCallback( uint32_t timerVal ) {
500
501       uint8_t followUpMain = DCC_SIG_FOLLOW_UP_NONE;
502       uint8_t followUpProg = DCC_SIG_FOLLOW_UP_NONE;
503
504       timeLeftMainTrack -= timeToInterrupt;
505       timeLeftProgTrack -= timeToInterrupt;
506
507       if ( timeLeftMainTrack == 0 ) mainTrack -> runDccSignalStateMachine( &timeLeftMainTrack, &followUpMain );
508       if ( timeLeftProgTrack == 0 ) progTrack -> runDccSignalStateMachine( &timeLeftProgTrack, &followUpProg );
509
510       // take out after test ...
511       // timeToInterrupt = min( timeLeftMainTrack, timeLeftProgTrack );
512
513       timeToInterrupt = (( timeLeftMainTrack < timeLeftProgTrack ) ? timeLeftMainTrack : timeLeftProgTrack );
514
515       CDC::setRepeatingTimerLimit( timeToInterrupt * TICK_IN_MICROSECONDS );
516
517       if (( followUpMain != DCC_SIG_FOLLOW_UP_NONE ) && ( followUpMain != DCC_SIG_FOLLOW_UP_MEASURE_CURRENT )) {
518
519           if      ( followUpMain == DCC_SIG_FOLLOW_UP_GET_BIT )          mainTrack -> getNextBit( );
520           else if ( followUpMain == DCC_SIG_FOLLOW_UP_GET_PACKET )       mainTrack -> getNextPacket( );
521           else if ( followUpMain == DCC_SIG_FOLLOW_UP_START_RAILCOM_IO ) mainTrack -> startRailComIO( );
522           else if ( followUpMain == DCC_SIG_FOLLOW_UP_STOP_RAILCOM_IO )  mainTrack -> stopRailComIO( );
523           else if ( followUpMain == DCC_SIG_FOLLOW_UP_RAILCOM_MSG )       mainTrack -> handleRailComMsg( );
524       }
525
526       if (( followUpProg != DCC_SIG_FOLLOW_UP_NONE ) && ( followUpProg != DCC_SIG_FOLLOW_UP_MEASURE_CURRENT )) {
527
528           if      ( followUpProg == DCC_SIG_FOLLOW_UP_GET_BIT )    progTrack -> getNextBit( );
529           else if ( followUpProg == DCC_SIG_FOLLOW_UP_GET_PACKET ) progTrack -> getNextPacket( );
530       }
531
532       if      ( followUpMain == DCC_SIG_FOLLOW_UP_MEASURE_CURRENT ) mainTrack -> powerMeasurement( );
533       else if ( followUpProg == DCC_SIG_FOLLOW_UP_MEASURE_CURRENT ) progTrack -> powerMeasurement( );
534
535   } // timerCallback
536
537   //-------------------------------------------------------------------------------------------------------------
538   // When all DCC track objects are initialized, the last thing to do before operation is to  start the timer
539   // heartbeat. We start b firing up the timer with a first short delay, so when it expires the timer routine
540   // will be called. The current time tick of zero and no ticks left, so the state machine for the signals
541   // will run.
542   //
543   //-------------------------------------------------------------------------------------------------------------
544   void initDccTrackProcessing( ) {
545
546       timeToInterrupt    = 0;
547       timeLeftMainTrack  = 0;
548       timeLeftProgTrack  = 0;
549
550       CDC::startRepeatingTimer( TICK_IN_MICROSECONDS );
551   }
552
553   //-------------------------------------------------------------------------------------------------------------
554   // DCC log functions for printing the DCC log buffer. The fist byte of each log entry has encoded the log
555   // entry type and the entry length. Depending on the log entry type, data is displayed as just the header,
556   // a numeric 16-bit value, a numeric 32-bit vale or as an array of data bytes. We return the length of the
557   // DCC log entry.
558   //
559   //-------------------------------------------------------------------------------------------------------------
560   void printLogTimeStamp( uint16_t index ) {
561
562       uint32_t ts = logBuf[ index ];
563       ts = ( ts << 8 ) | logBuf[ index + 1 ];
564       ts = ( ts << 8 ) | logBuf[ index + 2 ];
565       ts = ( ts << 8 ) | logBuf[ index + 3 ];
566       printf( "0x%x", ts );
567   }
568
569   void printLogVal( uint16_t index ) {
570
571       uint16_t val = logBuf[ index ] << 8 | logBuf[ index + 1 ];
572       printf( "0x%04x", val );
573   }
574
575   void printLogData( uint16_t index, uint8_t len ) {
576
577       for ( int i = 0; i < len; i++ ) printf( "0x%02x ", logBuf[ index + i ] );
578   }
579
580   uint8_t printLogEntry( uint16_t index ) {
581
582       if ( index < LOG_BUF_SIZE ) {
583
584           uint8_t logEntryId  = logBuf[ index ] >> 4;
585           uint8_t logEntryLen = logBuf[ index ] & 0x0F;
586
587           switch ( logEntryId ) {
588
589               case LOG_NIL:      printf( "NIL       " ); break;
590               case LOG_BEGIN:    printf( "BEGIN     " ); break;
591               case LOG_END:      printf( "END       " ); break;
592               case LOG_TSTAMP:   printf( "TSTAMP    " ); break;
593               case LOG_DCC_IDL:  printf( "DCC_IDLE  " ); break;
```

```
594                 case LOG_DCC_RST:   printf( "DCC_RESET   " ); break;
595                 case LOG_DCC_PKT:   printf( "DCC_PKT     " ); break;
596                 case LOG_DCC_RCM:   printf( "DCC_RCOM    " ); break;
597                 case LOG_VAL:       printf( "VAL         " ); break;
598                 default:            printf( "INVALID ( 0x%02 )", logBuf[ index ] >> 4 );
599             }
600
601             if      ( logEntryId == LOG_TSTAMP  )  printLogTimeStamp( index + 1 );
602             else if ( logEntryId == LOG_VAL     )  printLogVal( index + 1 );
603             else                                   printLogData( index + 1, logEntryLen );
604
605             return ( logEntryLen + 1 );
606         }
607         else return ( 0 );
608 }
609
610 //---------------------------------------------------------------------------------------------------------
611 // There are a couple of routines to write the log data. For convenience, some of the log entry types are
612 // available as a direct call. The order of data entry for numeric types is big endian, i.e. most significant
613 // byte first.
614 //
615 //---------------------------------------------------------------------------------------------------------
616 void writeLogData( uint8_t id, uint8_t *buf, uint8_t len ) {
617
618     if ( logActive ) {
619
620         len = len % 16;
621         if ( logBufIndex + len + 1 < LOG_BUF_SIZE ) {
622
623             logBuf[ logBufIndex ++ ] = ( id << 4 ) | len;
624             for ( uint8_t i = 0; i < len; i++ ) logBuf[ logBufIndex ++ ] = buf[ i ];
625         }
626     }
627 }
628
629 void writeLogId( uint8_t id ) {
630
631     if ( logActive ) logBuf[ logBufIndex ++ ] = ( id << 4 ) | 1;
632 }
633
634 void writeLogTs( ) {
635
636     if ( logActive ) {
637
638         uint32_t ts = CDC::getMicros( );
639         logBuf[ logBufIndex ++ ] = ( LOG_TSTAMP << 4 ) | 4;
640         logBuf[ logBufIndex ++ ] = ( ts >> 24 ) & 0xFF;
641         logBuf[ logBufIndex ++ ] = ( ts >> 16 ) & 0xFF;
642         logBuf[ logBufIndex ++ ] = ( ts >> 8  ) & 0xFF;
643         logBuf[ logBufIndex ++ ] = ( ts >> 0  ) & 0xFF;
644     }
645 }
646
647 void writeLogVal( uint8_t valId, uint16_t val ) {
648
649     if ( logActive ) {
650
651         logBuf[ logBufIndex ++ ] = ( LOG_VAL << 4 ) | 3;
652         logBuf[ logBufIndex ++ ] = valId;
653         logBuf[ logBufIndex ++ ] = val >> 8;
654         logBuf[ logBufIndex ++ ] = val & 0xFF;
655     }
656 }
657
658 //---------------------------------------------------------------------------------------------------------
659 // The log management routines. A typical transaction to log would start the logging process and then end
660 // it after the operation to analyze/debug. The "enableLog" call should be used to enable the logging
661 // process all together, the other calls will only do work when the log is enabled. With this call the
662 // recording process could be controlled from a command line setting or so.
663 //
664 //---------------------------------------------------------------------------------------------------------
665 void enableLog( bool arg ) {
666
667     logEnabled = arg;
668     logActive  = false;
669 }
670
671 void beginLog( ) {
672
673     if ( logEnabled ) {
674
675         logActive   = true;
676         logBufIndex = 0;
677         writeLogId( LOG_BEGIN );
678         writeLogTs( );
679     }
680 }
681
682 void endLog( ) {
683
684     if ( logActive ) {
685
686         writeLogTs( );
687         writeLogId( LOG_END );
688         logActive = false;
689     }
690 }
691
692 //---------------------------------------------------------------------------------------------------------
```

```
693   // A simple routine to print out the log data, one entry on one line.
694   //
695   // ??? what is exactly the stop condition ? The END entry having a length of zero ?
696   //------------------------------------------------------------------------------------------------------------
697   void printLog( ) {
698
699       if ( logEnabled ) {
700
701           if ( ! logActive ) {
702
703               if ( logBufIndex > 0 ) {
704
705                   printf( "\n" );
706
707                   uint16_t entryIndex  = 0;
708                   uint8_t  entryLen    = 0;
709
710                   while ( entryIndex < logBufIndex ) {
711
712                       entryLen = printLogEntry( entryIndex );
713                       printf( "\n" );
714
715                       if ( entryLen > 0 ) entryIndex += entryLen;
716                       else                break;
717                   }
718               }
719               else printf( "DCC Log Buf: Nothing recorded\n" );
720           }
721           else printf( "DCC Log Active\n" );
722       }
723       else printf( "DCC Log disabled\n" );
724   }
725
726   }; // namespace
727
728
729   //=============================================================================================================
730   //=============================================================================================================
731   //
732   // Object part.
733   //
734   //=============================================================================================================
735   //=============================================================================================================
736
737
738   //------------------------------------------------------------------------------------------------------------
739   // "startDccProcessing" will kick off the DCC timer for the track signal processing. The idea is that the
740   // program first creates all the DCC track objects, does whatever else needs to be initialized and then starts
741   // the signal generation with this routine.
742   //
743   //------------------------------------------------------------------------------------------------------------
744   void LcsBaseStationDccTrack::startDccProcessing( ) {
745
746       initDccTrackProcessing( );
747   }
748
749   //------------------------------------------------------------------------------------------------------------
750   // Object instance section. The DccTrack constructor. Nothing to do so far.
751   //
752   //------------------------------------------------------------------------------------------------------------
753   LcsBaseStationDccTrack::LcsBaseStationDccTrack( ) { }
754
755   //------------------------------------------------------------------------------------------------------------
756   // "setupDccTrack" performs the setup tasks for the DCC track.  We will configure the hardware, the DCC
757   // packet options such as preamble and postamble length, the initial state machine state current consumption
758   // limit and load the initial packet into the active buffer. There is quite a list of parameters and options
759   // that can be set. This routine does the following checking:
760   //
761   //    - the pins used in the CDC layer must be a pair ( for atmega controllers ).
762   //    - the sensePin must be an analog input pin.
763   //    - if the track is a service track, cutout and RailCom are not supported.
764   //    - if RailCom is set, Cutout must be set too.
765   //    - the initial current limit consumption setting must be less than the current limit setting.
766   //    - the current limit setting must be less than the maximum current limit setting.
767   //
768   // Once the DCC track object is initialized, the last thing to do is to remember the object instance in the
769   // file static variables. This is necessary for the interrupt handlers to work. If any of the checks fails,
770   // the flag field will have the error bit set.
771   //
772   //------------------------------------------------------------------------------------------------------------
773   uint8_t LcsBaseStationDccTrack::setupDccTrack( LcsBaseStationTrackDesc* trackDesc ) {
774
775       if ((  trackDesc -> enablePin  == CDC::UNDEFINED_PIN ) ||
776           (  trackDesc -> dccSigPin1 == CDC::UNDEFINED_PIN ) ||
777           (  trackDesc -> dccSigPin2 == CDC::UNDEFINED_PIN ) ||
778           (  trackDesc -> sensePin   == CDC::UNDEFINED_PIN )) {
779
780           flags = DT_F_CONFIG_ERROR;
781           return ( ERR_DCC_PIN_CONFIG );
782       }
783
784       if ((( trackDesc -> options & DT_OPT_SERVICE_MODE_TRACK ) && ( trackDesc -> options & DT_OPT_CUTOUT ))    ||
785           (( trackDesc -> options & DT_OPT_SERVICE_MODE_TRACK ) && ( trackDesc -> options & DT_OPT_RAILCOM ))   ||
786           (( trackDesc -> options & DT_OPT_RAILCOM ) && ( ! ( trackDesc -> options & DT_OPT_CUTOUT )))          ||
787           ( trackDesc -> initCurrentMilliAmp  > trackDesc -> limitCurrentMilliAmp )                             ||
788           ( trackDesc -> limitCurrentMilliAmp > trackDesc -> maxCurrentMilliAmp )                               ||
789           ( trackDesc -> startTimeThresholdMillis > MAX_START_TIME_THRESHOLD_MILLIS )                           ||
790           ( trackDesc -> stopTimeThresholdMillis > MAX_STOP_TIME_THRESHOLD_MILLIS )                             ||
791           ( trackDesc -> overloadTimeThresholdMillis > MAX_OVERLOAD_TIME_THRESHOLD_MILLIS )                     ||
```

128

```
792            ( trackDesc -> overloadEventThreshold > MAX_OVERLOAD_EVENT_COUNT )                                           ||
793            ( trackDesc -> overloadRestartThreshold > MAX_OVERLOAD_RESTART_COUNT )
794            ) {
795
796            flags = DT_F_CONFIG_ERROR;
797            return ( ERR_DCC_TRACK_CONFIG );
798        }
799
800        signalState               = DCC_SIG_START_BIT;
801        trackState                = DCC_TRACK_POWER_OFF;
802        flags                     = DT_F_DEFAULT_SETTING;
803        options                   = trackDesc -> options;
804        enablePin                 = trackDesc -> enablePin;
805        dccSigPin1                = trackDesc -> dccSigPin1;
806        dccSigPin2                = trackDesc -> dccSigPin2;
807        sensePin                  = trackDesc -> sensePin;
808        uartRxPin                 = trackDesc -> uartRxPin;
809        initCurrentMilliAmp       = trackDesc -> initCurrentMilliAmp;
810        limitCurrentMilliAmp      = trackDesc -> limitCurrentMilliAmp;
811        maxCurrentMilliAmp        = trackDesc -> maxCurrentMilliAmp;
812        startTimeThreshold        = trackDesc -> startTimeThresholdMillis;
813        stopTimeThreshold         = trackDesc -> stopTimeThresholdMillis;
814        overloadTimeThreshold     = trackDesc -> overloadTimeThresholdMillis;
815        overloadEventThreshold    = trackDesc -> overloadEventThreshold;
816        overloadRestartThreshold  = trackDesc -> overloadRestartThreshold;
817
818        // ??? MILLI_VOLT_PER_DIGIT is actually 4,72V / 1024 = 4,6 mV. How to make this more precise ?
819
820        milliVoltPerAmp           = trackDesc -> milliVoltPerAmp;
821        digitsPerAmp              = milliVoltPerAmp / MILLI_VOLT_PER_DIGIT;
822
823        limitCurrentDigitValue    = milliAmpToDigitValue( initCurrentMilliAmp, digitsPerAmp );
824        ackThresholdDigitValue    = milliAmpToDigitValue( ACK_TRESHOLD_VAL, digitsPerAmp );
825        actualCurrentDigitValue   = 0;
826        dccPacketsSend            = 0;
827        totalPwrSamplesTaken      = 0;
828        lastPwrSamplePerSecTaken  = 0;
829        pwrSamplesPerSec          = 0;
830
831        CDC::configureDio( enablePin, CDC::OUT );
832        CDC::configureDio( dccSigPin1, CDC::OUT );
833        CDC::configureDio( dccSigPin2, CDC::OUT );
834        CDC::configureAdc( sensePin );
835
836        CDC::writeDio( enablePin, false );
837        CDC::writeDioPair( dccSigPin1, false, dccSigPin2, false );
838
839        CDC::onTimerEvent( timerCallback );
840
841        if ( options & DT_OPT_SERVICE_MODE_TRACK ) {
842
843            progTrack     =   this;
844            preambleLen   =   PROG_PACKET_PREAMBLE_LEN;
845            postambleLen  =   PROG_PACKET_POSTAMBLE_LEN;
846            flags        |=   DT_F_SERVICE_MODE_ON;
847            activeBufPtr  = &resetDccPacket;
848            pendingBufPtr = &dccBuf1;
849        }
850        else {
851
852            mainTrack     =   this;
853            preambleLen   =   MAIN_PACKET_PREAMBLE_LEN;
854            postambleLen  =   MAIN_PACKET_POSTAMBLE_LEN;
855            activeBufPtr  = &idleDccPacket;
856            pendingBufPtr = &dccBuf1;
857        }
858
859        if ( trackDesc -> options & DT_OPT_CUTOUT ) {
860
861            preambleLen =  MAIN_PACKET_PREAMBLE_LEN - DCC_PACKET_CUTOUT_LEN;
862            flags       |= DT_F_CUTOUT_MODE_ON;
863            signalState =  DCC_SIG_CUTOUT_START;
864        }
865
866        if ( trackDesc -> options & DT_OPT_RAILCOM ) {
867
868            flags |= DT_F_RAILCOM_MODE_ON;
869            if ( CDC::configureUart( uartRxPin, CDC::UNDEFINED_PIN, 250000, CDC::UART_MODE_8N1 ) != ALL_OK ) {
870
871                flags = DT_F_CONFIG_ERROR;
872                return ( ERR_DCC_TRACK_CONFIG );
873            }
874        }
875
876        return ( ALL_OK );
877    }
878
879    //---------------------------------------------------------------------------------------------------------------------
880    // DCC signal generation is done through a state machine that is invoked when the DCC timer interrupts. The
881    // interrupt timer thinks in multiples of 29us, which we will just call a "tick" in the description below. It
882    // runs as part of the timer interrupt handler, so we need to be short and quick. First, the HW signals are
883    // set. This keeps the track signals in their timing. Next, the new signal state, time to run again and any
884    // other follow up action of this invocation are set. The idea is to separate HW signal generation and follow
885    // up actions. The timer interrupt handler will first call both state machines, MAIN and PROG, and then work
886    // on the optional follow-up actions. The state machine has the following states:
887    //
888    // DCC_SIG_CUTOUT_START: if the cutout option is on, a new DCC packet starts with this signal state. The
889    // DCC signal goes HIGH for one tick and the signal state advances to signal state DCC_SIG_CUTOUT_1.
890    //
```

```
891   // DCC_SIG_CUTOUT_1: this stage sets the signal to CUTOUT for cutout period ticks. Also, if the RailCom
892   // is enabled, there is a follow up request to start the serial IO read function. The signal state advances
893   // to signal state DCC_SIG_CUTOUT_2.
894   //
895   // DCC_SIG_CUTOUT_2: this stage sets the signal to LOW for the cutout end tick. The signal state advances
896   // to signal state DCC_SIG_CUTOUT_3.
897   //
898   // DC_SIG_CUTOUT_3: the DC_SIG_CUTOUT_3 and DC_SIG_END_CUTOUT states represent the first DCC "One" after
899   // the cutout. The DCC signal is set to HIGH and the next period is two ticks. The follow-up request is to
900   // disable the UART receiver. The signal state advances to DC_SIG_CUTOUT_END.
901   //
902   // DC_SIG_CUTOUT_END: The DC_SIG_END_CUTOUT state is the second half of the DCC one. The signal is set
903   // to low and the next period to two ticks. If RailCom is enabled, this is the state where a follow up
904   // to handle the RailCom data takes place. The next state is then DCC_SIG_START_BIT to handle the next
905   // packet, starting with the preamble of DCC ones.
906   //
907   // DCC_SIG_START_BIT: this stage is the start of the DCC packet bits, which are preamble, the data bytes
908   // with separators and postamble. If the cutout option is off, this is also the start for the DCC packet.
909   // The signal is set HIGH, the tick count is two and we need a follow up to get the current bit, which
910   // determines the length of the signal for the bit we just started. The next stage is signal state
911   // DCC_SIG_TEST_BIT.
912   //
913   // DCC_SIG_TEST_BIT: coming from signal state DCC_SIG_START_BIT, we need to see if the current bit is a ONE
914   // or ZERO bit. If a ONE bit, the signal needs to become LOW, the next period is 2 ticks and the next state
915   // is signal state DCC_SIG_START_BIT. If it is the last ONE bit of the postamble, the next packet and
916   // signal state needs to be determined. For a CUTOUT enabled track this is state DCC_SIG_START_CUTOUT, else
917   // DCC_SIG_START_BIT. If a ZERO bit, the signal is kept HIGH for another two ticks and the state is
918   // DCC_SIG_ZERO_SECOND_HALF.
919   //
920   // The ZERO bit case is also a good place to do a current measurement. We are already two ticks into the
921   // signal polarity change and there should be no spike from the signal level transition. However, we do
922   // not want to measure all zero bits since this would mean several hundreds to few thousands per second.
923   // Each data byte starts with a DCC ZERO bit. We will just sample the current there and end up with a few
924   // hundred samples per second, which is less of a burden but still often enough for overload detection
925   // and so on.
926   //
927   // DCC_SIG_ZERO_SECOND_HALF: coming from signal state DCC_SIG_TEST_BIT, we need to transmit the second half
928   // of the ZERO bit. The signal is set to LOW for four ticks and set the next stage is signal state to
929   // DCC_SIG_START_BIT.
930   //
931   // Note: for a 16Mhz Atmega the implementation for the cutout support is a close call. If the timer value
932   // setting takes place after the internal timer counter HW has passed this value, you wrap around and the
933   // interrupt happens the next time the timer value matches, which is about 4 milliseconds later! If you see
934   // such a gap in the DCC signal, this is perhaps the issue. When using the railcom/cutout option it is
935   // recommended to set the processor frequency to 20Mhz, which you can do in your own design, but not on
936   // an Arduino board.
937   //
938   //------------------------------------------------------------------------------------------------------------
939   void LcsBaseStationDccTrack::runDccSignalStateMachine(
940
941       volatile uint8_t  *timeToInterrupt,
942       uint8_t           *followUpAction
943
944       ) {
945
946       switch ( signalState ) {
947
948           case DCC_SIG_CUTOUT_START: {
949
950               CDC::writeDioPair( dccSigPin1, true, dccSigPin2, false );
951               *timeToInterrupt  = TICKS_29_MICROS;
952               *followUpAction   = DCC_SIG_FOLLOW_UP_NONE;
953               signalState       = DCC_SIG_CUTOUT_1;
954
955           } break;
956
957           case DCC_SIG_CUTOUT_1: {
958
959               CDC::writeDioPair( dccSigPin1, false, dccSigPin2, false );
960               *timeToInterrupt  = TICKS_CUTOUT_MICROS;
961               *followUpAction   = (( flags & DT_F_RAILCOM_MODE_ON ) ?
962                                   DCC_SIG_FOLLOW_UP_START_RAILCOM_IO : DCC_SIG_FOLLOW_UP_NONE );
963               signalState       = DCC_SIG_CUTOUT_2;
964
965           } break;
966
967           case DCC_SIG_CUTOUT_2: {
968
969               CDC::writeDioPair( dccSigPin1, false, dccSigPin2, true );
970               *timeToInterrupt  = TICKS_29_MICROS;
971               *followUpAction   = DCC_SIG_FOLLOW_UP_NONE;
972               signalState       = DCC_SIG_CUTOUT_3;
973
974           } break;
975
976           case DCC_SIG_CUTOUT_3: {
977
978               CDC::writeDioPair( dccSigPin1, true, dccSigPin2, false );
979               *timeToInterrupt  = TICKS_58_MICROS;
980               signalState       = DCC_SIG_CUTOUT_END;
981
982               if ( flags & DT_F_RAILCOM_MODE_ON ) {
983
984                   flags            |= DT_F_RAILCOM_MSG_PENDING;
985                   *followUpAction = DCC_SIG_FOLLOW_UP_STOP_RAILCOM_IO;
986               }
987               else *followUpAction = DCC_SIG_FOLLOW_UP_NONE;
988
989           } break;
```

```
 990
 991            case DCC_SIG_CUTOUT_END: {
 992
 993                CDC::writeDioPair( dccSigPin1, false, dccSigPin2, true );
 994                *timeToInterrupt  = TICKS_58_MICROS;
 995                *followUpAction   = (( flags & DT_F_RAILCOM_MODE_ON ) ?
 996                                    DCC_SIG_FOLLOW_UP_RAILCOM_MSG : DCC_SIG_FOLLOW_UP_NONE );
 997                signalState       = DCC_SIG_START_BIT;
 998
 999            } break;
1000
1001            case DCC_SIG_START_BIT: {
1002
1003                CDC::writeDioPair( dccSigPin1, true, dccSigPin2, false );
1004                *timeToInterrupt  = TICKS_58_MICROS;
1005                *followUpAction   = DCC_SIG_FOLLOW_UP_GET_BIT;
1006                signalState       = DCC_SIG_TEST_BIT;
1007
1008            } break;
1009
1010            case DCC_SIG_TEST_BIT: {
1011
1012                if ( currentBit ) {
1013
1014                    CDC::writeDioPair( dccSigPin1, false, dccSigPin2, true );
1015
1016                    if ( postambleSent >= postambleLen ) {
1017
1018                        *followUpAction = DCC_SIG_FOLLOW_UP_GET_PACKET;
1019                        signalState     = (( flags & DT_F_CUTOUT_MODE_ON ) ? DCC_SIG_CUTOUT_START : DCC_SIG_START_BIT );
1020                    }
1021                    else {
1022
1023                        *followUpAction = DCC_SIG_FOLLOW_UP_NONE;
1024                        signalState     = DCC_SIG_START_BIT;
1025                    }
1026                }
1027                else {
1028
1029                    *followUpAction   = (( bitsSent == 0 ) ? DCC_SIG_FOLLOW_UP_MEASURE_CURRENT :  DCC_SIG_FOLLOW_UP_NONE );
1030                    signalState       = DCC_SIG_ZERO_SECOND_HALF;
1031                }
1032
1033                *timeToInterrupt  = TICKS_58_MICROS;
1034
1035            } break;
1036
1037            case DCC_SIG_ZERO_SECOND_HALF: {
1038
1039                CDC::writeDioPair( dccSigPin1, false, dccSigPin2, true );
1040                *timeToInterrupt  = TICKS_116_MICROS;
1041                *followUpAction   = DCC_SIG_FOLLOW_UP_NONE;
1042                signalState       = DCC_SIG_START_BIT;
1043
1044            } break;
1045
1046            default: {
1047
1048                *followUpAction   = DCC_SIG_FOLLOW_UP_NONE;
1049                *timeToInterrupt  = TICKS_58_MICROS;
1050            }
1051        }
1052 }
1053
1054 //--------------------------------------------------------------------------------------------------------
1055 // The "getNextBit" routine works through the active packet buffer bit for bit. A packet consists of the
1056 // optional cutout sequence, the preamble bits, the data bytes separated by a ZERO bit and the postamble bits.
1057 // The cutout option, the preamble and postamble are configured at DCC track object init time. The preamble
1058 // length is different for MAIN and PROG tracks with the the cutout period overlaid at the beginning of the
1059 // preamble. The postamble is currently always just one HIGH bit, according to standard.
1060 //
1061 // The routine works first through the preamble bit count, then through the data byte bits, and finally
1062 // through the postamble bits. The bits to select from the data byte is done with a 9-bit mask. Remember that
1063 // the first bit to send is the data byte separator, which is always a zero. We run from 0 to 8 through the
1064 // bit mask, the first bit being the ZERO bit.
1065 //
1066 //--------------------------------------------------------------------------------------------------------
1067 void LcsBaseStationDccTrack::getNextBit( ) {
1068
1069     if ( preambleSent < preambleLen ) {
1070
1071         currentBit = true;
1072         preambleSent ++;
1073     }
1074     else if ( bytesSent < activeBufPtr -> len ) {
1075
1076         currentBit = activeBufPtr -> buf[ bytesSent ] & bitMask9[ bitsSent ];
1077         bitsSent ++;
1078
1079         if ( bitsSent == 9 ) {
1080
1081             bytesSent ++;
1082             bitsSent = 0;
1083         }
1084     }
1085     else if ( postambleSent < postambleLen ) {
1086
1087         currentBit = true;
1088         postambleSent ++;
```

```
1089          }
1090    }
1091
1092    //-------------------------------------------------------------------------------------------------------
1093    // If all bits of a packet have been processed, the next packet will be determined during the last ONE bit
1094    // transmission of the postamble. If there is a non-zero repeat count on the current packet, the same packet
1095    // is sent again until the repeat count drops to zero. On a zero repeat count, we check if there is a pending
1096    // packet. If so, it is copied to the active buffer and the pending flag is reset. This signals anyone waiting,
1097    // that the next packet can be queued. If there is no pending packet, we still need to keep the track going and
1098    // will load an IDLE or RESET packet.
1099    //
1100    // For non-service mode packets, there is a requirement that a decoder should not be receive two consecutive
1101    // packets. The standards talks about 5 milliseconds between two packets to the same decoder. For now, we will
1102    // not do anything special. A decoder will most likely, if there is more than one decoder active, not be
1103    // addressed in two consecutive packets, simply because the session refresh mechanism will go round robin
1104    // through the session list. However, if there is only one decoder active, two packets will be sent in a
1105    // row, but the decoders are robust enough to ignore this fact. Better run more than one loco :-).
1106    //
1107    // This routine is the central place to submit a DCC packet to the track and therefore a good place to write
1108    // a DCC_LOG record. We distinguish between a RESET, an IDLE and a data packet. Note that these records will
1109    // only be written when DCC logging is enabled.
1110    //
1111    //-------------------------------------------------------------------------------------------------------
1112    void LcsBaseStationDccTrack::getNextPacket( ) {
1113
1114        bytesSent     = 0;
1115        bitsSent      = 0;
1116        preambleSent  = 0;
1117        postambleSent = 0;
1118
1119        if ( activeBufPtr -> repeat > 0 ) {
1120
1121            activeBufPtr -> repeat --;
1122
1123            writeLogData( LOG_DCC_PKT, activeBufPtr -> buf, activeBufPtr -> len );
1124        }
1125        else if ( flags & DT_F_DCC_PACKET_PENDING ) {
1126
1127            activeBufPtr  = pendingBufPtr;
1128            pendingBufPtr = (( pendingBufPtr == &dccBuf1 ) ? &dccBuf2 : &dccBuf1 );
1129            flags &= ~ DT_F_DCC_PACKET_PENDING;
1130
1131            writeLogData( LOG_DCC_PKT, activeBufPtr -> buf, activeBufPtr -> len );
1132        }
1133        else {
1134
1135            if ( flags & DT_F_SERVICE_MODE_ON ) {
1136
1137                activeBufPtr = &resetDccPacket;
1138                writeLogId( LOG_DCC_RST );
1139            }
1140            else {
1141
1142                activeBufPtr = &idleDccPacket;
1143                writeLogId( LOG_DCC_IDL );
1144            }
1145        }
1146
1147        dccPacketsSend ++;
1148    }
1149
1150    //-------------------------------------------------------------------------------------------------------
1151    // Railcom. If the cutout period and the RailCom feature is enabled, the signal state machine will also start
1152    // and stop the UART reader for RailCom data. The final message is then to handle that message. In the cutout
1153    // period, a decoder sends 8 data bytes. They are divided into two channels, 2bytes and another 6 bytes. The
1154    // bytes themselves are encoded such that each byte has four bits set, i.e. a hamming weight of 4. The first
1155    // channel is used to just send the locomotive address when the decoder is addressed. The second channel is
1156    // used only when the decoder is explicitly addressed via a CV operation command to provide the answer to the
1157    // request.
1158    //
1159    // The received datagrams are also recorded in the DCC_LOG, if enabled.
1160    //
1161    // ??? under construction....
1162    // ??? we could store the last loco address in some global variable.
1163    // ??? we could store the channel 2 datagram in the corresponding session.
1164    // ??? still, both pieces of data needs to go somewhere before the next message is received...
1165    //-------------------------------------------------------------------------------------------------------
1166    void LcsBaseStationDccTrack::startRailComIO( ) {
1167
1168        CDC::startUartRead( uartRxPin );
1169    }
1170
1171    void LcsBaseStationDccTrack::stopRailComIO( ) {
1172
1173        CDC::stopUartRead( uartRxPin );
1174    }
1175
1176    uint8_t LcsBaseStationDccTrack::handleRailComMsg( ) {
1177
1178        railComBufIndex = CDC::getUartBuffer( uartRxPin, railComMsgBuf, sizeof( railComMsgBuf ));
1179
1180        writeLogData( LOG_DCC_RCM, railComMsgBuf, railComBufIndex );
1181
1182        for ( uint8_t i = 0; i < railComBufIndex; i++ ) {
1183
1184            uint8_t dataByte = railComDecode[ railComMsgBuf[ i ]];
1185
1186            if      ( dataByte == ACK ) ;
1187            else if ( dataByte == NACK ) ;
```

```
1188            else if ( dataByte == BUSY ) ;
1189            else if ( dataByte < 64 ) {
1190
1191                // ??? valid
1192                // ??? a railCom message can have multiple datagrams
1193                // we would need to handle each datagram, one at a time or fill them into a kind of structure
1194                // that has a slot for the up to maximum 4 datagrams per railCom cutout period.
1195            }
1196            else {
1197
1198                // ??? invalid packet ... if this is channel2, discard the entire message.
1199            }
1200
1201            railComMsgBuf[ i ] = dataByte;
1202        }
1203
1204        flags &= ~ DT_F_RAILCOM_MSG_PENDING;
1205        return ( ALL_OK );
1206 }
1207
1208 // ??? not very useful, but good for debugging and initial testing .... and it works like a champ :-)
1209
1210 uint8_t LcsBaseStationDccTrack::getRailComMsg( uint8_t *buf, uint8_t bufLen ) {
1211
1212        if (( railComBufIndex > 0 ) && ( bufLen > 0 )) {
1213
1214            uint8_t i = 0;
1215
1216            do {
1217
1218                buf[ i ] = railComMsgBuf[ i ];
1219                i++;
1220
1221            } while (( i < railComBufIndex ) && ( i < bufLen ));
1222
1223            return ( i );
1224
1225        } else return ( 0 );
1226 }
1227
1228 //-------------------------------------------------------------------------------------------------------------
1229 // DCC track power is not just a matter of turning power on or off. To address all the requirements of the
1230 // standard, the track is managed by a state machine that implements the start and stop sequences. It is also
1231 // important that we do not really block the progress of the entire base station, so any timing calls are
1232 // handled by timestamp comparison in state machine WAIT states. The track state machine routine is expected
1233 // to be called very often.
1234 //
1235 //  DCC_TRACK_POWER_START1    - this is the first state of a start sequence. When the track should be powered
1236 //                              on, the first activity is to set the status flags and enable the power module.
1237 //                              We set the power module current consumption to the initial limit configured.
1238 //                              The next state is TRACK_POWER_START2.
1239 //
1240 //  DCC_TRACK_POWER_START2    - we stay in this state until the threshold time has passed. Once the threshold
1241 //                              is reached, the current consumption limit is set to the configured limit.
1242 //                              Then we move on to DCC_TRACK_POWER_ON.
1243 //
1244 //  DCC_TRACK_POWER_ON        - this is the state when power is on and things are running normal. An overload
1245 //                              situation is set by the current measurement routines through setting the
1246 //                              overload status flag. We make sure that we have seen a couple of overloads
1247 //                              in a row before taking action which is to turn power off and set the
1248 //                              DCC_TRACK_POWER_OVERLOAD state. Otherwise we stay in this state.
1249 //
1250 //  DCC_TRACK_POWER_OVERLOAD  - with power turned off, we stay in this state until the threshold time has
1251 //                              passed. If passed, the overload restart count is incremented and checked for
1252 //                              its threshold. If reached, we have tried to restart several times and failed.
1253 //                              The track state becomes DCC_TRACK_POWER_STOP1, something is wrong on the track.
1254 //                              If not, we move on to DCC_TRACK_POWER_START1.
1255 //
1256 //  DCC_TRACK_POWER_STOP1     - this state initiates a shutdown sequence. We disable the power module, set
1257 //                              status flags and advance to the DCC_TRACK_POWER_STOP2 state.
1258 //
1259 //  DCC_TRACK_POWER_STOP2     - we stay in this state until the configured threshold has passed. Then we move
1260 //                              on to DCC_TRACK_POWER_OFF. The key reason for this time delay is to implement
1261 //                              the requirement that track turned off and perhaps switched to another mode,
1262 //                              should be powerless for one second. Switch track modes becomes simply a matter
1263 //                              of stopping and then starting again.
1264 //
1265 //  DCC_TRACK_POWER_OFF       - the track is disabled. We just stay in this state until the state is set to
1266 //                              a different state from outside.
1267 //
1268 // During the power on state, we also append the actual current measurement value to a circular buffer when
1269 // the time interval for this kind of measurement has passed. The idea is to measure the samples at a more
1270 // or less constant interval rate and compute the power consumption RMS value from the data in the buffer
1271 // when requested. In the interest of minimizing the controller load, the calculation is done in digit values
1272 // the result is presented in then in milliAmps.
1273 //
1274 //-------------------------------------------------------------------------------------------------------------
1275 void LcsBaseStationDccTrack::runDccTrackStateMachine( ) {
1276
1277        switch ( trackState ) {
1278
1279            case DCC_TRACK_POWER_START1: {
1280
1281                // ??? do we need a way to check for overload during this initial phase, just like we do when ON ?
1282
1283                trackTimeStamp          = CDC::getMillis( );
1284                flags                  |= DT_F_POWER_ON;
1285                flags                  &= ~DT_F_POWER_OVERLOAD;
1286                flags                  &= ~DT_F_MEASUREMENT_ON;
```

```
1287            limitCurrentDigitValue  = milliAmpToDigitValue( initCurrentMilliAmp, digitsPerAmp );
1288
1289            CDC::writeDio( enablePin, true );
1290            trackState = DCC_TRACK_POWER_START2;
1291
1292        }  break;
1293
1294        case DCC_TRACK_POWER_START2: {
1295
1296            if (( CDC::getMillis( ) - trackTimeStamp ) > startTimeThreshold ) {
1297
1298                highWaterMarkDigitValue = 0;
1299                actualCurrentDigitValue = 0;
1300                overloadRestartCount    = 0;
1301                overloadEventCount      = 0;
1302                flags                  |= DT_F_POWER_ON | DT_F_MEASUREMENT_ON;
1303                limitCurrentDigitValue  = milliAmpToDigitValue( limitCurrentMilliAmp, digitsPerAmp );
1304
1305                CDC::writeDio( enablePin, true );
1306                trackState = DCC_TRACK_POWER_ON;
1307            }
1308
1309        } break;
1310
1311        case DCC_TRACK_POWER_ON: {
1312
1313            if (( CDC::getMillis( ) - lastPwrSampleTimeStamp ) > PWR_SAMPLE_TIME_INTERVAL_MILLIS ) {
1314
1315                pwrSampleBuf[ pwrSampleBufIndex % DCC_TRACK_POWER_ON ] = actualCurrentDigitValue;
1316                pwrSampleBufIndex ++;
1317                lastPwrSampleTimeStamp = CDC::getMillis( );
1318            }
1319
1320            if (( CDC::getMillis( ) - lastPwrSamplePerSecTimeStamp ) > 1000 ) {
1321
1322                pwrSamplesPerSec        = totalPwrSamplesTaken - lastPwrSamplePerSecTaken;
1323                lastPwrSamplePerSecTaken  = totalPwrSamplesTaken;
1324                lastPwrSamplePerSecTimeStamp = CDC::getMillis( );
1325            }
1326
1327            if ( flags & DT_F_POWER_OVERLOAD ) {
1328
1329                overloadEventCount  ++;
1330
1331                if ( overloadEventCount > overloadEventThreshold ) {
1332
1333                    if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_TRACK_POWER_MGMT )) {
1334
1335                        printf( "Overload detected: " );
1336
1337                        if ( options &  DT_OPT_SERVICE_MODE_TRACK ) printf( "Prog Track: " );
1338                        else                                        printf( "Main Track: " );
1339
1340                        #if 0
1341                        printf( "(hwm(mA): %d : limit(mA): %d )\n",
1342                                digitValueToMilliAmp( highWaterMarkDigitValue, digitsPerAmp ),
1343                                digitValueToMilliAmp( limitCurrentDigitValue, digitsPerAmp ));
1344
1345                        #else
1346                        printf( "(hwm(dVal): %d  : limit(dVal): %d )\n", highWaterMarkDigitValue, limitCurrentDigitValue );
1347                        #endif
1348                    }
1349
1350                    trackTimeStamp  = CDC::getMillis( );
1351                    flags          |= DT_F_POWER_OVERLOAD;
1352                    flags          &= ~DT_F_POWER_ON;
1353                    flags          &= ~DT_F_MEASUREMENT_ON;
1354
1355                    CDC::writeDio( enablePin, false );
1356                    trackState = DCC_TRACK_POWER_OVERLOAD;
1357                }
1358            }
1359
1360        }  break;
1361
1362        case DCC_TRACK_POWER_OVERLOAD: {
1363
1364            if ( CDC::getMillis( ) - trackTimeStamp > overloadTimeThreshold ) {
1365
1366                overloadRestartCount ++;
1367
1368                if ( overloadRestartCount > overloadRestartThreshold ) {
1369
1370                    if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_TRACK_POWER_MGMT )) {
1371
1372                        printf( "Overload restart failed, Cnt:%d\n", overloadRestartCount );
1373                    }
1374
1375                    trackState = DCC_TRACK_POWER_STOP1;
1376                }
1377                else trackState = DCC_TRACK_POWER_START1;
1378            }
1379
1380        }  break;
1381
1382        case DCC_TRACK_POWER_STOP1: {
1383
1384            trackTimeStamp  = CDC::getMillis( );
1385            flags          &= ~DT_F_POWER_ON;
```

```
1386                flags           &= ~DT_F_POWER_OVERLOAD;
1387                flags           &= ~DT_F_MEASUREMENT_ON;
1388
1389                CDC::writeDio( enablePin, false );
1390                trackState = DCC_TRACK_POWER_STOP2;
1391
1392            }  break;
1393
1394            case DCC_TRACK_POWER_STOP2: {
1395
1396                if ( CDC::getMillis( ) - trackTimeStamp > stopTimeThreshold ) trackState = DCC_TRACK_POWER_OFF;
1397
1398            } break;
1399
1400            case DCC_TRACK_POWER_OFF: {
1401
1402            } break;
1403        }
1404 }
1405
1406 //----------------------------------------------------------------------------------------------------------------
1407 // Some getter functions. Straightforward.
1408 //
1409 //----------------------------------------------------------------------------------------------------------------
1410 uint16_t LcsBaseStationDccTrack::getFlags( ) {
1411
1412     return ( flags );
1413 }
1414
1415 uint16_t LcsBaseStationDccTrack::getOptions( ) {
1416
1417     return ( options );
1418 }
1419
1420 uint32_t LcsBaseStationDccTrack::getDccPacketsSend( ) {
1421
1422     return ( dccPacketsSend );
1423 }
1424
1425 uint32_t LcsBaseStationDccTrack::getPwrSamplesTaken( ) {
1426
1427     return ( totalPwrSamplesTaken );
1428 }
1429
1430 uint16_t LcsBaseStationDccTrack::getPwrSamplesPerSec( ) {
1431
1432     return ( pwrSamplesPerSec );
1433 }
1434
1435 bool LcsBaseStationDccTrack::isPowerOn( ) {
1436
1437     return ( flags & DT_F_POWER_ON );
1438 }
1439
1440 bool LcsBaseStationDccTrack::isPowerOverload( ) {
1441
1442     return ( flags & DT_F_POWER_OVERLOAD );
1443 }
1444
1445 bool LcsBaseStationDccTrack::isServiceModeOn( ) {
1446
1447     return ( flags & DT_F_SERVICE_MODE_ON );
1448 }
1449
1450 bool LcsBaseStationDccTrack::isCutoutOn( ) {
1451
1452     return ( flags & DT_F_CUTOUT_MODE_ON );
1453 }
1454
1455 bool LcsBaseStationDccTrack::isRailComOn( ) {
1456
1457     return ( flags & DT_F_RAILCOM_MODE_ON );
1458 }
1459
1460 //----------------------------------------------------------------------------------------------------------------
1461 // DCC track power management functions. The actual state of track power is kept in the track status field
1462 // and can be queried or set by setting the respective flag. Starting and stopping track power is done by
1463 // setting the respective START or STOP state.
1464 //
1465 //----------------------------------------------------------------------------------------------------------------
1466 void LcsBaseStationDccTrack::powerStart( ) {
1467
1468     trackState = DCC_TRACK_POWER_START1;
1469 }
1470
1471 void LcsBaseStationDccTrack::powerStop( ) {
1472
1473     trackState = DCC_TRACK_POWER_STOP1;
1474 }
1475
1476 void LcsBaseStationDccTrack::serviceModeOn( ) {
1477
1478     if ( options & DT_OPT_SERVICE_MODE_TRACK ) flags |= DT_F_SERVICE_MODE_ON;
1479 }
1480
1481 void LcsBaseStationDccTrack::serviceModeOff( ) {
1482
1483     if ( options & DT_OPT_SERVICE_MODE_TRACK ) flags &= ~DT_F_SERVICE_MODE_ON;
1484 }
```

```
1485
1486   void LcsBaseStationDccTrack::cutoutOn( ) {
1487
1488        if ( ! ( options & DT_OPT_SERVICE_MODE_TRACK )) {
1489
1490             preambleLen =  MAIN_PACKET_PREAMBLE_LEN - DCC_PACKET_CUTOUT_LEN;
1491             flags       |= DT_F_CUTOUT_MODE_ON;
1492        }
1493   }
1494
1495   void LcsBaseStationDccTrack::cutoutOff( ) {
1496
1497        if ( ! ( options & DT_OPT_SERVICE_MODE_TRACK )) {
1498
1499             preambleLen =  MAIN_PACKET_PREAMBLE_LEN;
1500             flags       &= ~DT_F_CUTOUT_MODE_ON;
1501             flags       &= ~DT_F_RAILCOM_MODE_ON;
1502        }
1503   }
1504
1505   void LcsBaseStationDccTrack::railComOn( ) {
1506
1507        if ( ! ( options & DT_OPT_SERVICE_MODE_TRACK )) {
1508
1509             flags |= DT_F_CUTOUT_MODE_ON | DT_F_RAILCOM_MODE_ON;
1510        }
1511   }
1512
1513   void LcsBaseStationDccTrack::railComOff( ) {
1514
1515        if ( ! ( options & DT_OPT_SERVICE_MODE_TRACK )) flags &= ~DT_F_RAILCOM_MODE_ON;
1516   }
1517
1518   //-------------------------------------------------------------------------------------------------------------
1519   // Power Consumption Management. There are two key values. The first is the actual current consumption as
1520   // measured by the ADC hardware on each ZERO DCC bit. This value is used to do the power overload checking.
1521   // The second value is the high water mark built from these measurements. This values is used for the DCC
1522   // decoder programming logic. The high water mark will be set to zero before collecting measurements. All
1523   // measurement values are actually ADC digit values for performance reason. Only on limit setting and external
1524   // data access are these values converted from and to milliAmps.
1525   //
1526   //-------------------------------------------------------------------------------------------------------------
1527   uint16_t LcsBaseStationDccTrack::getLimitCurrent( ) {
1528
1529        return ( limitCurrentMilliAmp );
1530   }
1531
1532   uint16_t LcsBaseStationDccTrack::getActualCurrent( ) {
1533
1534        return ( digitValueToMilliAmp( actualCurrentDigitValue, digitsPerAmp ));
1535   }
1536
1537   uint16_t LcsBaseStationDccTrack::getInitCurrent( ) {
1538
1539        return ( initCurrentMilliAmp );
1540   }
1541
1542   uint16_t LcsBaseStationDccTrack::getMaxCurrent( ) {
1543
1544        return ( maxCurrentMilliAmp );
1545   }
1546
1547   void LcsBaseStationDccTrack::setLimitCurrent( uint16_t val ) {
1548
1549        if      ( val < initCurrentMilliAmp )  val = initCurrentMilliAmp;
1550        else if ( val > maxCurrentMilliAmp  )  val = maxCurrentMilliAmp;
1551
1552        limitCurrentMilliAmp    = val;
1553        limitCurrentDigitValue  = milliAmpToDigitValue( val, digitsPerAmp );
1554   }
1555
1556   //-------------------------------------------------------------------------------------------------------------
1557   // The "getRMSCurrent" function returns the power consumption based on the samples taken and stored in the
1558   // sample buffer. The function computes the square root of the sum of the squares of the power array elements. The
1559   // result is returned in milliAmps. Note that our measurement is based on unsigned 16-bit quantities that come
1560   // from the controller ADC converter. We compute the RMS based on 16-bit unsigned integers, which compared
1561   // to floating point computation is not really precise. However, for our purpose to just show a rough power
1562   // consumption, the error should be not a big issue. We will not use RMS values for power overload detection
1563   // or decoder ACK detection.
1564   //
1565   //-------------------------------------------------------------------------------------------------------------
1566   uint16_t LcsBaseStationDccTrack::getRMSCurrent( ) {
1567
1568        uint32_t res = 0;
1569
1570        for ( uint8_t i = 0; i < PWR_SAMPLE_BUF_SIZE; i++ ) res += pwrSampleBuf[ i ] * pwrSampleBuf[ i ];
1571
1572        return ( digitValueToMilliAmp( sqrt( res / PWR_SAMPLE_BUF_SIZE ), digitsPerAmp ));
1573   }
1574
1575   //-------------------------------------------------------------------------------------------------------------
1576   // This function is called whenever a power measurement operation completes from the analog conversion
1577   // interrupt handler. This typically takes place on the first half of the DCC "0" bit. If power measurement
1578   // is enabled, we increment the number of samples taken, check the measured value for an overload situation
1579   // and also set the high water mark accordingly. Since we are part of an interrupt handler, keep the amount
1580   // work really short.
1581   //
1582   //-------------------------------------------------------------------------------------------------------------
1583   void LcsBaseStationDccTrack::powerMeasurement( ) {
```

```
1584
1585        if ( flags & DT_F_MEASUREMENT_ON ) {
1586
1587            actualCurrentDigitValue = CDC::readAdc( sensePin );
1588
1589            totalPwrSamplesTaken ++;
1590
1591            if ( actualCurrentDigitValue > highWaterMarkDigitValue ) highWaterMarkDigitValue = actualCurrentDigitValue;
1592            if ( actualCurrentDigitValue > limitCurrentDigitValue ) flags |= DT_F_POWER_OVERLOAD;
1593        }
1594 }
1595
1596 //-----------------------------------------------------------------------------------------------------------------
1597 // The DCC decoder programming requires the detection of a current consumption change. This is the way a DCC
1598 // decoder signals an acknowledgement. To detect the consumption change we need first an idea what the actual
1599 // average current baseline consumption of the decoder is. This method will send the required DCC reset packets
1600 // according to the DCC standard and at the same time determine the current consumption as a baseline. We use
1601 // the high water mark for this purpose.
1602 //
1603 // ??? although the routines for decoder ACK detection work, they will produce quite a number of packets.
1604 // During this time, other LCS work is blocked. Perhaps we need a kind of state machine approach to cut the
1605 // long sequence in smaller chunks to allow other work in between.
1606 //-----------------------------------------------------------------------------------------------------------------
1607 uint16_t LcsBaseStationDccTrack::decoderAckBaseline( uint8_t resetPacketsToSend ) {
1608
1609        if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1610
1611            printf( "\nDecoder Ack setup: ( " );
1612        }
1613
1614        uint16_t sum = 0;
1615
1616        for ( uint8_t i = 0; i < resetPacketsToSend; i++ ) {
1617
1618            highWaterMarkDigitValue = 0;
1619
1620            loadPacket( resetDccPacketData, 2, 0 );
1621
1622            if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1623
1624                printf( "%d ", highWaterMarkDigitValue );
1625            }
1626
1627            sum += highWaterMarkDigitValue;
1628        }
1629
1630        if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1631
1632            printf( ") -> %d\n", ( sum + resetPacketsToSend - 1 ) / resetPacketsToSend );
1633        }
1634
1635        return (( sum + resetPacketsToSend - 1 ) / resetPacketsToSend );
1636 }
1637
1638 //-----------------------------------------------------------------------------------------------------------------
1639 // "decoderAckDetect" is the counterpart to the decoder ack setup routine. The setup method established a base
1640 // line for the power consumption and put the decoder in CV programming mode by sending the RESET packets. The
1641 // decoder ACK detect routine now sends out resets packets to follow the programming packets required and
1642 // monitors the current consumption. We use the high water mark for this purpose. The DCC standard specifies
1643 // a time window in which the decoder should raise its power consumption level and signal an acknowledge this
1644 // way. We will send out a series of reset packets and monitor after each packet the consumption level. The
1645 // number of retries depends on whether it is a read ( 50ms window ) or a write ( 100ms window). If we detect
1646 // a raised value the decoder did signal a positive outcome. If not, we time out after the last reset packet.
1647 // The programming operation either failed or the decoder did on purpose not answer. We cannot tell.
1648 //
1649 // ??? although the routines for decoder ACK detection work, they will produce quite a number of packets.
1650 // During this time, other LCS work is blocked. Perhaps we need a kind of state machine approach to cut the
1651 // long sequence in smaller chunks to allow other work in between.
1652 //-----------------------------------------------------------------------------------------------------------------
1653 bool LcsBaseStationDccTrack::decoderAckDetect( uint16_t baseDigitValue, uint8_t retries ) {
1654
1655        if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1656
1657            printf( "Decoder Ack detect: ( %d : %d : ( ", baseDigitValue, ackThresholdDigitValue );
1658        }
1659
1660        for ( uint8_t i = 0; i < retries; i++ ) {
1661
1662            highWaterMarkDigitValue = 0;
1663
1664            loadPacket( resetDccPacketData, 2, 0 );
1665
1666            if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1667
1668                printf( "%d ", highWaterMarkDigitValue );
1669            }
1670
1671            if (( highWaterMarkDigitValue >= baseDigitValue ) &&
1672                ( highWaterMarkDigitValue - baseDigitValue >= ackThresholdDigitValue )) {
1673
1674                if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1675
1676                    printf( "[ %d ] ) -> OK\n", abs( highWaterMarkDigitValue - baseDigitValue ));
1677                }
1678
1679                return ( true );
1680            }
1681        }
1682
```

137

```
1683        if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_DCC_ACK_DETECT )) {
1684
1685            printf ( ") -> FAILED" );
1686        }
1687
1688        return ( false );
1689 }
1690
1691 //------------------------------------------------------------------------------------------------------
1692 // LoadPacket is the central entry point to submit a DCC packet. The incoming packet is the the data to be
1693 // sent without checksum, i.e. it is just the payload. The DCC track signal generator has two packet buffers.
1694 // The first buffer holds the packet currently being transmitted. The second is the pending buffer. If it is
1695 // used, we will simply busy wait for our turn to load the packet into the pending buffer. Upon completion of
1696 // sending the active packet, the interrupt handler copies the currently pending buffer to the active buffer
1697 // and then resets the pending flag. Either way, then it is our turn. We fill the pending buffer, compute the
1698 // checksum and set the pending flag.
1699 //
1700 // ??? For a high number of session we may want to think about a queuing approach. Right now, this routine
1701 // waits when there is a packet already queued, i.e. pending. This may cause issues in delaying other tasks
1702 // such as receiving a CAN bus message.
1703 //------------------------------------------------------------------------------------------------------
1704 void LcsBaseStationDccTrack::loadPacket( const uint8_t *packet, uint8_t len, uint8_t repeat ) {
1705
1706        if ( ! isInRangeU( len, MIN_DCC_PACKET_SIZE, MAX_DCC_PACKET_SIZE )) return;
1707        if ( ! isInRangeU( repeat, MIN_DCC_PACKET_REPEATS, MAX_DCC_PACKET_REPEATS )) return;
1708
1709        while ( flags & DT_F_DCC_PACKET_PENDING );
1710
1711        pendingBufPtr -> len    = len + 1;
1712        pendingBufPtr -> repeat = repeat;
1713
1714        uint8_t checkSum = 0;
1715        uint8_t *bufPtr  = pendingBufPtr -> buf;
1716
1717        for ( uint8_t i = 0; i < len; i++ ) {
1718
1719            bufPtr[ i ] =   packet[ i ];
1720            checkSum    ^=  bufPtr[ i ];
1721        }
1722
1723        bufPtr[ len ] = checkSum;
1724        flags         |= DT_F_DCC_PACKET_PENDING;
1725 }
1726
1727 //------------------------------------------------------------------------------------------------------
1728 // The log management routines. A typical transaction to log would start the logging process and then end
1729 // it after the operation to analyze/debug. The "enableLog" call should be used to enable the logging
1730 // process all together, the other calls will only do work when the log is enabled. With this call the
1731 // recording process could be controlled from a command line setting or so. "beginLog" and "endLog" start
1732 // and end a recording sequence.
1733 //
1734 //------------------------------------------------------------------------------------------------------
1735 void LcsBaseStationDccTrack::enableLog( bool arg ) {
1736
1737        logEnabled = arg;
1738        logActive  = false;
1739 }
1740
1741 void LcsBaseStationDccTrack::beginLog( ) {
1742
1743        if ( logEnabled ) {
1744
1745            logActive   = true;
1746            logBufIndex = 0;
1747            writeLogId( LOG_BEGIN );
1748            writeLogTs( );
1749        }
1750 }
1751
1752 void LcsBaseStationDccTrack::endLog( ) {
1753
1754        if ( logActive ) {
1755
1756            writeLogTs( );
1757            writeLogId( LOG_END );
1758            logActive = false;
1759        }
1760 }
1761
1762 //------------------------------------------------------------------------------------------------------
1763 // There are a couple of routines to write the log data when the logging is active. For convenience, some of
1764 // the log entry types are available as a direct call. The order of data entry for numeric types is big endian,
1765 // i.e. most significant byte first.
1766 //
1767 //------------------------------------------------------------------------------------------------------
1768 void LcsBaseStationDccTrack::writeLogData( uint8_t id, uint8_t *buf, uint8_t len ) {
1769
1770        if ( logActive ) {
1771
1772            len = len % 16;
1773            if ( logBufIndex + len + 1 < LOG_BUF_SIZE ) {
1774
1775                logBuf[ logBufIndex ++ ] = ( id << 4 ) | len;
1776                for ( uint8_t i = 0; i < len; i++ ) logBuf[ logBufIndex ++ ] = buf[ i ];
1777            }
1778        }
1779 }
1780
1781 void LcsBaseStationDccTrack::writeLogId( uint8_t id ) {
```

```
1782
1783          if ( logActive ) logBuf[ logBufIndex ++ ] = ( id << 4 );
1784  }
1785
1786  void LcsBaseStationDccTrack::writeLogTs( ) {
1787
1788          if ( logActive ) {
1789
1790                  uint32_t ts = CDC::getMicros( );
1791                  logBuf[ logBufIndex ++ ] = ( LOG_TSTAMP << 4 ) | 4;
1792                  logBuf[ logBufIndex ++ ] = ( ts >> 24 ) & 0xFF;
1793                  logBuf[ logBufIndex ++ ] = ( ts >> 16 ) & 0xFF;
1794                  logBuf[ logBufIndex ++ ] = ( ts >> 8  ) & 0xFF;
1795                  logBuf[ logBufIndex ++ ] = ( ts >> 0  ) & 0xFF;
1796          }
1797  }
1798
1799  void LcsBaseStationDccTrack::writeLogVal( uint8_t valId, uint16_t val ) {
1800
1801          if ( logActive ) {
1802
1803                  logBuf[ logBufIndex ++ ] = ( LOG_VAL << 4 ) | 3;
1804                  logBuf[ logBufIndex ++ ] = valId;
1805                  logBuf[ logBufIndex ++ ] = val >> 8;
1806                  logBuf[ logBufIndex ++ ] = val & 0xFF;
1807          }
1808  }
1809
1810  //-----------------------------------------------------------------------------------------------------------
1811  // Print out the log data, one entry on one line. We only print the log buffer when there is no log sequence
1812  // active.
1813  //
1814  //-----------------------------------------------------------------------------------------------------------
1815  void LcsBaseStationDccTrack::printLog( ) {
1816
1817          if ( logEnabled ) {
1818
1819                  if ( ! logActive ) {
1820
1821                          if ( logBufIndex > 0 ) {
1822
1823                                  printf( "\n" );
1824
1825                                  uint16_t entryIndex  = 0;
1826                                  uint8_t  entryLen    = 0;
1827
1828                                  while ( entryIndex < logBufIndex ) {
1829
1830                                          entryLen = printLogEntry( entryIndex );
1831                                          printf( "\n" );
1832
1833                                          if ( entryLen > 0 ) entryIndex += entryLen;
1834                                          else                break;
1835                                  }
1836                          }
1837                          else printf( "DCC Log Buf: Nothing recorded\n" );
1838                  }
1839                  else printf( "DCC Log Active\n" );
1840          }
1841          else printf( "DCC Log disabled\n" );
1842  }
1843
1844  //-----------------------------------------------------------------------------------------------------------
1845  // Print out the DCC Track configuration data. For debugging purposes.
1846  //
1847  //-----------------------------------------------------------------------------------------------------------
1848  void LcsBaseStationDccTrack::printDccTrackConfig( ) {
1849
1850          printf( "DccTrack Config: " );
1851
1852          if ( options & DT_OPT_SERVICE_MODE_TRACK ) printf( "PROG \n" );
1853          else                                       printf( "MAIN \n" );
1854
1855          printf( " Config options: ( 0x%x ) -> ", flags );
1856
1857          if ( options &  DT_OPT_SERVICE_MODE_TRACK ) printf( "SvcMode Track " );
1858          if ( options & DT_OPT_CUTOUT ) printf( "Cutout " );
1859          if ( options & DT_OPT_RAILCOM ) printf( "Railcom " );
1860          printf( "\n" );
1861
1862          printf( " Current Initial(mA): %d Current Limit(mA): %d Current Max(mA): %d\n",
1863                  getInitCurrent( ), getLimitCurrent( ), getMaxCurrent( ));
1864          printf( " milliVoltPerAmp: %d\n", milliVoltPerAmp );
1865          printf( " digitsPerAmp: %d\n", digitsPerAmp );
1866
1867          printf( " Limit Digit Value: %d\n", limitCurrentDigitValue );
1868          printf( " Ack Threshold Digit Value:%d\n", ackThresholdDigitValue );
1869
1870          printf( " CDC enable Pin: %d, DCC signal Pins: (%d:%d), Sensor Pin: %d, RailCom Pin: %d\n",
1871                  enablePin, dccSigPin1, dccSigPin2, sensePin, uartRxPin );
1872
1873          printf( " PreambleLen: %d, PostambleLen: %d\n", preambleLen, postambleLen );
1874  }
1875
1876  //-----------------------------------------------------------------------------------------------------------
1877  // Print out the DCC Track status.
1878  //
1879  //-----------------------------------------------------------------------------------------------------------
1880  void LcsBaseStationDccTrack::printDccTrackStatus( ) {
```

```
1881
1882        printf( "DccTrack: " );
1883
1884        if ( options & DT_OPT_SERVICE_MODE_TRACK )  printf( "PROG" );
1885        else                                        printf( "MAIN" );
1886
1887        printf( ", Track Status: ( 0x%x ) -> ", flags );
1888
1889        if ( flags & DT_F_POWER_ON          ) printf( "PowerOn " );
1890        if ( flags & DT_F_POWER_OVERLOAD    ) printf( "PowerOverload " );
1891        if ( flags & DT_F_MEASUREMENT_ON    ) printf( "PowerMeasOn " );
1892        if ( flags & DT_F_SERVICE_MODE_ON   ) printf( "SvcModeOn " );
1893        if ( flags & DT_F_CUTOUT_MODE_ON    ) printf( "CutoutOn " );
1894        if ( flags & DT_F_RAILCOM_MODE_ON   ) printf( "RailcomOn " );
1895        if ( flags & DT_F_CONFIG_ERROR      ) printf( "ConfigError " );
1896        printf( "\n" );
1897
1898        printf( "Packets Send: %d\n", dccPacketsSend );
1899        printf( "Total Power Samples: %d\n", totalPwrSamplesTaken );
1900        printf( "Power Samples per Sec: %d\n", pwrSamplesPerSec );
1901        printf( "Power consumption (RMS): %d\n", getRMSCurrent( ));
1902        printf( "\n" );
1903 }
```

```
1    //------------------------------------------------------------------------------------------------------------------
2    //
3    // LCS Base Station - Loco Session Management - implementation file
4    //
5    //------------------------------------------------------------------------------------------------------------------
6    // The locomotive session object is the besides the two DCC tracks the other main component of a base station.
7    // Each engine to run needs a session on this session object. Typically, the handheld will "open" a session.
8    // The session identifier is then the handle to the locomotive.
9    //
10   //
11   //
12   //------------------------------------------------------------------------------------------------------------------
13   //
14   // LCS - Base Station
15   // Copyright (C) 2019 - 2024  Helmut Fieres
16   //
17   // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
18   // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
19   // option) any later version.
20   //
21   // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
22   // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
23   // for more details.
24   //
25   // You should have received a copy of the GNU General Public License along with this program. If not, see
26   // http://www.gnu.org/licenses
27   //
28   //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
29   //
30   //------------------------------------------------------------------------------------------------------------------
31   #include "LcsBaseStation.h"
32   #include <malloc.h>
33
34   using namespace LCS;
35
36   //------------------------------------------------------------------------------------------------------------------
37   // External global variables.
38   //
39   //------------------------------------------------------------------------------------------------------------------
40   extern uint16_t debugMask;
41
42   //------------------------------------------------------------------------------------------------------------------
43   // Loco Session implementation file - local declarations.
44   //
45   //------------------------------------------------------------------------------------------------------------------
46   namespace {
47
48   //------------------------------------------------------------------------------------------------------------------
49   // DCC packet definitions. A DCC packet payload is at most 10 bytes long, excluding the checksum byte. This
50   // is true for XPOM support, otherwise it is according to NMRA up to 6 bytes.
51   //
52   //------------------------------------------------------------------------------------------------------------------
53   const uint8_t   MIN_DCC_PACKET_SIZE        = 2;
54   const uint8_t   MAX_DCC_PACKET_SIZE        = 16;
55   const uint8_t   MIN_DCC_PACKET_REPEATS     = 0;
56   const uint8_t   MAX_DCC_PACKET_REPEATS     = 8;
57
58   //------------------------------------------------------------------------------------------------------------------
59   // Utility routines.
60   //
61   //------------------------------------------------------------------------------------------------------------------
62   bool isInRangeU( uint8_t val, uint8_t lower, uint8_t upper ) {
63
64       return (( val >= lower ) && ( val <= upper ));
65   }
66
67   bool isInRangeU( uint16_t val, uint16_t lower, uint16_t upper ) {
68
69       return (( val >= lower ) && ( val <= upper ));
70   }
71
72   bool isInRangeU( uint32_t val, uint32_t lower, uint32_t upper ) {
73
74       return (( val >= lower ) && ( val <= upper ));
75   }
76
77   bool validCabId( uint16_t cabId ) {
78
79       return ( isInRangeU( cabId, MIN_CAB_ID, MAX_CAB_ID ));
80   }
81
82   bool validCvId( uint16_t cvId ) {
83
84       return ( isInRangeU( cvId, MIN_DCC_CV_ID, MAX_DCC_CV_ID ));
85   }
86
87   bool validFunctionId( uint8_t fId ) {
88
89       return ( isInRangeU( fId, MIN_DCC_FUNC_ID, MAX_DCC_FUNC_ID ));
90   }
91
92   bool validFunctionGroupId( uint8_t fGroup ) {
93
94       return ( isInRangeU( fGroup, MIN_DCC_FUNC_GROUP_ID , MAX_DCC_FUNC_GROUP_ID ));
95   }
96
97   bool validDccPacketlen( uint8_t len ) {
98
```

```
 99       return ( isInRangeU( len, MIN_DCC_PACKET_SIZE, MAX_DCC_PACKET_SIZE ));
100 }
101
102 bool validDccPacketRepeatCnt( uint8_t nRepeat ) {
103
104       return ( isInRangeU( nRepeat, MIN_DCC_PACKET_REPEATS, MAX_DCC_PACKET_REPEATS ));
105 }
106
107 uint8_t lowByte( uint16_t arg ) {
108
109       return( arg & 0xFF );
110 }
111
112 uint8_t highByte( uint16_t arg ) {
113
114       return( arg >> 8 );
115 }
116
117 uint8_t bitRead( uint8_t arg, uint8_t pos ) {
118
119       return ( arg >> ( pos % 8 )) & 1;
120 }
121
122 void bitWrite( uint8_t *arg, uint8_t pos, bool val ) {
123
124       if ( val )   *arg |= ( 1 << pos );
125       else         *arg &= ~( 1 << pos );
126 }
127
128 //-------------------------------------------------------------------------------------------------------------
129 // DDC function flags. The DCC function flags F0 .. F68 are stored in ten groups. Group 0 contains F0 .. F4
130 // stored in DCC command byte format. Group 1 contains F5 .. F8, Group 2 contains F9 .. F12 in DCC command
131 // byte format. The remainder F13 .. F68 are stored in 8 bits groups also in DCC command byte format. The
132 // routines support the get/set of an individual bit as well as setting an entire function group. A DCC
133 // function group is labelled starting with index 1.
134 //
135 //-------------------------------------------------------------------------------------------------------------
136 bool getDccFuncBit( uint8_t *funcFlags, uint8_t fNum ) {
137
138       if      ( fNum == 0 )                 return ( bitRead( funcFlags[ 0 ], 4 ));
139       else if ( isInRangeU( fNum, 1, 4 ))   return ( bitRead( funcFlags[ 0 ], fNum - 1 ));
140       else if ( isInRangeU( fNum, 5, 8 ))   return ( bitRead( funcFlags[ 1 ], fNum - 5 ));
141       else if ( isInRangeU( fNum, 9, 12 ))  return ( bitRead( funcFlags[ 2 ], fNum - 9 ));
142       else if ( isInRangeU( fNum, 13, 68 )) {
143
144           return ( bitRead( funcFlags[ ( fNum - 13 ) / 8 + 3 ], ( fNum - 13 ) % 8 ));
145       }
146       else return false;
147 }
148
149 void setDccFuncBit( uint8_t *funcFlags, uint8_t fNum, bool val ) {
150
151       if      ( fNum == 0 )                 bitWrite( &funcFlags[ 0 ], 4, val );
152       else if ( isInRangeU( fNum, 1, 4 ))   bitWrite( &funcFlags[ 0 ], fNum - 1, val );
153       else if ( isInRangeU( fNum, 5, 8 ))   bitWrite( &funcFlags[ 1 ], fNum - 5, val );
154       else if ( isInRangeU( fNum, 9, 12 ))  bitWrite( &funcFlags[ 2 ], fNum - 9, val );
155       else if ( isInRangeU( fNum, 13, 68 )) {
156
157           bitWrite( &funcFlags[ ( fNum - 13 ) / 8 + 3 ], ( fNum - 13 ) % 8, val );
158       }
159 }
160
161 void setDccFuncGroupByte( uint8_t *funcFlags, uint8_t fGroup, uint8_t dccByte ) {
162
163       if      ( fGroup == 1 )               funcFlags[ 0 ] = dccByte & 0x1F;
164       else if ( fGroup == 2 )               funcFlags[ 1 ] = dccByte & 0x0F;
165       else if ( fGroup == 3 )               funcFlags[ 2 ] = dccByte & 0x0F;
166       else if ( isInRangeU( fGroup, 4, 10 )) funcFlags[ fGroup - 1 ] = dccByte;
167 }
168
169 uint8_t dccFunctionBitToGroup( uint8_t fNum ) {
170
171       if      ( isInRangeU( fNum, 0, 4 ))    return ( 1 );
172       else if ( isInRangeU( fNum, 5, 8 ))    return ( 2 );
173       else if ( isInRangeU( fNum, 9, 12 ))   return ( 3 );
174       else if ( isInRangeU( fNum, 13, 68 ))  return (( fNum - 13 ) / 8 + 4 );
175       else                                   return ( 0 );
176 }
177
178 }; // namespace
179
180 //=============================================================================================================
181 //=============================================================================================================
182 //
183 // Object part.
184 //
185 //=============================================================================================================
186 //=============================================================================================================
187
188 //-------------------------------------------------------------------------------------------------------------
189 // "LocoSession" constructor. Nothing to do here.
190 //
191 //-------------------------------------------------------------------------------------------------------------
192 LcsBaseStationLocoSession::LcsBaseStationLocoSession( ) { }
193
194 //-------------------------------------------------------------------------------------------------------------
195 // Loco Session Map configuration. The session map contains an array of loco sessions entries. We are passed
196 // the sessionMap descriptor and object handles to the core library and the two tracks. Loco sessions are
197 // numbered from 1 to MAX_SESSION_ID. During compilation there is a maximum number of sessions that the
```

```
198    // session map will support. This number cannot be changed other than recompile with a different setting.
199    //
200    //-------------------------------------------------------------------------------------------------------------
201    uint8_t LcsBaseStationLocoSession::setupSessionMap(
202
203        LcsBaseStationSessionMapDesc    *sessionMapDesc,
204        LcsBaseStationDccTrack          *mainTrack,
205        LcsBaseStationDccTrack          *progTrack
206
207        ) {
208
209        if (( mainTrack == nullptr                              ) ||
210            ( progTrack == nullptr                              ) ||
211            ( sessionMapDesc -> maxSessions > MAX_CAB_SESSIONS  )) return ( ERR_SESSION_SETUP );
212
213        this -> mainTrack     = mainTrack;
214        this -> progTrack     = progTrack;
215
216        options               = sessionMapDesc -> options;
217        flags                 = SM_F_DEFAULT_SETTING;
218        sessionMap            = (SessionMapEntry *) calloc( sessionMapDesc -> maxSessions, sizeof( SessionMapEntry ));
219        lastAliveCheckTime    = CDC::getMillis( );
220
221        sessionMapHwm         = sessionMap;
222        sessionMapLimit       = &sessionMap[ sessionMapDesc -> maxSessions ];
223        sessionMapNextRefresh = sessionMap;
224
225        if ( options & SM_OPT_ENABLE_REFRESH )      flags |= SM_F_ENABLE_REFRESH;
226        if ( options & SM_OPT_KEEP_ALIVE_CHECKING ) flags |= SM_F_KEEP_ALIVE_CHECKING;
227
228        for ( SessionMapEntry *smePtr = sessionMap; smePtr < sessionMapLimit; smePtr++ ) initSessionEntry( smePtr );
229
230        return ( ALL_OK );
231    }
232
233    //-------------------------------------------------------------------------------------------------------------
234    // "requestSession" is the entry point to establish a session. There are several modes. The NORMAL mode is
235    // to allocate a new session. There should be no session already existing for this cabId. The STEAL mode
236    // grabs an existing session from the current session holder. The use case is that a dispatched locomotive
237    // can be taken over by another handheld. The SHARED option allows several handheld controller to share the
238    // session entry and issue commands to the same locomotive. Right now, the STEAL and SHARED option are not
239    // implemented.
240    //
241    //-------------------------------------------------------------------------------------------------------------
242    uint8_t LcsBaseStationLocoSession::requestSession( uint16_t cabId, uint8_t mode, uint8_t *sId ) {
243
244        *sId = NIL_LOCO_SESSION_ID;
245        if ( ! validCabId( cabId )) return ( ERR_INVALID_CAB_ID );
246
247        switch ( mode ) {
248
249            case LSM_NORMAL: {
250
251                SessionMapEntry *smePtr = allocateSessionEntry( cabId );
252                if ( smePtr == nullptr ) return ( ERR_LOCO_SESSION_ALLOCATE );
253
254                smePtr -> flags |= SME_SPDIR_ONLY_REFRESH;
255
256                *sId = smePtr - sessionMap + 1;
257                return ( ALL_OK );
258            }
259
260            case LSM_STEAL: {
261
262                // ??? need to inform the current handheld and put the new handheld in its place.
263                return ( ERR_NOT_IMPLEMENTED );
264
265            } break;
266
267            case LSM_SHARED: {
268
269                // ??? essentially, add another handheld to the session. We perhaps need a counter on how many handhelds
270                // share the session ...
271                return ( ERR_NOT_IMPLEMENTED );
272
273            } break;
274
275            default: return ( ERR_NOT_IMPLEMENTED ); // ??? rather "invalid mode" ?
276        }
277    }
278
279    //-------------------------------------------------------------------------------------------------------------
280    // A cab session can be released, freeing up the slot in the cab session table.
281    //
282    // ??? for a shared session, what does this mean ?
283    //-------------------------------------------------------------------------------------------------------------
284    uint8_t LcsBaseStationLocoSession::releaseSession( uint8_t sId ) {
285
286        SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
287        if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
288
289        deallocateSessionEntry( smePtr );
290        return ( ALL_OK );
291    }
292
293    //-------------------------------------------------------------------------------------------------------------
294    // "updateSession" informs the base station about changes in the loco session setting. To be implemented once
295    // we know what the flags and the update concept should be ...
296    //
```

```
297   //-------------------------------------------------------------------------------------------------------------
298   uint8_t LcsBaseStationLocoSession::updateSession( uint8_t sId, uint8_t flags ) {
299
300       SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
301       if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
302
303       return ( ERR_NOT_IMPLEMENTED );
304   }
305
306   //-------------------------------------------------------------------------------------------------------------
307   // "markSessionAlive" sets the keep alive time stamp on a loco session. This routine is typically called by
308   // the LCS message receiver to update the session last "alive" timestamp. The base station will periodically
309   // check this value to see if a session is still alive.
310   //
311   //-------------------------------------------------------------------------------------------------------------
312   uint8_t LcsBaseStationLocoSession::markSessionAlive( uint8_t sId ) {
313
314       SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
315       if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
316
317       smePtr -> lastKeepAliveTime = CDC::getMillis( );
318       return ( ALL_OK );
319   }
320
321   //-------------------------------------------------------------------------------------------------------------
322   // "refreshActiveSessions" walks through the session map up to the high water mark and invokes the session
323   // refresh function for each used entry. As the refresh entry routine will show, we will do this refreshing
324   // in small pieces in order to stay responsive to external requests.
325   //
326   //
327   // ??? this may should perhaps all be reworked. There are many more duties to do periodically.
328   // ??? an active loco ( speed > 0 ) needs to be address at least every 2.5 seconds.
329   //
330   // ??? also a base station needs to broadcast its capabilities every
331   //
332   //-------------------------------------------------------------------------------------------------------------
333   void LcsBaseStationLocoSession::refreshActiveSessions( ) {
334
335       if (( flags & SM_F_ENABLE_REFRESH ) && ( sessionMapHwm > sessionMap )) {
336
337           refreshSessionEntry( sessionMapNextRefresh );
338
339           sessionMapNextRefresh ++;
340           if ( sessionMapNextRefresh >= sessionMapHwm ) sessionMapNextRefresh = sessionMap;
341       }
342   }
343
344   //-------------------------------------------------------------------------------------------------------------
345   // "refreshSessionEntry" checks first that the session is still alive and then issues the next DCC packet for
346   // refreshing the loco session. To avoid DCC bandwidth issues, a loco session refresh is done in several small
347   // steps. There is one state for speed and direction and steps to refresh the function groups 1 to 5. If the
348   // function refresh option is set, we use the DCC command that sets speed, direction and the function flags in
349   // one DCC command.
350   //
351   //     Step 0  -> refresh speed and direction ( if FUNC_REFRESH is set also functions F0 .. F28 )
352   //     Step 1  -> refresh function group 0 ( F0  .. F4  )
353   //     Step 2  -> refresh function group 1 ( F5  .. F8  )
354   //     Step 3  -> refresh function group 2 ( F9  .. F12 )
355   //     Step 4  -> refresh function group 3 ( F13 .. F20 )
356   //     Step 5  -> refresh function group 4 ( F21 .. F28 )
357   //
358   // ??? should we alternate when SPDIR and FUNC are sent separately ?
359   // ??? is it something like: SPDIR, FG1, SPDIR, FG2, ...
360   //
361   // ??? what to do for emergency stop, keep refreshing ? keep alive checking ?
362   // ??? how do we integrate the STEAL/SHARE/DISPATCHED concept ?
363   //
364   // ??? separate out the check alive functionality ? it is a separate task...
365   // ??? sessionMapNextAliveCheck var needed ...
366   //-------------------------------------------------------------------------------------------------------------
367   void LcsBaseStationLocoSession::refreshSessionEntry( SessionMapEntry *smePtr ) {
368
369       // ??? introduce a return status ?
370
371       if ( smePtr -> cabId != NIL_CAB_ID ) {
372
373           if ( flags & SM_F_KEEP_ALIVE_CHECKING ) {
374
375               if (( CDC::getMillis( ) - smePtr -> lastKeepAliveTime ) > refreshAliveTimeOutVal ) {
376
377                   if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_CHECK_ALIVE_SESSIONS )) {
378
379                       printf( "Session: %d expired\n", smePtr - sessionMap );
380                   }
381
382                   deallocateSessionEntry( smePtr );
383               }
384           }
385
386           // ??? separate keep alive checking and refresh options...
387
388           else {
389
390               // ??? if ( smePtr -> speed > 0 )  // only active locos are refreshed...
391
392               if ( smePtr -> nextRefreshStep == 0 ) {
393
394                   setThrottle( smePtr, smePtr -> speed, smePtr -> direction );
395
```

```
396                     smePtr -> nextRefreshStep = ((( smePtr -> flags & SME_COMBINED_REFRESH ) ||
397                                          ( smePtr -> flags & SME_SPDIR_ONLY_REFRESH )) ? 0 : 1 );
398                 }
399                 else if ( smePtr -> nextRefreshStep <= 5 ) {
400
401                     uint8_t fGroup = smePtr -> nextRefreshStep;
402
403                     setDccFunctionGroup( smePtr, fGroup, smePtr -> functions[ fGroup - 1 ] );
404                     smePtr -> nextRefreshStep = (( smePtr -> nextRefreshStep >= 5 ) ? 0 : smePtr -> nextRefreshStep + 1 );
405
406                 }
407             }
408         }
409 }
410
411 //-----------------------------------------------------------------------------------------------------------
412 // "emergencyStopAll" is called when one of the clients issued an emergency stop all request. There is a DCC
413 // broadcast packet that causes all decoders to stop the locos. In addition, the base station is expected to
414 // discontinue sending non-zero speed packets until the situation is cleared. The standard does not really say
415 // what exactly to do. In our base station, we will first issue the ESTOP DCC broadcast packet and then set
416 // the speed value in each session to one, which is the value for emergency stop. All else is unchanged.
417 //
418 //-----------------------------------------------------------------------------------------------------------
419 void LcsBaseStationLocoSession::emergencyStopAll( ) {
420
421     mainTrack -> loadPacket( eStopDccPacketData, 2, 4 );
422
423     for ( SessionMapEntry *smePtr = sessionMap; smePtr < sessionMapHwm; smePtr++ ) {
424
425         if ( smePtr -> cabId != NIL_CAB_ID ) smePtr -> speed = 1;
426     }
427 }
428
429 //-----------------------------------------------------------------------------------------------------------
430 // Getter methods for session related info. Straightforward.
431 //
432 //-----------------------------------------------------------------------------------------------------------
433 uint8_t LcsBaseStationLocoSession::getSessionIdByCabId( uint16_t cabId ) {
434
435     SessionMapEntry *smePtr = lookupSessionEntry( cabId );
436     return (( smePtr == nullptr ) ? NIL_LOCO_SESSION_ID : (( smePtr - sessionMap ) + 1 ));
437 }
438
439 uint16_t LcsBaseStationLocoSession::getOptions( ) {
440
441     return ( options );
442 }
443
444 uint16_t LcsBaseStationLocoSession::getFlags( ) {
445
446     return ( flags );
447 }
448
449 uint8_t LcsBaseStationLocoSession::getSessionMapHwm( ) {
450
451     return ( sessionMapHwm - sessionMap );
452 }
453
454 uint32_t LcsBaseStationLocoSession::getSessionKeepAliveInterval( ) {
455
456     return ( refreshAliveTimeOutVal );
457 }
458
459 uint8_t LcsBaseStationLocoSession::getActiveSessions( ) {
460
461     uint8_t sessionCnt = 0;
462
463     for ( SessionMapEntry *smePtr = sessionMap; smePtr < sessionMapHwm; smePtr++ ) {
464
465         if ( smePtr -> cabId != NIL_CAB_ID ) sessionCnt++;
466     }
467
468     return ( sessionCnt );
469 }
470
471 //-----------------------------------------------------------------------------------------------------------
472 // "setThrottle" is perhaps the most used function. After all, we want to run engines on the track. This
473 // signature will just locate the session map entry and then invoke the internal signature with accepts a
474 // pointer to the entry.
475 //
476 //-----------------------------------------------------------------------------------------------------------
477 uint8_t LcsBaseStationLocoSession::setThrottle( uint8_t sId, uint8_t speed, uint8_t direction ) {
478
479     SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
480     if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
481
482     return ( setThrottle( smePtr, speed, direction ));
483 }
484
485 //-----------------------------------------------------------------------------------------------------------
486 // "setThrottle" will send a DCC packet with speed and direction for a loco. If the combined speed and
487 // function refresh option is enabled, the DCC command will specify speed, direction and functions to refresh
488 // in one packet.
489 //
490 //-----------------------------------------------------------------------------------------------------------
491 uint8_t LcsBaseStationLocoSession::setThrottle( SessionMapEntry *smePtr, uint8_t speed, uint8_t direction ) {
492
493     uint8_t pBuf[ MAX_DCC_PACKET_SIZE ];
494     uint8_t pLen = 0;
```

```
495
496          smePtr -> speed        = speed & 0x7F;
497          smePtr -> direction   = direction % 2;
498
499          if ( smePtr -> cabId > 127 ) pBuf[pLen++] = highByte( smePtr -> cabId ) | 0xC0;
500          pBuf[pLen++] = lowByte( smePtr -> cabId );
501
502          pBuf[pLen++] = (( smePtr -> flags & SME_COMBINED_REFRESH ) ? 0x3c : 0x3F );
503          pBuf[pLen++] = (( smePtr -> speed & 0x7F ) | (( smePtr -> direction ) ? 0x80 : 0 ));
504
505          if ( smePtr -> flags & SME_COMBINED_REFRESH ) {
506
507              pBuf[pLen++]  = ((( smePtr -> functions[0] & 0x10 ) >> 4 ) |
508                               (( smePtr -> functions[0] & 0x0F ) << 1 ) |
509                               (( smePtr -> functions[1] & 0x07 ) << 5 ));
510
511              pBuf[pLen++]  = ((( smePtr -> functions[1] & 0x0F ) >> 3 ) |
512                               (( smePtr -> functions[2] & 0x0F ) << 1 ) |
513                               (( smePtr -> functions[3] & 0x07 ) << 5 ));
514
515              pBuf[pLen++]  = ((( smePtr -> functions[3] & 0xf80 ) >> 3 ) |
516                               (( smePtr -> functions[4] & 0x07 ) << 5 ));
517
518              pBuf[pLen++]  = (( smePtr -> functions[4] & 0xf80 ) >> 3 );
519          }
520
521          mainTrack -> loadPacket( pBuf, pLen );
522          return ( ALL_OK );
523      }
524
525      //----------------------------------------------------------------------------------------------------
526      // "setDccFunctionBit" controls the functions in a decoder. The DCC function flags F0 .. F68 are stored in
527      // ten groups. The routines first updates the function bit in the loco session entry data structure, so we
528      // can keep track of the values. This is important as the DCC commands send out entire groups only. The
529      // actual work is then done by the "setDccFunctionGroup" method.
530      //
531      //----------------------------------------------------------------------------------------------------
532      uint8_t LcsBaseStationLocoSession::setDccFunctionBit( uint8_t sId, uint8_t fNum, uint8_t val ) {
533
534          SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
535          if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
536
537          if ( ! validFunctionId( fNum )) return ( ERR_INVALID_FUNC_ID );
538          setDccFuncBit( smePtr -> functions, fNum, val );
539
540          uint8_t fGroup = dccFunctionBitToGroup( fNum );
541
542          return ( setDccFunctionGroup( smePtr, fGroup, smePtr -> functions[ fGroup - 1 ] ));
543      }
544
545      //----------------------------------------------------------------------------------------------------
546      // "setDccFunctionGroup" sets an entire group of function flags. This signature will first find the session
547      // entry, do the argument checks and the invoke the internal signature.
548      //
549      //----------------------------------------------------------------------------------------------------
550      uint8_t LcsBaseStationLocoSession::setDccFunctionGroup( uint8_t sId, uint8_t fGroup, uint8_t dccByte ) {
551
552          SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
553          if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
554
555          return ( setDccFunctionGroup( smePtr, fGroup, dccByte ));
556      }
557
558      //----------------------------------------------------------------------------------------------------
559      // "setDccFunctionGroup" sets an entire group of function flags.The DCC function flags F0 .. F68 are stored
560      // in ten groups.
561      //
562      //      Group 1:  F0, F4, F3, F2, F1      DCC Command Format: 100DDDDD
563      //      Group 2:  F8, F7, F6, F5          DCC Command Format: 1011DDDD
564      //      Group 3:  F12, F11, F10, F9       DCC Command Format: 1010DDDD
565      //      Group 4:  F20 .. F13              DCC Command Format: 0xDE DDDDDDDD
566      //      Group 5:  F28 .. F21              DCC Command Format: 0xDF DDDDDDDD
567      //      Group 6:  F36 .. F29              DCC Command Format: 0xD8 DDDDDDDD
568      //      Group 7:  F44 .. F37              DCC Command Format: 0xD9 DDDDDDDD
569      //      Group 8:  F52 .. F45              DCC Command Format: 0xDA DDDDDDDD
570      //      Group 9:  F60 .. F53              DCC Command Format: 0xDB DDDDDDDD
571      //      Group 10: F68 .. F61              DCC Command Format: 0xDC DDDDDDDD
572      //
573      // The routines updates the entire function group byte in the loco session entry, so we can keep track of the
574      // values. The function command is repeated 4 times to the track.
575      //
576      //----------------------------------------------------------------------------------------------------
577      uint8_t LcsBaseStationLocoSession::setDccFunctionGroup( SessionMapEntry *smePtr, uint8_t fGroup, uint8_t dccByte ) {
578
579          if ( ! validFunctionGroupId( fGroup )) return ( ERR_INVALID_FGROUP_ID );
580          setDccFuncGroupByte( smePtr -> functions, fGroup, dccByte );
581
582          uint8_t pBuf[ MAX_DCC_PACKET_SIZE];
583          uint8_t pLen = 0;
584
585          if ( smePtr -> cabId > 127 ) pBuf[pLen++] = highByte( smePtr -> cabId ) | 0xC0;
586          pBuf[pLen++] = lowByte( smePtr -> cabId );
587
588          switch ( fGroup - 1 ) {
589
590              case 0: pBuf[pLen++] = ( smePtr -> functions[ 0 ] & 0x1F ) | 0x80; break;
591              case 1: pBuf[pLen++] = ( smePtr -> functions[ 1 ] & 0x0F ) | 0xB0; break;
592              case 2: pBuf[pLen++] = ( smePtr -> functions[ 2 ] & 0x0F ) | 0xA0; break;
593
```

```
594            case 3: pBuf[pLen++] = 0xDE; pBuf[pLen++] = smePtr -> functions[ 3 ]; break;
595            case 4: pBuf[pLen++] = 0xDF; pBuf[pLen++] = smePtr -> functions[ 4 ]; break;
596            case 5: pBuf[pLen++] = 0xD8; pBuf[pLen++] = smePtr -> functions[ 5 ]; break;
597            case 6: pBuf[pLen++] = 0xD9; pBuf[pLen++] = smePtr -> functions[ 6 ]; break;
598            case 7: pBuf[pLen++] = 0xDA; pBuf[pLen++] = smePtr -> functions[ 7 ]; break;
599            case 8: pBuf[pLen++] = 0xDB; pBuf[pLen++] = smePtr -> functions[ 8 ]; break;
600            case 9: pBuf[pLen++] = 0xDC; pBuf[pLen++] = smePtr -> functions[ 9 ]; break;
601        }
602
603        mainTrack -> loadPacket( pBuf, pLen, 4 );
604        return ( ALL_OK );
605    }
606
607    //-------------------------------------------------------------------------------------------------------
608    // "writeCVMain" writes a CV value to the decoder on the main track. CV numbers range from 1 to 1024, but are
609    // encoded from 0 to 1023. The DCC standard defines various modes for retrieving CV values. This function
610    // implements CV write mode mode 0 and 1, by calling the respective method. The other modes are not supported.
611    // For bit mode access, the bit position and bit value are encoded in the "val" parameter with bit 3 containing
612    // the data and bit 0 ..2 the bit offset.
613    //
614    //    0 Direct Byte
615    //    1 Direct Bit
616    //    2 Page Mode
617    //    3 Register Mode
618    //    4 Address Only Mode
619    //
620    //
621    // Note on the MAIN track, there is no way for the decoder to answer via a raise in power consumption. The
622    // command shown here is just sent. If however RailCom is available, the decoder can answer with the CV
623    // value in a following cutout. This is currently not implemented.
624    //-------------------------------------------------------------------------------------------------------
625    uint8_t LcsBaseStationLocoSession::writeCVMain( uint8_t sId, uint16_t cvId, uint8_t mode, uint8_t val ) {
626
627        if          ( mode == 0 )  return ( writeCVByteMain( sId, cvId, val ));
628        else if     ( mode == 1 )  return ( writeCVBitMain( sId, cvId, ( val & 0x07 ), (( val & 0x08 ) >> 3 )));
629        else                       return ( ERR_INVALID_CV_MODE );
630    }
631
632    //-------------------------------------------------------------------------------------------------------
633    // "writeCVByteMain" writes a byte to the CV while the loco is on the main track. The CV numbers range from
634    // 1 to 1024, but are encoded from 0 to 1023. This function implements CV write mode mode 0, which is write
635    // a byte at a time. There is no way to validate our operation, only writes are possible. The packet is sent
636    // four times.
637    //
638    //-------------------------------------------------------------------------------------------------------
639    uint8_t LcsBaseStationLocoSession::writeCVByteMain( uint8_t sId, uint16_t cvId, uint8_t val ) {
640
641        uint8_t    pBuf[ MAX_DCC_PACKET_SIZE ];
642        uint8_t    pLen = 0;
643
644        SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
645        if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
646
647        if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
648        cvId--;
649
650        if ( smePtr -> cabId > 127 ) pBuf[pLen++] = highByte( smePtr -> cabId ) | 0xC0;
651        pBuf[pLen++] = lowByte( smePtr -> cabId );
652        pBuf[pLen++] = 0xEC + ( highByte( cvId ) & 0x03 );
653        pBuf[pLen++] = lowByte( cvId );
654        pBuf[pLen++] = val;
655
656        mainTrack -> loadPacket( pBuf, pLen, 4 );
657        return ( ALL_OK );
658    }
659
660    //-------------------------------------------------------------------------------------------------------
661    // "writeCVBitMain" writes a bit to the CV while the loco is on the main track. The CV numbers range from 1
662    // to 1024, but are encoded from 0 to 1023. his function implements CV write mode mode 1, which is write a
663    // bit at a time. On input the "val" parameter encodes the bit position in bits 0 - 2 and the bit value in
664    // bit 3.  There is no way to validate our operation, only CV writes are possible. The packet is sent four
665    // times.
666    //
667    //-------------------------------------------------------------------------------------------------------
668    uint8_t LcsBaseStationLocoSession::writeCVBitMain( uint8_t sId, uint16_t cvId, uint8_t bitPos, uint8_t val ) {
669
670        SessionMapEntry *smePtr = getSessionMapEntryPtr( sId );
671        if ( smePtr == nullptr ) return ( ERR_INVALID_SESSION_ID );
672
673        if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
674        cvId--;
675
676        uint8_t pBuf[ MAX_DCC_PACKET_SIZE ];
677        uint8_t pLen = 0;
678
679        if ( smePtr -> cabId > 127 ) pBuf[pLen++] = highByte( smePtr -> cabId ) | 0xC0;
680        pBuf[pLen++] = lowByte( smePtr -> cabId );
681        pBuf[pLen++] = 0xE8 + (highByte( cvId ) & 0x03 );
682        pBuf[pLen++] = lowByte( cvId );
683        pBuf[pLen++] = 0xF0 + (( val % 2 ) << 3 ) + ( bitPos % 8 );
684
685        mainTrack -> loadPacket( pBuf, pLen, 4 );
686        return ( ALL_OK );
687    }
688
689    //-------------------------------------------------------------------------------------------------------
690    // "readCV" retrieves a CV value from the decoder in service mode. CV numbers range from 1 to 1024, but are
691    // encoded from 0 to 1023. This command is only available in service mode, i.e. on a programming track. The
692    // DCC standard defines various modes for retrieving CV values. We only support mode 0 and 1. The other modes
```

```
693    // are not supported. For bit mode access, the bit position and bit value are encoded in the "val" parameter
694    // with bit 3 containing the data and bit 0 ..2 the bit offset.
695    //
696    //    0 - Direct Byte
697    //    1 - Direct Bit
698    //    2 - Page Mode
699    //    3 - Register Mode
700    //    4 - Address Only Mode
701    //
702    // This function implements the CV read mode 0 and 1, which is reading a byte or a bit at a time by calling
703    // the respective method.
704    //
705    //-----------------------------------------------------------------------------------------------------------
706    uint8_t LcsBaseStationLocoSession::readCV( uint16_t cvId, uint8_t mode, uint8_t *val ) {
707
708        if          ( mode == 0 )  return ( readCVByte( cvId, val ));
709        else if   ( mode == 1 )  return ( readCVBit( cvId, *val % 8, val ));
710        else                       return ( ERR_INVALID_CV_MODE );
711    }
712
713    //-----------------------------------------------------------------------------------------------------------
714    // "readCVByte" will retrieve a complete byte from the decoder. CV numbers range from 1 to 1024, but are
715    // encoded from 0 to 1023. This command is only available in service mode, i.e. on a programming track.
716    // Reading a CV value where the decoder can only respond with a "yes" or "no" is a tedious matter. We are
717    // actually reading the CV value bit by bit and then ask if the assembled byte read is the one just read. The
718    // general packet sequence is a according to DCC standard standard 3 or more RESET packets, 5 or more identical
719    // READ packets and then RESET packages until acknowledge or timeout. The RESET packet preamble and postamble
720    // series are sent during the decoder ack setup and detect call to the DCC track object. During the preamble
721    // we  figure out the base current consumption of the decoder, during the postamble packets we measure to get
722    // the decoder acknowledge, which is a short raise in power consumption to indicate an ACK.
723    //
724    //
725    // ??? This command may take a long time, a lot of packets are sent. While this not an issue with the signal
726    // generation, which is done via interrupt handlers, it may be an issue with any other work of the base
727    // station. This code needs to be redesigned to use a kind of state machine that sends a packet at a time
728    // so other work can interleave.
729    //-----------------------------------------------------------------------------------------------------------
730    uint8_t LcsBaseStationLocoSession::readCVByte( uint16_t cvId, uint8_t *val ) {
731
732        if ( ! ( progTrack -> isServiceModeOn( ))) return ( ERR_NO_SVC_MODE );
733        if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
734        cvId --;
735
736        uint8_t   pBuf[ MAX_DCC_PACKET_SIZE ];
737        uint8_t   bValue  = 0;
738        uint16_t  base    = progTrack -> decoderAckBaseline( 5 );
739
740        pBuf[0]  = 0x78 + ( highByte( cvId ) & 0x03 );
741        pBuf[1]  = lowByte( cvId );
742
743        for ( int i = 0; i < 8; i++ ) {
744
745            pBuf[2] = 0xE8 + i;
746            progTrack -> loadPacket( pBuf, 3, 5 );
747            bitWrite( &bValue, i, progTrack -> decoderAckDetect( base, 9 ));
748        }
749
750        *val     = bValue;
751        pBuf[0] = 0x74 + ( highByte( cvId ) & 0x03 );
752        pBuf[1] = lowByte( cvId );
753        pBuf[2] = bValue;
754        progTrack -> loadPacket( pBuf, 3, 5 );
755
756        return (( progTrack -> decoderAckDetect( base, 9 )) ? ALL_OK : (LcsErrorCodes) ERR_CV_OP_FAILED );
757    }
758
759    //-----------------------------------------------------------------------------------------------------------
760    // "readCVBit" will retrieve one bit from a CV variable from the decoder. CV numbers range from 1 to 1024,
761    // but are encoded from 0 to 1023. This command is only available in service mode, i.e. on a programming
762    // track. The "val" parameter encodes the bit position in bits 0 - 2. We are reading the CV value bit and
763    // then ask if the bit read is the one just read. We first try to validate a zero bit. If that succeeds,
764    // fine. Otherwise we try to validate a one bit. If that succeeds, fine. Otherwise we have a CV read error.
765    // The general packet sequence is a according to DCC standard 3 or more RESET packets, 5 or more identical
766    // READ packets and then RESET packages until acknowledge or timeout. The RESET packet preamble and postamble
767    // are sent during the decoder ack setup and detect call to the DCC track object. During the preamble we
768    // figure out the base current consumption of the decoder, during the postamble we measure to get the decoder
769    // acknowledge, which is a short raise in power consumption to indicate an ACK.
770    //
771    // ??? This command may take a long time, a lot of packets are sent. While this not an issue with the signal
772    // generation, which is done via interrupt handlers, it may be an issue with any other work of the base
773    // station. This code needs to be redesigned to use a kind of state machine that sends a packet at a time
774    // so other work can interleave.
775    //-----------------------------------------------------------------------------------------------------------
776    uint8_t LcsBaseStationLocoSession::readCVBit( uint16_t cvId, uint8_t bitPos, uint8_t *val ) {
777
778        if ( ! ( progTrack -> isServiceModeOn( ))) return ( ERR_NO_SVC_MODE );
779
780        if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
781        cvId --;
782
783        uint8_t  pBuf[ MAX_DCC_PACKET_SIZE ];
784        int    base = progTrack -> decoderAckBaseline( 5 );
785
786        pBuf[0]  = 0x78 + ( highByte( cvId ) & 0x03 );
787        pBuf[1]  = lowByte( cvId );
788        pBuf[2]  = 0xE8 + ( bitPos % 8 );
789
790        progTrack -> loadPacket( pBuf, 3, 5 );
791
```

```
792         if ( ! ( progTrack -> decoderAckDetect ( base, 9 ))) {
793
794              pBuf[2] = 0xE8 + 8 + ( bitPos % 8 );
795              progTrack -> loadPacket ( pBuf, 3, 5 );
796
797              if ( progTrack -> decoderAckDetect ( base, 9 )) {
798
799                  *val = 1;
800                  return ( ALL_OK );
801              }
802              else return ( ERR_CV_OP_FAILED );
803         }
804         else return ( ALL_OK );
805 }
806
807 //-------------------------------------------------------------------------------------------------------
808 // "writeCV" writes a CV value to the decoder. CV numbers range from 1 to 1024, but are encoded from 0 to
809 // 1023. This command is only available in service mode, i.e. on a programming track. The DCC standard defines
810 // various modes for accessing CV values. For bit mode access, the bit position and bit value are encoded in
811 // the "val" parameter with bit 3 containing the data and bit 0 .. 2 the bit offset.
812 //
813 //    0 Direct Byte
814 //    1 Direct Bit
815 //    2 Page Mode
816 //    3 Register Mode
817 //    4 Address Only Mode
818 //
819 // This function implements the CV write mode 0 and 1, which is writing a byte or a bit at a time by calling
820 // the respective method.
821 //
822 //-------------------------------------------------------------------------------------------------------
823 uint8_t LcsBaseStationLocoSession::writeCV( uint16_t cvId, uint8_t mode, uint8_t val ) {
824
825     if         ( mode == 0 )  return ( writeCVByte( cvId, val ));
826     else if    ( mode == 1 )  return ( writeCVBit( cvId, ( val & 0x07 ), (( val & 0x08 ) >> 3 )));
827     else                      return ( ERR_INVALID_CV_MODE );
828 }
829
830 //-------------------------------------------------------------------------------------------------------
831 // "writeCVByte" puts a data byte into the CV on the decoder. This function is only available in service mode.
832 // The CV numbers range from 1 to 1024, but are encoded from 0 to 1023. The data byte written will also be
833 // verified. The packet sequence follows the DCC standard. We will send the CV byte write packet four times,
834 // send out several RESET packets and the send the verify packets to get the acknowledge from the decoder that
835 // the operation was successful.
836 //
837 // ??? This command may take a long time, a lot of packets are sent. While this not an issue with the signal
838 // generation, which is done via interrupt handlers, it may be an issue with any other work of the base
839 // station. This code needs to be redesigned to use a kind of state machine that sends a packet at a time
840 // so other work can interleave.
841 //-------------------------------------------------------------------------------------------------------
842 uint8_t LcsBaseStationLocoSession::writeCVByte( uint16_t cvId, uint8_t val ) {
843
844     if ( ! ( progTrack -> isServiceModeOn( ))) return ( ERR_NO_SVC_MODE );
845
846     if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
847     cvId --;
848
849     uint8_t pBuf[ MAX_DCC_PACKET_SIZE ];
850     int     base = progTrack -> decoderAckBaseline( 5 );
851
852     pBuf[0] = 0x7C + ( highByte( cvId ) & 0x03 );
853     pBuf[1] = lowByte( cvId );
854     pBuf[2] = val;
855
856     progTrack -> loadPacket ( pBuf, 3, 4 );
857     progTrack -> loadPacket ( resetDccPacketData, 2, 11 );
858
859     pBuf[0] = 0x74 + ( highByte( cvId ) & 0x03 );
860     progTrack -> loadPacket ( pBuf, 3, 5 );
861
862     return (( progTrack -> decoderAckDetect ( base, 9 )) ? ALL_OK : (LcsErrorCodes) ERR_CV_OP_FAILED );
863 }
864
865 //-------------------------------------------------------------------------------------------------------
866 // "writeCVBit" puts a data bit into the CV on the decoder. This function is only available in session mode.
867 // The CV numbers range from 1 to 1024, but are encoded from 0 to 1023. For the bit mode, the "val" parameter
868 // encodes the bit position in bits 0 - 2 and the bit value in bit 3. The packet sequence follows the DCC
869 // standard, similar to the byte write operation.
870 //
871 // ??? This command may take a long time, a lot of packets are sent. While this not an issue with the signal
872 // generation, which is done via interrupt handlers, it may be an issue with any other work of the base
873 // station. This code needs to be redesigned to use a kind of state machine that sends a packet at a time
874 // so other work can interleave.
875 //-------------------------------------------------------------------------------------------------------
876 uint8_t LcsBaseStationLocoSession::writeCVBit( uint16_t cvId, uint8_t bitPos, uint8_t val ) {
877
878     if ( ! ( progTrack -> isServiceModeOn( ))) return ( ERR_NO_SVC_MODE );
879     if ( ! validCvId( cvId )) return ( ERR_INVALID_CV_ID );
880     cvId --;
881
882     uint8_t pBuf[ MAX_DCC_PACKET_SIZE ];
883     int     base = progTrack -> decoderAckBaseline( 5 );
884
885     pBuf[0] = 0x78 + ( highByte( cvId ) & 0x03 );
886     pBuf[1] = lowByte( cvId );
887     pBuf[2] = 0xF0 + (( val % 2 ) * 8 ) + ( bitPos % 8 );
888
889     progTrack -> loadPacket ( pBuf, 3, 4 );
890     progTrack -> loadPacket ( resetDccPacketData, 2, 11 );
```

```
891
892        bitWrite( &pBuf[2], 4, false );
893        progTrack -> loadPacket( pBuf, 3, 5 );
894
895        return (( progTrack -> decoderAckDetect( base, 9 )) ? ALL_OK : (LcsErrorCodes) ERR_CV_OP_FAILED );
896    }
897
898    //-------------------------------------------------------------------------------------------------------------
899    // "writeDccPacketMain" just load the DCC packet into the buffer and out it goes to the main track without
900    // any further checks.
901    //
902    //-------------------------------------------------------------------------------------------------------------
903    uint8_t LcsBaseStationLocoSession::writeDccPacketMain( uint8_t *pBuf, uint8_t pLen, uint8_t nRepeat ) {
904
905        if ( ! validDccPacketlen( pLen )) return ( ERR_INVALID_PACKET_LEN );
906        if ( ! validDccPacketRepeatCnt( nRepeat )) return ( ERR_INVALID_REPEATS );
907
908        mainTrack -> loadPacket( pBuf, pLen, nRepeat );
909        return ( ALL_OK );
910    }
911
912    //-------------------------------------------------------------------------------------------------------------
913    // "writeDccPacketProg" just load the DCC packet into the buffer and out it goes to the programming track
914    // without any further checks.
915    //
916    //-------------------------------------------------------------------------------------------------------------
917    uint8_t LcsBaseStationLocoSession::writeDccPacketProg( uint8_t *pBuf, uint8_t pLen, uint8_t nRepeat ) {
918
919        if ( ! validDccPacketlen( pLen )) return ( ERR_INVALID_PACKET_LEN );
920        if ( ! validDccPacketRepeatCnt( nRepeat )) return ( ERR_INVALID_REPEATS );
921
922        progTrack -> loadPacket( pBuf, pLen, nRepeat );
923        return ( ALL_OK );
924    }
925
926    //-------------------------------------------------------------------------------------------------------------
927    // "allocateSessionEntry" allocates a new loco session entry and returns a pointer to the entry. We first
928    // check if there is already a session for the cabId and if so, we return a null pointer. If not, we try to
929    // find a free entry and if that fails try to raise the high water mark. If that fails, we are out of luck
930    // and return a null pointer.
931    //
932    //-------------------------------------------------------------------------------------------------------------
933    SessionMapEntry* LcsBaseStationLocoSession::allocateSessionEntry( uint16_t cabId ) {
934
935        if ( lookupSessionEntry( cabId ) != nullptr ) return ( nullptr );
936
937        SessionMapEntry *freePtr = lookupSessionEntry( NIL_CAB_ID );
938
939        if (( freePtr == nullptr ) && ( sessionMapHwm < sessionMapLimit )) freePtr = sessionMapHwm ++;
940
941        if ( freePtr != nullptr ) {
942
943            initSessionEntry( freePtr );
944            freePtr -> cabId  = cabId;
945            freePtr -> flags  |= SME_ALLOCATED;
946
947            if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_SESSION )) {
948
949                printf( "Allocate session entry: %d, HWM: %d\n",
950                    ( freePtr - sessionMap + 1 ), ( sessionMapHwm - sessionMap ));
951            }
952        }
953
954        return ( freePtr );
955    }
956
957    //-------------------------------------------------------------------------------------------------------------
958    // "deallocateSessionEntry" is the counterpart to the entry allocation. We just free up the entry. If the
959    // entry is at the high water mark, we try to free up all possibly free entries from the high water mark
960    // downward, decrementing the high water mark. This way the high water mark shrinks again and we do not need
961    // to work through unused entries in the middle.
962    //
963    //-------------------------------------------------------------------------------------------------------------
964    void LcsBaseStationLocoSession::deallocateSessionEntry( SessionMapEntry *smePtr ) {
965
966        if (( smePtr != nullptr ) && ( smePtr >= sessionMap ) && ( smePtr < sessionMapHwm )) {
967
968            if ( smePtr == ( sessionMapHwm - 1 )) {
969
970                do {
971
972                    initSessionEntry( smePtr );
973                    smePtr --;
974                }
975                while (( smePtr -> cabId == NIL_CAB_ID ) && ( smePtr >= sessionMap ));
976
977                sessionMapHwm = smePtr + 1;
978            }
979            else initSessionEntry( smePtr );
980
981            if (( debugMask & DBG_BS_CONFIG ) && ( debugMask & DBG_BS_SESSION )) {
982
983                printf( "Released Session, sId: %d, ,new  HWM: %d\n",
984                    ( smePtr - sessionMap + 1 ), ( sessionMapHwm - sessionMap ));
985            }
986        }
987    }
988
989    //-------------------------------------------------------------------------------------------------------------
```

```cpp
990   // "lookupSessionEntry" scans the session map for a session entry for the cabId. If none is found, a nullptr
991   // is returned. Note that a NIL_CAB_ID as argument is also a valid input and will return the first free entry.
992   //
993   //-------------------------------------------------------------------------------------------------------------
994   SessionMapEntry *LcsBaseStationLocoSession::lookupSessionEntry( uint16_t cabId ) {
995
996       SessionMapEntry *smePtr = sessionMap;
997
998       while ( smePtr < sessionMapHwm ) {
999
1000          if ( smePtr -> cabId == cabId ) return ( smePtr );
1001          else smePtr ++;
1002      }
1003
1004      return ( nullptr );
1005  }
1006
1007  //-------------------------------------------------------------------------------------------------------------
1008  // "initSessionEntry" initializes a session map entry with default values.
1009  //
1010  //-------------------------------------------------------------------------------------------------------------
1011  void LcsBaseStationLocoSession::initSessionEntry( SessionMapEntry *smePtr ) {
1012
1013      smePtr -> flags            = SME_DEFAULT_SETTING;
1014      smePtr -> cabId            = NIL_CAB_ID;
1015      smePtr -> speedSteps       = DCC_SPEED_STEPS_128;
1016      smePtr -> speed            = 0;
1017      smePtr -> direction        = 0;
1018      smePtr -> engineState      = 0;
1019      smePtr -> lastKeepAliveTime = 0;
1020      smePtr -> nextRefreshStep  = 0;
1021
1022      for ( int i = 0; i < MAX_DCC_FUNC_GROUP_ID; i++ ) smePtr -> functions[ i ] = 0;
1023  }
1024
1025  //-------------------------------------------------------------------------------------------------------------
1026  // "getSessionMapEntryPtr" returns a pointer to a valid and used sessionMap entry. The sessionId starts with
1027  // index 1.
1028  //
1029  //-------------------------------------------------------------------------------------------------------------
1030  SessionMapEntry *LcsBaseStationLocoSession::getSessionMapEntryPtr( uint8_t sId ) {
1031
1032      if ( ! isInRangeU( sId, MIN_LOCO_SESSION_ID, ( sessionMapHwm - sessionMap ))) return ( nullptr );
1033      return (( sessionMap[ sId - 1 ].cabId == NIL_CAB_ID ) ? nullptr : &sessionMap[ sId - 1 ] );
1034  }
1035
1036  //-------------------------------------------------------------------------------------------------------------
1037  // "printSessionMapConfig" lists cab session map configuration data.
1038  //
1039  //-------------------------------------------------------------------------------------------------------------
1040  void LcsBaseStationLocoSession::printSessionMapConfig( ) {
1041
1042      printf( "Session Map Config\n" );
1043      printf( " Options: 0x%x\n", options );
1044      printf( " Session Map Size: %d\n", ( sessionMapLimit - sessionMap ));
1045  }
1046
1047  //-------------------------------------------------------------------------------------------------------------
1048  // "printSessionMapInfo" lists the cab session map data.
1049  //
1050  //-------------------------------------------------------------------------------------------------------------
1051  void LcsBaseStationLocoSession::printSessionMapInfo( ) {
1052
1053      printf( "Session Map Info\n" );
1054
1055      printf( " Flags: 0x%x\n", flags );
1056
1057      // ??? decode the flags ?  e.g. "[ f f f f ]"
1058
1059      printf( " Session Map Hwm: %d\n", ( sessionMapHwm - sessionMap ));
1060
1061      for ( SessionMapEntry *smePtr = sessionMap; smePtr < sessionMapHwm; smePtr ++ ) {
1062
1063          if ( smePtr -> cabId != NIL_CAB_ID ) printSessionEntry( smePtr );
1064      }
1065
1066       printf( "\n" );
1067  }
1068
1069  //-------------------------------------------------------------------------------------------------------------
1070  // "printSessionEntry" lists a cab session.
1071  //
1072  //-------------------------------------------------------------------------------------------------------------
1073  void LcsBaseStationLocoSession::printSessionEntry( SessionMapEntry *smePtr ) {
1074
1075    if ( smePtr != nullptr ) {
1076
1077      printf( " sId: %d, cabId: %d, speed: %d ", ( smePtr - sessionMap + 1 ), smePtr -> cabId, smePtr -> speed );
1078
1079      printf( "%s", (( smePtr -> direction ) ? "Rev" : "Fwd" ));
1080      printf( ", functions: " );
1081
1082      for ( uint8_t i = 0; i < MAX_DCC_FUNC_GROUP_ID; i++ ) {
1083
1084         printf( " 0x%x ", smePtr -> functions[ i ] );
1085      }
1086
1087      printf( " Flags: 0x%x", ( smePtr -> flags ));
1088
```

151

```
1089        // ??? decode the flags ? e.g. "[ f f f f ]"
1090    }
1091
1092    printf( "\n" );
1093 }
```

```
1   //-----------------------------------------------------------------------------------------------------------
2   //
3   // LCS - Base Station
4   //
5   //-----------------------------------------------------------------------------------------------------------
6   // This is the main program for the LCS base station. Every layout would need at least a base station. Its
7   // primary task is to manage the DCC loco sessions, generate the DCC signals and manage the dual DCC track
8   // power outputs.
9   //
10  // Like all other LcsNodes, the base station will provide a rich set of variable that can be set and queried.
11  // In addition, the base features a command line extension which implements the DCC++ style commands and
12  // some more base station specific commands. The idea for the DCC++ command syntax and commands is that these
13  // command can also be submitted by a third party software ( e.g. JMRI ). An example would be the JMRI CV
14  // programming tool.
15  //
16  // ??? we need an idea of system time like DCC. To be broadcasted periodically.
17  // ??? we also need a broadcast of the layout system capabilities....
18  //
19  //-----------------------------------------------------------------------------------------------------------
20  //
21  // LCS - Controller Dependent Code - Raspberry PI Pico Implementation
22  // Copyright (C) 2022 - 2024 Helmut Fieres
23  //
24  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
25  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
26  // option) any later version.
27  //
28  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
29  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
30  // for more details.
31  //
32  // You should have received a copy of the GNU General Public License along with this program. If not, see
33  // http://www.gnu.org/licenses
34  //
35  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
36  //
37  //-----------------------------------------------------------------------------------------------------------
38  #include "LcsCdcLib.h"
39  #include "LcsRuntimeLib.h"
40  #include "LcsBaseStation.h"
41
42  using namespace LCS;
43
44  //-----------------------------------------------------------------------------------------------------------
45  // Base station global data.
46  //
47  // ??? can the objects for track and session just use these variables instead of keeping them locally as a
48  // field ?
49  //-----------------------------------------------------------------------------------------------------------
50  uint16_t                    debugMask;
51  CDC::CdcConfigDesc          cdcConfig;
52  LCS::LcsConfigDesc          lcsConfig;
53  LcsBaseStationCommand       serialCmd;
54  LcsBaseStationDccTrack      mainTrack;
55  LcsBaseStationDccTrack      progTrack;
56  LcsBaseStationLocoSession   locoSessions;
57  LcsBaseStationMsgInterface  msgInterface;
58
59  //-----------------------------------------------------------------------------------------------------------
60  // Setup the configuration of the HW board. The CDC config contains the HW pin mapping. The dual bridge pins
61  // for enabling the bridge and controlling its direction. The pins are mapped to the CDC pin names DIO2 to
62  // DIO7 as show below. DIO-0 and DIO-1 are routed to the extension connector board.
63  //
64  //      cdcConfig.DIO_PIN_0     -> DIO-0
65  //      cdcConfig.DIO_PIN_1     -> DIO-1
66  //      cdcConfig.DIO_PIN_2     -> Main dcc1
67  //      cdcConfig.DIO_PIN_3     -> Main dcc2
68  //      cdcConfig.DIO_PIN_4     -> Prog ddc1
69  //      cdcConfig.DIO_PIN_5     -> Prog ddc2
70  //      cdcConfig.DIO_PIN_6     -> Main enable
71  //      cdcConfig.DIO_PIN_7     -> Prog enable
72  //
73  // Current mapping: Main Controller Board B.01.00 - PICO - newest version.
74  //
75  //      cdcConfig.DIO_PIN_0     = 8;
76  //      cdcConfig.DIO_PIN_1     = 12;
77  //      cdcConfig.DIO_PIN_2     = 21;
78  //      cdcConfig.DIO_PIN_3     = 20;
79  //      cdcConfig.DIO_PIN_4     = 19;
80  //      cdcConfig.DIO_PIN_5     = 18;
81  //      cdcConfig.DIO_PIN_6     = 6;
82  //      cdcConfig.DIO_PIN_7     = 7;
83  //
84  // In addition, the HW pins for I2C, analog inputs and so on are set. Check the schematic for the board
85  // to see all pin assign,ents.
86  //
87  // ??? one day we will have several base station versions. Although they will perhaps differ, their the CDC
88  // pin names used should not change. But we would need to come up with an idea which configuration to use
89  // when preparing an image for the base station board.
90  //-----------------------------------------------------------------------------------------------------------
91  void setupConfigInfo( ) {
92
93      cdcConfig = CDC::getConfigDefault( );
94      lcsConfig = LCS::getConfigDefault( );
95
96      cdcConfig.ADC_PIN_0         = 26;
97      cdcConfig.ADC_PIN_1         = 27;
98
```

```
 99        cdcConfig.PFAIL_PIN              = 5;
100        cdcConfig.EXT_INT_PIN            = 22;
101        cdcConfig.READY_LED_PIN          = 14;
102        cdcConfig.ACTIVE_LED_PIN         = 15;
103
104        cdcConfig.DIO_PIN_0              = 8;
105        cdcConfig.DIO_PIN_1              = 12;
106        cdcConfig.DIO_PIN_2              = 21;
107        cdcConfig.DIO_PIN_3              = 20;
108        cdcConfig.DIO_PIN_4              = 19;
109        cdcConfig.DIO_PIN_5              = 18;
110        cdcConfig.DIO_PIN_6              = 6;
111        cdcConfig.DIO_PIN_7              = 7;
112
113        cdcConfig.UART_RX_PIN_1          = 13;
114        cdcConfig.UART_RX_PIN_2          = 9;
115
116        cdcConfig.NVM_I2C_SCL_PIN        = 3;
117        cdcConfig.NVM_I2C_SDA_PIN        = 2;
118        cdcConfig.NVM_I2C_ADR_ROOT       = 0x50;
119
120        cdcConfig.EXT_I2C_SCL_PIN        = 17;
121        cdcConfig.EXT_I2C_SDA_PIN        = 16;
122        cdcConfig.EXT_I2C_ADR_ROOT       = 0x50;
123
124        cdcConfig.CAN_BUS_RX_PIN         = 0;
125        cdcConfig.CAN_BUS_TX_PIN         = 1;
126        cdcConfig.CAN_BUS_CTRL_MODE      = CAN_BUS_LIB_PICO_PIO_125K_M_CORE;
127        cdcConfig.CAN_BUS_DEF_ID         = 100;
128
129        cdcConfig.NODE_NVM_SIZE          = 8192;
130        cdcConfig.EXT_NVM_SIZE           = 4096;
131
132        lcsConfig.options                |= NOPT_SKIP_NODE_ID_CONFIG;
133    }
134
135    //-------------------------------------------------------------------------------------------------------
136    // Some little helper functions.
137    //
138    //-------------------------------------------------------------------------------------------------------
139    void printLcsMsg( uint8_t *msg ) {
140
141      int msgLen = (( msg[0] >> 5 ) + 1 ) % 8;
142
143      for ( int i = 0; i < msgLen; i++ ) printf( "0x%x ", msg[i] );
144      printf( "\n" );
145    }
146
147    uint8_t printStatus (uint8_t status ) {
148
149      printf( "Status: " );
150      if ( status == LCS::ALL_OK ) printf( "OK\n" );
151      else printf ( "FAILED: %d\n", status );
152      return ( status );
153    }
154
155    //-------------------------------------------------------------------------------------------------------
156    // The node and port initialization callback.
157    //
158    // ??? when we know what ports we actually need / use, disable the rest of the ports.
159    //-------------------------------------------------------------------------------------------------------
160    uint8_t lcsInitCallback( uint16_t npId ) {
161
162        switch ( npId & 0xF ) {
163
164            case 0:     printf( "Node Init Callback: 0x%x\n", npId >> 4     ); break;
165            default:    printf( "Port Init Callback: 0x%x\n", npId &  0xF   );
166        }
167
168        return( ALL_OK );
169    }
170
171    //-------------------------------------------------------------------------------------------------------
172    // The node or port reset callback.
173    //
174    //-------------------------------------------------------------------------------------------------------
175    uint8_t lcsResetCallback( uint16_t npId ) {
176
177        switch ( npId & 0xF ) {
178
179            case 0:     printf( "Node Reset Callback: 0x%x\n", npId >> 4     ); break;
180            default:    printf( "Port Reset Callback: 0x%x\n", npId &  0xF   );
181        }
182
183        return( ALL_OK );
184    }
185
186    //-------------------------------------------------------------------------------------------------------
187    // The node or port power fail callback.
188    //
189    //-------------------------------------------------------------------------------------------------------
190    uint8_t lcsPfailCallback( uint16_t npId ) {
191
192        switch ( npId & 0xF ) {
193
194            case 0:     printf( "Node Power Fail Callback: 0x%x\n", npId >> 4     ); break;
195            default:    printf( "Port Power Fail Callback: 0x%x\n", npId &  0xF   );
196        }
197
```

```
198        return( ALL_OK );
199    }
200
201    //------------------------------------------------------------------------------------------------------------------
202    // The base station has also a command line interpreter. The callback is invoked by the core library when
203    // there is a command that it does not handle.
204    //
205    //------------------------------------------------------------------------------------------------------------------
206    uint8_t lcsCmdCallback( char *cmdLine ) {
207
208        serialCmd.handleSerialCommand( cmdLine );
209        return( ALL_OK );
210    }
211
212    //------------------------------------------------------------------------------------------------------------------
213    // Other LCS message callbacks. All we do is to list their invocation. ( for now )
214    //
215    //------------------------------------------------------------------------------------------------------------------
216    uint8_t lcsMsgCallback( uint8_t *msg ) {
217
218        printf( "MsgCallback: ", msg  );
219
220        for ( int i = 0; i < 8; i++ ) printf( "0x%2x " );
221        printf( "\n" );
222        return( ALL_OK );
223    }
224
225    //------------------------------------------------------------------------------------------------------------------
226    // The LCS core library ends in a loop that manages its internal workings, invoking the callbacks where
227    // needed. One set of callbacks are the periodic tasks. The base station needs to periodically run the DCC
228    // track state machine for power consumption measurement and so on.  Another periodic task is to refresh the
229    // active locomotive session entries.
230    //
231    //------------------------------------------------------------------------------------------------------------------
232    uint8_t bsMainTrackCallback( ) {
233
234        mainTrack.runDccTrackStateMachine( );
235        return( ALL_OK );
236    }
237
238    uint8_t bsProgTrackCallback( ) {
239
240        progTrack.runDccTrackStateMachine( );
241        return( ALL_OK );
242    }
243
244    uint8_t bsRefreshActiveSessionCallback( ) {
245
246        locoSessions.refreshActiveSessions( );
247        return( ALL_OK );
248    }
249
250    //------------------------------------------------------------------------------------------------------------------
251    // When the base station node receives a request with an item defined in the user item range or the base
252    // station itself issues such a request, the defined callback is invoked.
253    //
254    //------------------------------------------------------------------------------------------------------------------
255    uint8_t lcsReqCallback( uint8_t npId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
256
257        printf( "REQ callback: npId: 0x%x, item: %d", npId, item );
258        if ( arg1 != nullptr ) printf( ", arg1: %d, ", *arg1 ); else printf( ", arg1: null" );
259        if ( arg2 != nullptr ) printf( ", arg2: %d, ", *arg2 ); else printf( ", arg2: null" );
260        return( ALL_OK );
261    }
262
263    //------------------------------------------------------------------------------------------------------------------
264    // When the base station gets a reply message for a request previously sent, this callback is invoked.
265    //
266    //------------------------------------------------------------------------------------------------------------------
267    uint8_t lcsRepCallback( uint8_t npId, uint8_t item, uint16_t arg1, uint16_t arg2, uint8_t ret ) {
268
269        printf( "REP callback: npId: 0x%x, item: %d, arg1: %d, arg2: %d, ret: %d ", npId, item , arg1, arg2, ret );
270        return( ALL_OK );
271    }
272
273    //------------------------------------------------------------------------------------------------------------------
274    // For any event on the LCS system that the base station is interested in, this callback is invoked.
275    //
276    //------------------------------------------------------------------------------------------------------------------
277    uint8_t lcsEventCallback( uint16_t npId, uint16_t eId, uint8_t eAction, uint16_t eData ) {
278
279        printf( "Event: npId: 0x%x, eId: %d, eAction: %d, eData: %d\n", npId, eId, eAction, eData );
280        return( ALL_OK );
281    }
282
283    //------------------------------------------------------------------------------------------------------------------
284    // Init the Runtime.
285    //
286    //------------------------------------------------------------------------------------------------------------------
287    uint8_t initLcsRuntime( ) {
288
289        setupConfigInfo( );
290
291        uint8_t rStat = LCS::initRuntime( &lcsConfig, &cdcConfig );
292        printf( "LCS Base Station\n" );
293
294        CDC::printConfigInfo( &cdcConfig );
295
296        printStatus( rStat );
```

```
297         return( rStat );
298     }
299
300     //----------------------------------------------------------------------------------------------------------------
301     // This routine initializes the Loco Session Map Object.
302     //
303     //----------------------------------------------------------------------------------------------------------------
304     uint8_t setupLocoSessions( ) {
305
306         LcsBaseStationSessionMapDesc sessionDesc;
307
308         sessionDesc.options     = SM_OPT_ENABLE_REFRESH;
309         sessionDesc.maxSessions = 16;
310
311         printf( "Setup Session Map -> " );
312         return ( printStatus( locoSessions.setupSessionMap( &sessionDesc, &mainTrack, &progTrack )));
313     }
314
315     //----------------------------------------------------------------------------------------------------------------
316     // This routine initializes the MAIN track object.
317     //
318     // ??? define constants such as: SENSE_OR1_OPAMP_11 to set the milliVolts per Amp.
319     //----------------------------------------------------------------------------------------------------------------
320     int setupDccTrackMain( ) {
321
322         LcsBaseStationTrackDesc mainTrackDesc;
323
324         mainTrackDesc.options                   = DT_OPT_RAILCOM | DT_OPT_CUTOUT;
325
326         mainTrackDesc.enablePin                 = cdcConfig.DIO_PIN_6;
327         mainTrackDesc.dccSigPin1                = cdcConfig.DIO_PIN_2;
328         mainTrackDesc.dccSigPin2                = cdcConfig.DIO_PIN_3;
329         mainTrackDesc.sensePin                  = cdcConfig.ADC_PIN_0;
330         mainTrackDesc.uartRxPin                 = cdcConfig.UART_RX_PIN_1;
331
332         mainTrackDesc.initCurrentMilliAmp       = 500;
333         mainTrackDesc.limitCurrentMilliAmp      = 1500;
334         mainTrackDesc.maxCurrentMilliAmp        = 2000;
335         mainTrackDesc.milliVoltPerAmp           = 100 * 11;   // ??? opAmp has Factor eleven ...
336         mainTrackDesc.startTimeThresholdMillis  = 1000;
337         mainTrackDesc.stopTimeThresholdMillis   = 500;
338         mainTrackDesc.overloadTimeThresholdMillis = 500;
339         mainTrackDesc.overloadEventThreshold    = 10;
340         mainTrackDesc.overloadRestartThreshold  = 5;
341
342         printf( "Setup MAIN track -> " );
343         return ( printStatus( mainTrack.setupDccTrack( &mainTrackDesc )));
344     }
345
346     //----------------------------------------------------------------------------------------------------------------
347     // This routine initializes the PROG track object.
348     //
349     // ??? define constants such as: SENSE_OR1_OPAMP_11 to set the milliVolts per Amp.
350     //----------------------------------------------------------------------------------------------------------------
351     uint8_t setupDccTrackProg( ) {
352
353         LcsBaseStationTrackDesc progTrackDesc;
354
355         progTrackDesc.options                   = DT_OPT_SERVICE_MODE_TRACK;
356
357         progTrackDesc.enablePin                 = cdcConfig.DIO_PIN_7;
358         progTrackDesc.dccSigPin1                = cdcConfig.DIO_PIN_4;
359         progTrackDesc.dccSigPin2                = cdcConfig.DIO_PIN_5;
360         progTrackDesc.sensePin                  = cdcConfig.ADC_PIN_1;
361         progTrackDesc.uartRxPin                 = cdcConfig.UART_RX_PIN_2;
362
363         progTrackDesc.initCurrentMilliAmp       = 500;
364         progTrackDesc.limitCurrentMilliAmp      = 500;
365         progTrackDesc.maxCurrentMilliAmp        = 1000;
366         progTrackDesc.milliVoltPerAmp           = 100 * 11;   // ??? opAmp has Factor eleven ...
367         progTrackDesc.startTimeThresholdMillis  = 1000;
368         progTrackDesc.stopTimeThresholdMillis   = 500;
369         progTrackDesc.overloadTimeThresholdMillis = 500;
370         progTrackDesc.overloadEventThreshold    = 10;
371         progTrackDesc.overloadRestartThreshold  = 5;
372
373         printf( "Setup PROG track -> " );
374         return ( printStatus( progTrack.setupDccTrack( &progTrackDesc )));
375     }
376
377     //----------------------------------------------------------------------------------------------------------------
378     // The base station has also a command interpreter, primarily for the DCC++ commands.
379     //
380     //----------------------------------------------------------------------------------------------------------------
381     uint8_t setupSerialCommand( ) {
382
383         printf( "Setup Serial Command -> " );
384         return ( printStatus( serialCmd.setupSerialCommand( &locoSessions, &mainTrack, &progTrack )));
385     }
386
387     //----------------------------------------------------------------------------------------------------------------
388     // The LCS message interface is initialized in the LCS core library. This routine will set up the receiver
389     // handler for incoming LCS message that concern the base station.
390     //
391     //----------------------------------------------------------------------------------------------------------------
392     uint8_t setupMsgInterface( ) {
393
394         printf( "Setup LCS Msg Interface -> " );
395         return ( printStatus( msgInterface.setupLcsMsgInterface( &locoSessions, &mainTrack, &progTrack )));
```

```
396  }
397
398  //------------------------------------------------------------------------------------------------------------
399  // After the initial setup of the runtime library , the callback are registered.
400  //
401  //------------------------------------------------------------------------------------------------------------
402  uint8_t registerCallbacks( ) {
403
404      printf( "Registering Callbacks\n" );
405
406      registerLcsMsgCallback( lcsMsgCallback );
407      registerCmdCallback( lcsCmdCallback );
408      registerInitCallback( lcsInitCallback );
409      registerResetCallback( lcsResetCallback );
410      registerPfailCallback( lcsPfailCallback );
411      registerReqCallback( lcsReqCallback );
412      registerRepCallback( lcsRepCallback );
413      registerEventCallback( lcsEventCallback );
414      registerTaskCallback( bsMainTrackCallback, MAIN_TRACK_STATE_TIME_INTERVAL );
415      registerTaskCallback( bsProgTrackCallback, PROG_TRACK_STATE_TIME_INTERVAL );
416      registerTaskCallback( bsRefreshActiveSessionCallback, SESSION_REFRESH_TASK_INTERVAL );
417
418      return( ALL_OK );
419  }
420
421  //------------------------------------------------------------------------------------------------------------
422  // Fire up the base station. First all base station modules are initialized. If this is OK, the DCC tack
423  // signal generation is enabled , i.e. the interrupt driven DCC packet broadcasting starts. Finally, the
424  // track power is turned on and we give control to the LCS runtime for processing events and requests.
425  //
426  //------------------------------------------------------------------------------------------------------------
427  uint8_t startBaseStation( ) {
428
429      uint8_t rStat = ALL_OK;
430
431      if ( rStat == ALL_OK ) rStat = setupSerialCommand( );
432      if ( rStat == ALL_OK ) rStat = setupMsgInterface( );
433      if ( rStat == ALL_OK ) rStat = setupLocoSessions( );
434      if ( rStat == ALL_OK ) rStat = setupDccTrackMain( );
435      if ( rStat == ALL_OK ) rStat = setupDccTrackProg( );
436
437      if ( rStat == ALL_OK ) {
438
439          LcsBaseStationDccTrack::startDccProcessing( );
440
441          mainTrack.powerStart( );
442          progTrack.powerStart( );
443
444          // ??? bracket so that it is not printed when no console...
445          mainTrack.printDccTrackStatus( );
446          progTrack.printDccTrackStatus( );
447          printf( "Ready...\n" );
448
449          startRuntime( );
450      }
451
452      return( ALL_OK );
453  }
454
455  //------------------------------------------------------------------------------------------------------------
456  // The main program. Setup the runtime , register the callbacks , and get the show on the road.
457  //
458  //------------------------------------------------------------------------------------------------------------
459  int main( ) {
460
461      uint8_t rStat = ALL_OK;
462
463      if ( rStat == ALL_OK ) rStat = initLcsRuntime( );
464      if ( rStat == ALL_OK ) rStat = registerCallbacks( );
465      if ( rStat == ALL_OK ) return( startBaseStation( ));
466  }
```

A.4   Block Controller

APPENDIX A. LISTINGS TEST

```
1    //------------------------------------------------------------------------------------------------------
2    //
3    // LCS Block Controller - Include file
4    //
5    //------------------------------------------------------------------------------------------------------
6    //
7    // ??? this is a first cut at the block controller software. It remains to be seen what we should factor out
8    // and use across base station and block controller.
9    //
10   //
11   //
12   //------------------------------------------------------------------------------------------------------
13   //
14   // LCS Block Controller
15   // Copyright (C) 2019 - 2024  Helmut Fieres
16   //
17   // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
18   // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
19   // option) any later version.
20   //
21   // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
22   // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
23   // for more details.
24   //
25   // You should have received a copy of the GNU General Public License along with this program. If not, see
26   // http://www.gnu.org/licenses
27   //
28   //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
29   //
30   //------------------------------------------------------------------------------------------------------
31   #ifndef LcsBlockController_h
32   #define LcsBlockController_h
33
34   #include "LcsCdcLib.h"
35   #include "LcsRuntimeLib.h"
36
37   //------------------------------------------------------------------------------------------------------
38   //
39   // Ideas how to use the node data:
40   //
41   // There is a static data portion, which describes the block. This is data is entered when the block is configured.
42   //
43   //  - block ID
44   //  - block length
45   //  - block name
46   //  - previous block(s)
47   //  - next block(s)
48   //
49   //  - number of sections
50   //  - section lengths
51   //  - speed level - slow, middle, high ...
52   //  - support DCC and analog flag
53   //  - max current limit
54   //  - periodic time to send data
55   //  - timeout values of all kinds ?
56   //
57   //
58   // There is a dynamic data portion, which contains the data about the block current state
59   //
60   //  - mode ( DCC or analog or off )
61   //  - actual current
62   //  - section occupancy
63   //  - section enter / leave timestamps
64   //  -
65   //
66   // ??? what is retrieved from the dynamic data on a restart ?
67   //
68   // The node attributes contains data about how many blocks this node contains ( nodeId + portId -> blockId )
69   //
70   // Most of the data is stored in attributes for the port.
71   //
72   //
73   // Finally, there are items that represent commands to the block.
74   //
75   //  - emergency stop
76   //  - switch to DCC or analog mode
77   //  - block on or off
78   //  - signals setting
79   //  - turnout setting
80   //  - ...
81
82   // There are predefined events that the controller node will send.
83   //
84   //  - block state change
85   //  - section occupied
86   //  - section entered
87   //  - section left
88   //  -
89   //
90   //
91   //------------------------------------------------------------------------------------------------------
92
93
94   //------------------------------------------------------------------------------------------------------
95   // The block controller maintains a set of debug flags. The overall concept is very similar to the LCS runtime
96   // library debug mask. Then following debug flags are defined:
97   //
98   //      DBG_BC_CONFIG                  -   DEBUG base station enabled
```

APPENDIX A. LISTINGS TEST

```
99    //      DBG_BC_SETUP                         -   show the setup steps
100   //      DBG_BC_LCS_MSG_INTERFACE             -   show the incoming LCS messages
101   //      DBG_BC_TRACK_POWER_MGMT              -   show the track power measurement data
102   //      DBG_BC_RAILCOM                       -   show the RailCom activity
103   //
104   // The way to use these flags is for example:
105   //
106   //      if (( debugMask & DBG_BC_CONFIG ) && ( debugMask & DBG_BC_SESSION ))
107   //
108   //-------------------------------------------------------------------------------------------------------------
109   enum BlockControllerDebugFlags : uint16_t {
110
111       DBG_BC_CONFIG                    = 1 << 15,       // DEBUG enabled
112       DBG_BC_SETUP                     = 1 << 1,        // show the setup steps
113       DBG_BC_LCS_MSG_INTERFACE         = 1 << 2,        // show the incoming LCS messages
114       DBG_BC_TRACK_POWER_MGMT          = 1 << 3,        // show the track power measurement data
115       DBG_BC_RAILCOM                   = 1 << 4         // show the RailCom activity
116
117   };
118
119   //-------------------------------------------------------------------------------------------------------------
120   // Base station errors. Note that they need to be in the assigned to the user number range of errors defined
121   // in the LCS runtime library.
122   //
123   //-------------------------------------------------------------------------------------------------------------
124   enum BlockControllerErrors : uint8_t {
125
126       BLOCK_CONTROLLER_ERR_BASE        = 128,
127
128       ERR_MSG_INTERFACE_SETUP          = BLOCK_CONTROLLER_ERR_BASE + 10,
129       ERR_DCC_TRACK_CONFIG             = BLOCK_CONTROLLER_ERR_BASE + 11,
130       ERR_PIN_CONFIG                   = BLOCK_CONTROLLER_ERR_BASE + 12,
131
132       ERR_TRACK_CONFIG                 = BLOCK_CONTROLLER_ERR_BASE + 13,
133
134
135       ERR_NVM_HW_SETUP                 = BLOCK_CONTROLLER_ERR_BASE + 15,
136       ERR_PIO_HW_SETUP                 = BLOCK_CONTROLLER_ERR_BASE + 16
137   };
138
139   //-------------------------------------------------------------------------------------------------------------
140   // Setup options to set for the DCC track. They are set when the track object is created.
141   //
142   //  DT_OPT_SERVICE_MODE_TRACK  - The track is a PROG track.
143   //  DT_OPT_RAILCOM             - The track support Railcom detection.
144   //
145   //-------------------------------------------------------------------------------------------------------------
146   enum BlockControllerTrackOptions : uint16_t {
147
148       BT_OPT_DEFAULT_SETTING     = 0,
149       BT_OPT_RAILCOM             = 1 << 1
150   };
151
152   //-------------------------------------------------------------------------------------------------------------
153   // The block track object has a set of flags to indicate its current status.
154   //
155   //  DT_F_POWER_ON             - The track is under power.
156   //  DT_F_POWER_OVERLOAD       - An overload situation was detected.
157   //  DT_F_MEASUREMENT_ON       - The power measurement is enabled.
158   //  DT_F_SERVICE_MODE_ON      - The track is currently in service mode, i.e. is a PROG track.
159   //  DT_F_CUTOUT_MODE_ON       - The track has the cutout generation enabled.
160   //  DT_F_RAILCOM_MODE_ON      - The track has the railcom detect enabled.
161   //  DT_F_RAILCOM_MSG_PENDING  - If railcom is enabled, a received datagram is indicated.
162   //  DT_F_CONFIG_ERROR         - The passed configuration descriptor has invalid options configured.
163   //
164   //-------------------------------------------------------------------------------------------------------------
165   enum TrackFlags : uint16_t {
166
167       BT_F_DEFAULT_SETTING     = 0,
168       BT_F_POWER_ON            = 1 << 0,
169       BT_F_POWER_OVERLOAD      = 1 << 1,
170       BT_F_MEASUREMENT_ON      = 1 << 2,
171       BT_F_RAILCOM_MODE_ON     = 1 << 5,
172       BT_F_RAILCOM_MSG_PENDING = 1 << 7,
173       BT_F_CONFIG_ERROR        = 1 << 15
174   };
175
176   //-------------------------------------------------------------------------------------------------------------
177   // The following constants are for the current consumption RMS measurement. The idea is to record the measured
178   // ADC values in a circular buffer, every time a certain amount of milliseconds has passed. This work is done
179   // by the DCC track state machine as part of the power on state.
180   //
181   //-------------------------------------------------------------------------------------------------------------
182   const uint8_t   PWR_SAMPLE_BUF_SIZE                = 64;
183   const uint32_t  PWR_SAMPLE_TIME_INTERVAL_MILLIS    = 16;
184
185
186   //-------------------------------------------------------------------------------------------------------------
187   // The base station items for nodeInfo and nodeControl calls .... tbd
188   //
189   // ??? the are mapped in the MEM / NVM range as well as in the USER range.
190   // ??? how to do it consistently and understandably ?
191   //-------------------------------------------------------------------------------------------------------------
192   enum BlockControllerItems : uint8_t {
193
194
195
196       BC_ITEM_INIT_CURRENT_VAL      = 140,
197       BC_ITEM_LIMIT_CURRENT_VAL     = 141,
```

```
198        BC_ITEM_MAX_CURRENT_VAL         = 142,
199        BC_ITEM_ACTUAL_CURRENT_VAL      = 143,
200
201        // thresholds
202
203        // eventID to send for events ?
204
205   };
206
207   //------------------------------------------------------------------------------------------------------
208   //
209   //
210   //------------------------------------------------------------------------------------------------------
211   const uint32_t TRACK_STATE_TIME_INTERVAL  = 10;
212
213   //------------------------------------------------------------------------------------------------------
214   // The block controller can contain up to four blocks. Each block track is described by the LcsBlockDesc
215   // descriptor. There are the hardware pins sel1Pin1, selPin2, sensePin and uartRxPin. In addition there are
216   // the limits for current consumption values, all specified in milliAmps. The initial current sets the current
217   // consumption limit after the track is turned on. The limit current consumption specifies the actual
218   // configured value that is checked for a track current overload situation. The maximum current defines what
219   // current the power module should never exceed. For the measurements to work, the power module needs to
220   // deliver a voltage that corresponds to the current drawn on the track. The value is measured in milliVolt
221   // per Ampere drawn. Finally, there are threshold times for managing the track overload and restart
222   // capability.
223   //
224   //------------------------------------------------------------------------------------------------------
225   struct LcsBlockTrackDesc {
226
227        uint16_t    options;
228        uint8_t     selPin1                       = CDC::UNDEFINED_PIN;
229        uint8_t     selPin2                       = CDC::UNDEFINED_PIN;
230        uint8_t     sensePin                      = CDC::UNDEFINED_PIN;
231        uint8_t     uartRxPin                     = CDC::UNDEFINED_PIN;
232
233        uint16_t    pwmFrequency              = 70;
234
235        uint16_t    initCurrentMilliAmp        = 0;
236        uint16_t    limitCurrentMilliAmp       = 0;
237        uint16_t    maxCurrentMilliAmp         = 0;
238        uint16_t    milliVoltPerAmp            = 0;
239
240        uint16_t    startTimeThresholdMillis    = 0;
241        uint16_t    stopTimeThresholdMillis     = 0;
242        uint16_t    overloadTimeThresholdMillis = 0;
243        uint16_t    overloadEventThreshold      = 0;
244        uint16_t    overloadRestartThreshold    = 0;
245   };
246
247
248   //------------------------------------------------------------------------------------------------------
249   //
250   //
251   //
252   //------------------------------------------------------------------------------------------------------
253   struct LcsBlockDesc {
254
255
256
257   };
258
259   //------------------------------------------------------------------------------------------------------
260   //
261   //
262   // ??? manages the H-Bridge for one track.
263   // ?? pins are sel1, sel2, sense and uart
264   // ??? runs the state machine for the track
265   //
266   //------------------------------------------------------------------------------------------------------
267   struct LcsBlockTrack {
268
269
270        public:
271
272        LcsBlockTrack( );
273
274        uint8_t                   setupBlockTrack( LcsBlockTrackDesc* trackDesc );
275
276        uint8_t                   setBlockTrackState( uint8_t state, uint8_t speed );
277
278        uint16_t                  getFlags( );
279        uint16_t                  getOptions( );
280
281        void                      runDccTrackStateMachine( );
282        void                      powerStart( );
283        void                      powerStop( );
284        bool                      isPowerOn( );
285        bool                      isPowerOverload( );
286
287        void                      railComOn( );
288        void                      railComOff( );
289        bool                      isRailComOn( );
290
291        void                      setLimitCurrent( uint16_t val );
292        uint16_t                  getLimitCurrent( );
293        uint16_t                  getActualCurrent( );
294        uint16_t                  getInitCurrent( );
295        uint16_t                  getMaxCurrent( );
296        uint16_t                  getRMSCurrent( );
```

```cpp
297
298        void                      checkOverload( );
299        void                      powerMeasurement( );
300
301        void                      startRailComIO( );
302        void                      stopRailComIO( );
303        uint8_t                   handleRailComMsg( );
304        uint8_t                   getRailComMsg( uint8_t *buf, uint8_t bufLen );
305
306        uint32_t                  getPwrSamplesTaken( );
307        uint16_t                  getPwrSamplesPerSec( );
308
309        void                      printTrackConfig( );
310        void                      printTrackStatus( );
311
312        private:
313
314        uint16_t                  options                          = BT_OPT_DEFAULT_SETTING;
315        volatile uint16_t         flags                            = BT_F_DEFAULT_SETTING;
316
317        volatile uint8_t          trackState                       = 0;
318        volatile uint32_t         trackTimeStamp                   = 0;
319        volatile uint8_t          overloadEventCount               = 0;
320        volatile uint8_t          overloadRestartCount             = 0;
321
322        uint8_t                   selPin1                          = CDC::UNDEFINED_PIN;
323        uint8_t                   selPin2                          = CDC::UNDEFINED_PIN;
324        uint8_t                   sensePin                         = CDC::UNDEFINED_PIN;
325        uint8_t                   uartRxPin                        = CDC::UNDEFINED_PIN;
326
327        uint16_t                  pwmFrequency                     = 0;
328        uint16_t                  initCurrentMilliAmp              = 0;
329        uint16_t                  limitCurrentMilliAmp             = 0;
330        uint16_t                  maxCurrentMilliAmp               = 0;
331
332        uint16_t                  startTimeThreshold               = 0;
333        uint16_t                  stopTimeThreshold                = 0;
334        uint16_t                  overloadTimeThreshold            = 0;
335        uint16_t                  overloadEventThreshold           = 0;
336        uint16_t                  overloadRestartThreshold         = 0;
337
338        uint16_t                  milliVoltPerAmp                  = 0;
339        uint16_t                  digitsPerAmp                     = 0;
340        volatile uint16_t         actualCurrentDigitValue          = 0;
341        volatile uint16_t         highWaterMarkDigitValue          = 0;
342        volatile uint16_t         limitCurrentDigitValue           = 0;
343
344        uint32_t                  totalPwrSamplesTaken             = 0;
345        uint32_t                  lastPwrSampleTimeStamp           = 0;
346
347        uint32_t                  lastPwrSamplePerSecTaken         = 0;
348        uint32_t                  lastPwrSamplePerSecTimeStamp     = 0;
349        uint32_t                  pwrSamplesPerSec                 = 0;
350
351        uint8_t                   pwrSampleBufIndex                    = 0;
352        uint16_t                  pwrSampleBuf[ PWR_SAMPLE_BUF_SIZE ]  = { 0 };
353
354   };
355
356   //-------------------------------------------------------------------------------------------------------------
357   //
358   //
359   //
360   //-------------------------------------------------------------------------------------------------------------
361   struct LcsOccDetect {
362
363
364   };
365
366   //-------------------------------------------------------------------------------------------------------------
367   //
368   //
369   //
370   //-------------------------------------------------------------------------------------------------------------
371   struct LcsSignal {
372
373
374   };
375
376
377   //-------------------------------------------------------------------------------------------------------------
378   //
379   //
380   //
381   // ??? runs the block logic
382   // ??? how to manage one to four blocks ?
383   // ??? how to assign occ detect an signals to the block ?
384   // ??? should message handling be a separate part ?
385   // ??? can we build the control logic in such a way that it is configurable via ITEMs ?
386   //-------------------------------------------------------------------------------------------------------------
387   struct LcsBlockControllerLogic {
388
389
390        LcsBlockControllerLogic( LcsBlockDesc *blockDesc );
391
392        uint8_t handleLcsRequest( uint8_t *msg );
393
394        private:
395
```

```
396        LcsBlockDesc *blockDesc;
397
398    };
399
400
401    #endif
```

```
1   //--------------------------------------------------------------------------------------------------------
2   //
3   // LCS - Block Controller
4   //
5   //--------------------------------------------------------------------------------------------------------
6   // This source file contains ...
7   //
8   //
9   //--------------------------------------------------------------------------------------------------------
10  //
11  // LCS - Block Controller - Raspberry PI Pico Implementation
12  // Copyright (C) 2022 - 2024 Helmut Fieres
13  //
14  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
15  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
16  // option) any later version.
17  //
18  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
19  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
20  // for more details.
21  //
22  // You should have received a copy of the GNU General Public License along with this program. If not, see
23  // http://www.gnu.org/licenses
24  //
25  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
26  //
27  //--------------------------------------------------------------------------------------------------------
28  #include "LcsCdcLib.h"
29  #include "LcsRuntimeLib.h"
30  #include "LcsBlockController.h"
31
32  using namespace LCS;
33
34  //--------------------------------------------------------------------------------------------------------
35  // Block Controller global data.
36  //
37  //--------------------------------------------------------------------------------------------------------
38  uint16_t                    debugMask;
39  CDC::CdcConfigDesc          cdcConfig;
40  LCS::LcsConfigDesc          lcsConfig;
41  LcsBlockTrackDesc           block1Desc;
42  LcsBlockTrackDesc           block2Desc;
43
44  LcsBlockTrack               *block1 = nullptr;
45  LcsBlockTrack               *block2 = nullptr;
46
47  // ??? other BC specific global data ...
48
49  //--------------------------------------------------------------------------------------------------------
50  // Setup the configuration of the HW board. The CDC config contains the HW pin mapping. The dual bridge pins
51  // for enabling the bridge and controlling its direction. The pins are mapped to the CDC pin names DIO2 to
52  // DIO5 as shown below.
53  //
54  //      cdcConfig.DIO_PIN_0     -> undefined
55  //      cdcConfig.DIO_PIN_1     -> undefined
56  //      cdcConfig.DIO_PIN_2     -> Select-0-1
57  //      cdcConfig.DIO_PIN_3     -> Select-0-2
58  //      cdcConfig.DIO_PIN_4     -> Select-1-1
59  //      cdcConfig.DIO_PIN_5     -> Select-1-2
60  //      cdcConfig.DIO_PIN_6     -> undefined
61  //      cdcConfig.DIO_PIN_7     -> Cut-Signal
62  //
63  // Current mapping: Dual Block Controller Board B.00.01 - PICO - newest version.
64  //
65  //      cdcConfig.DIO_PIN_2     = 21;
66  //      cdcConfig.DIO_PIN_3     = 20;
67  //      cdcConfig.DIO_PIN_4     = 19;
68  //      cdcConfig.DIO_PIN_5     = 18;
69  //      cdcConfig.DIO_PIN_7     = 4;
70  //
71  // In addition, the HW pins for I2C, analog inputs and so on are set. Check the schematic for the board
72  // to see all pin assign,ents.
73  //
74  // ??? one day we will have several base station versions. Although they will perhaps differ, their the CDC
75  // pin names used should not change. But we would need to come up with an idea which configuration to use
76  // when preparing an image for the base station board.
77  //--------------------------------------------------------------------------------------------------------
78  uint8_t setupConfigInfo( ) {
79
80      cdcConfig = CDC::getConfigDefault( );
81      lcsConfig = LCS::getConfigDefault( );
82
83      cdcConfig.ADC_PIN_0         = 26;
84      cdcConfig.ADC_PIN_1         = 27;
85
86      cdcConfig.PFAIL_PIN         = 5;
87      cdcConfig.EXT_INT_PIN       = 22;
88      cdcConfig.READY_LED_PIN     = 14;
89      cdcConfig.ACTIVE_LED_PIN    = 15;
90
91      cdcConfig.DIO_PIN_2         = 21;
92      cdcConfig.DIO_PIN_3         = 20;
93      cdcConfig.DIO_PIN_4         = 19;
94      cdcConfig.DIO_PIN_5         = 18;
95      cdcConfig.DIO_PIN_7         = 4;
96
97      cdcConfig.PWM_PIN_0         = 21;
98      cdcConfig.PWM_PIN_1         = 20;
```

```
 99         cdcConfig.PWM_PIN_2              = 19;
100         cdcConfig.PWM_PIN_3              = 18;
101
102         // ??? more PWM channels ?
103
104         cdcConfig.UART_RX_PIN_1          = 13;
105         cdcConfig.UART_RX_PIN_2          = 9;
106
107         cdcConfig.NVM_I2C_SCL_PIN        = 3;
108         cdcConfig.NVM_I2C_SDA_PIN        = 2;
109         cdcConfig.NVM_I2C_ADR_ROOT       = 0x50;
110
111         cdcConfig.EXT_I2C_SCL_PIN        = 17;
112         cdcConfig.EXT_I2C_SDA_PIN        = 16;
113         cdcConfig.EXT_I2C_ADR_ROOT       = 0x50;
114
115         cdcConfig.CAN_BUS_RX_PIN         = 0;
116         cdcConfig.CAN_BUS_TX_PIN         = 1;
117         cdcConfig.CAN_BUS_CTRL_MODE      = CAN_BUS_LIB_PICO_PIO_125K_M_CORE;
118         cdcConfig.CAN_BUS_DEF_ID         = 100;
119
120         cdcConfig.NODE_NVM_SIZE          = 8192;
121         cdcConfig.EXT_NVM_SIZE           = 4096;
122
123         lcsConfig.options               |= NOPT_SKIP_NODE_ID_CONFIG;
124
125         return( ALL_OK );
126     }
127
128     uint8_t setupBlockDesc1( ) {
129
130         block1Desc.options                      = 0;
131         block1Desc.selPin1                      = cdcConfig.PWM_PIN_0;
132         block1Desc.selPin2                      = cdcConfig.PWM_PIN_1;
133         block1Desc.sensePin                     = cdcConfig.ADC_PIN_0;
134         block1Desc.uartRxPin                    = CDC::UNDEFINED_PIN;
135
136         block1Desc.pwmFrequency             = 70;
137
138         block1Desc.initCurrentMilliAmp      = 500;
139         block1Desc.limitCurrentMilliAmp     = 1500;
140         block1Desc.maxCurrentMilliAmp       = 2000;
141         block1Desc.milliVoltPerAmp          = 100 * 11; // ??? opAmp has Factor eleven ...
142
143         block1Desc.startTimeThresholdMillis     = 1000;
144         block1Desc.stopTimeThresholdMillis      = 500;
145         block1Desc.overloadTimeThresholdMillis  = 500;
146         block1Desc.overloadEventThreshold       = 10;
147         block1Desc.overloadRestartThreshold     = 5;
148
149         return( ALL_OK );
150     }
151
152     uint8_t setupBlockDesc2( ) {
153
154         block1Desc.options                      = 0;
155         block1Desc.selPin1                      = cdcConfig.PWM_PIN_2;
156         block1Desc.selPin2                      = cdcConfig.PWM_PIN_3;
157         block1Desc.sensePin                     = cdcConfig.ADC_PIN_1;
158         block1Desc.uartRxPin                    = CDC::UNDEFINED_PIN;
159
160         block1Desc.pwmFrequency             = 70;
161
162         block1Desc.initCurrentMilliAmp      = 500;
163         block1Desc.limitCurrentMilliAmp     = 1500;
164         block1Desc.maxCurrentMilliAmp       = 2000;
165         block1Desc.milliVoltPerAmp          = 100 * 11; // ??? opAmp has Factor eleven ...
166
167         block1Desc.startTimeThresholdMillis     = 1000;
168         block1Desc.stopTimeThresholdMillis      = 500;
169         block1Desc.overloadTimeThresholdMillis  = 500;
170         block1Desc.overloadEventThreshold       = 10;
171         block1Desc.overloadRestartThreshold     = 5;
172
173         return( ALL_OK );
174     }
175
176
177     //-----------------------------------------------------------------------------------------------------------
178     // Some little helper functions.
179     //
180     //-----------------------------------------------------------------------------------------------------------
181     void printLcsMsg( uint8_t *msg ) {
182
183       int msgLen = (( msg[0] >> 5 ) + 1 ) % 8;
184
185       for ( int i = 0; i < msgLen; i++ ) printf( "0x%x ", msg[i] );
186       printf( "\n" );
187     }
188
189     uint8_t printStatus (uint8_t status ) {
190
191       printf( "Status: " );
192       if ( status == LCS::ALL_OK ) printf( "OK\n" );
193       else printf ( "FAILED: %d\n", status );
194       return ( status );
195     }
196
197     // ??? pass the callbacks to block controller logic ?
```

```
198
199     //----------------------------------------------------------------------------------------------------------------
200     // The node and port initialization callback.
201     //
202     // ??? when we know what ports we actually need / use, disable the rest of the ports.
203     //----------------------------------------------------------------------------------------------------------------
204     uint8_t lcsInitCallback( uint16_t npId ) {
205
206         switch ( npId & 0xF ) {
207
208             case 0:     printf( "Node Init Callback: 0x%x\n", npId >> 4     ); break;
209             default:    printf( "Port Init Callback: 0x%x\n", npId &  0xF   );
210         }
211
212         return( ALL_OK );
213     }
214
215     //----------------------------------------------------------------------------------------------------------------
216     // The node or port reset callback.
217     //
218     //----------------------------------------------------------------------------------------------------------------
219     uint8_t lcsResetCallback( uint16_t npId ) {
220
221         switch ( npId & 0xF ) {
222
223             case 0:     printf( "Node Reset Callback: 0x%x\n", npId >> 4     ); break;
224             default:    printf( "Port Reset Callback: 0x%x\n", npId &  0xF   );
225         }
226
227         return( ALL_OK );
228     }
229
230     //----------------------------------------------------------------------------------------------------------------
231     // The node or port power fail callback.
232     //
233     //----------------------------------------------------------------------------------------------------------------
234     uint8_t lcsPfailCallback( uint16_t npId ) {
235
236         switch ( npId & 0xF ) {
237
238             case 0:     printf( "Node Power Fail Callback: 0x%x\n", npId >> 4     ); break;
239             default:    printf( "Port Power Fail Callback: 0x%x\n", npId &  0xF   );
240         }
241
242         return( ALL_OK );
243     }
244
245     //----------------------------------------------------------------------------------------------------------------
246     // The base station has also a command line interpreter. The callback is invoked by the core library when
247     // there is a command that it does not handle.
248     //
249     // ??? should we have a block controller specific command interpreter ?
250     //----------------------------------------------------------------------------------------------------------------
251     uint8_t lcsCmdCallback( char *cmdLine ) {
252
253
254         return( ALL_OK );
255     }
256
257     //----------------------------------------------------------------------------------------------------------------
258     // Other LCS message callbacks. All we do is to list their invocation. ( for now )
259     //
260     //----------------------------------------------------------------------------------------------------------------
261     uint8_t lcsMsgCallback( uint8_t *msg ) {
262
263         printf( "MsgCallback: ", msg  );
264         printLcsMsg( msg );
265         return( ALL_OK );
266     }
267
268     //-----------------------------------------------------------------------------------------------------------------
269     // When the base station node receives a request with an item defined in the user item range or the base
270     // station itself issues such a request, the defined callback is invoked.
271     //
272     //-----------------------------------------------------------------------------------------------------------------
273     uint8_t lcsReqCallback( uint8_t npId, uint8_t item, uint16_t *arg1, uint16_t *arg2 ) {
274
275         printf( "REQ callback: npId: 0x%x, item: %d", npId, item );
276         if ( arg1 != nullptr ) printf( ", arg1: %d, ", *arg1 ); else printf( ", arg1: null" );
277         if ( arg2 != nullptr ) printf( ", arg2: %d, ", *arg2 ); else printf( ", arg2: null" );
278
279
280         return( ALL_OK );
281     }
282
283     //-----------------------------------------------------------------------------------------------------------------
284     // When the base station gets a reply message for a request previously sent, this callback is invoked.
285     //
286     //-----------------------------------------------------------------------------------------------------------------
287     uint8_t lcsRepCallback( uint8_t npId, uint8_t item, uint16_t arg1, uint16_t arg2, uint8_t ret ) {
288
289         printf( "REP callback: npId: 0x%x, item: %d, arg1: %d, arg2: %d, ret: %d ", npId, item , arg1, arg2, ret );
290         return( ALL_OK );
291     }
292
293     //-----------------------------------------------------------------------------------------------------------------
294     // For any event on the LCS system that the base station is interested in, this callback is invoked.
295     //
296     //-----------------------------------------------------------------------------------------------------------------
```

```
297  uint8_t lcsEventCallback( uint16_t npId, uint16_t eId, uint8_t eAction, uint16_t eData ) {
298
299      printf( "Event: npId: 0x%x, eId: %d, eAction: %d, eData: %d\n", npId, eId, eAction, eData );
300      return( ALL_OK );
301  }
302
303  //--------------------------------------------------------------------------------------------------------
304  // We need to run the track state machines on a periodic basis.
305  //
306  //--------------------------------------------------------------------------------------------------------
307  uint8_t tackStateMachine( ) {
308
309      if ( block1 != nullptr ) block1 -> runDccTrackStateMachine( );
310      if ( block2 != nullptr ) block2 -> runDccTrackStateMachine( );
311      return( ALL_OK );
312  }
313
314  //--------------------------------------------------------------------------------------------------------
315  // Init the Runtime.
316  //
317  //--------------------------------------------------------------------------------------------------------
318  uint8_t initLcsRuntime( ) {
319
320      setupConfigInfo( );
321
322      uint8_t rStat = initRuntime( &lcsConfig, &cdcConfig );
323      printf( "LCS Block Controller\n" );
324
325      CDC::printConfigInfo( &cdcConfig );
326
327      printStatus( rStat );
328      return( rStat );
329  }
330
331  //--------------------------------------------------------------------------------------------------------
332  // After the initial setup of the runtime library, the callback are registered.
333  //
334  //--------------------------------------------------------------------------------------------------------
335  uint8_t registerCallbacks( ) {
336
337      printf( "Registering Callbacks\n" );
338
339      registerLcsMsgCallback( lcsMsgCallback );
340      registerCmdCallback( lcsCmdCallback );
341      registerInitCallback( lcsInitCallback );
342      registerResetCallback( lcsResetCallback );
343      registerPfailCallback( lcsPfailCallback );
344      registerReqCallback( lcsReqCallback );
345      registerRepCallback( lcsRepCallback );
346      registerEventCallback( lcsEventCallback );
347      registerTaskCallback( tackStateMachine, 10 ); // ?? for testing just use 10ms
348
349      return( ALL_OK );
350  }
351
352  //--------------------------------------------------------------------------------------------------------
353  // Fire up the base station. First all base station modules are initialized. If this is OK, the DCC tack
354  // signal generation is enabled, i.e. the interrupt driven DCC packet broadcasting starts. Finally, the
355  // track power is turned on and we give control to the LCS runtime for processing events and requests.
356  //
357  //--------------------------------------------------------------------------------------------------------
358  uint8_t startBlockController( ) {
359
360      printf( "Start Block controller\n" );
361
362      uint8_t rStat = ALL_OK;
363
364      block1 = new LcsBlockTrack( );
365      block2 = new LcsBlockTrack( );
366
367      // if ( rStat == ALL_OK ) block1 -> setupBlockTrack( &block1Desc );
368      // if ( rStat == ALL_OK ) block1 -> setupBlockTrack( &block2Desc );
369
370      // ??? for the quick test ....
371      printf( "Configure PWM pins\n" );
372      rStat = CDC::configurePwm( cdcConfig.PWM_PIN_0, 70 );
373      if ( rStat != ALL_OK ) printStatus( rStat );
374
375      rStat = CDC::configurePwm( cdcConfig.PWM_PIN_1, 70 );
376      if ( rStat != ALL_OK ) printStatus( rStat );
377
378      rStat = CDC::configurePwm( cdcConfig.PWM_PIN_2, 70 );
379      if ( rStat != ALL_OK ) printStatus( rStat );
380
381      rStat = CDC::configurePwm( cdcConfig.PWM_PIN_3, 70 );
382      if ( rStat != ALL_OK ) printStatus( rStat );
383
384      printf( "Set output to pins\n" );
385      rStat = CDC::writePwm(cdcConfig.PWM_PIN_0, 255 );
386      if ( rStat != ALL_OK ) printStatus( rStat );
387      rStat = CDC::writePwm(cdcConfig.PWM_PIN_1, 255 );
388      if ( rStat != ALL_OK ) printStatus( rStat );
389      rStat = CDC::writePwm(cdcConfig.PWM_PIN_2, 255 );
390      if ( rStat != ALL_OK ) printStatus( rStat );
391      rStat = CDC::writePwm(cdcConfig.PWM_PIN_3, 255 );
392      if ( rStat != ALL_OK ) printStatus( rStat );
393
394      printf( "Block 1 Config:" );
395      if ( block1 != nullptr ) block1 -> printTrackConfig( );
```

```
396
397         printf( "Block 2 Config:" );
398         if ( block2 != nullptr ) block2 -> printTrackConfig( );
399
400         if ( rStat == ALL_OK ) {
401
402             printf( "Ready...\n" );
403             startRuntime( );
404         }
405
406         return( ALL_OK );
407     }
408
409     //------------------------------------------------------------------------------------------------------
410     // The main program. Setup the runtime, register the callbacks, and get the show on the road.
411     //
412     //------------------------------------------------------------------------------------------------------
413     int main( ) {
414
415         uint8_t rStat = ALL_OK;
416
417         if ( rStat == ALL_OK ) rStat = initLcsRuntime( );
418         if ( rStat == ALL_OK ) rStat = registerCallbacks( );
419         if ( rStat == ALL_OK ) return( startBlockController( ));
420     }
```

```
1   //------------------------------------------------------------------------------------------------------------
2   //
3   // LCS Block Controller - Control Logic
4   //
5   //------------------------------------------------------------------------------------------------------------
6   //
7   // LCS Block Controller
8   // Copyright (C) 2019 - 2024  Helmut Fieres
9   //
10  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
11  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
12  // option) any later version.
13  //
14  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
15  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
16  // for more details.
17  //
18  // You should have received a copy of the GNU General Public License along with this program. If not, see
19  // http://www.gnu.org/licenses
20  //
21  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
22  //
23  //------------------------------------------------------------------------------------------------------------
24
25  #include "LcsBlockController.h"
26
27  // ??? contains the main code, the setup, the message handler, etc.
28
29  using namespace LCS;
30
31  //------------------------------------------------------------------------------------------------------------
32  //
33  //
34  //------------------------------------------------------------------------------------------------------------
35  LcsBlockControllerLogic::LcsBlockControllerLogic( LcsBlockDesc *blockDesc ) {
36
37      this -> blockDesc = blockDesc;
38
39  }
40
41  //------------------------------------------------------------------------------------------------------------
42  //
43  //
44  //------------------------------------------------------------------------------------------------------------
45   uint8_t LcsBlockControllerLogic::handleLcsRequest( uint8_t *msg ) {
46
47      switch ( msg[ 0 ] ) {
48
49          // ??? define a few request for testing ...
50
51          default: ;
52      }
53
54      return( ALL_OK );
55   }
```

169

```cpp
1   //-------------------------------------------------------------------------------------------------------------
2   //
3   // LCS Block Controller - Track Power
4   //
5   //-------------------------------------------------------------------------------------------------------------
6   //
7   //
8   // ??? contains the code that manage the track power
9   //
10  // ??? leverage the DCC track module in base station.
11  //
12  // ??? descriptor has to specify the four pins for each H-Bridge
13  //
14  //-------------------------------------------------------------------------------------------------------------
15  //
16  // LCS Block Controller - Track Power
17  // Copyright (C) 2019 - 2024  Helmut Fieres
18  //
19  // This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
20  // Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
21  // option) any later version.
22  //
23  // This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
24  // implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU General Public License
25  // for more details.
26  //
27  // You should have received a copy of the GNU General Public License along with this program. If not, see
28  // http://www.gnu.org/licenses
29  //
30  //  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
31  //
32  //-------------------------------------------------------------------------------------------------------------
33  #include "LcsBlockController.h"
34  #include <math.h>
35
36  //-------------------------------------------------------------------------------------------------------------
37  // External global variables.
38  //
39  //-------------------------------------------------------------------------------------------------------------
40  extern uint16_t debugMask;
41
42  //-------------------------------------------------------------------------------------------------------------
43  // The Block Track Object local definitions. The hardware lower layers can be found in controller dependent
44  // code (CDC) layer.
45  //
46  //-------------------------------------------------------------------------------------------------------------
47  namespace {
48
49  using namespace LCS;
50
51  //-------------------------------------------------------------------------------------------------------------
52  // DCC and RailCom definitions.
53  //
54  //-------------------------------------------------------------------------------------------------------------
55  const uint8_t   RAILCOM_BUFFER_SIZE         = 8;
56
57  //-------------------------------------------------------------------------------------------------------------
58  // Block controller global limits. Perhaps to move to a configurable place...
59  //
60  //-------------------------------------------------------------------------------------------------------------
61  const uint16_t MILLI_VOLT_PER_DIGIT       = 5;
62  const uint16_t MILLI_VOLT_PER_AMP         = 1500;
63
64  //-------------------------------------------------------------------------------------------------------------
65  // Block track power management is also a a state machine managing the state of the power track. Maximum
66  // values for the track power start and stop sequence as well as limits for power overload events are defined.
67  // We also define reasonable default values.
68  //
69  //-------------------------------------------------------------------------------------------------------------
70  const uint16_t MAX_START_TIME_THRESHOLD_MILLIS     = 2000;
71  const uint16_t MAX_STOP_TIME_THRESHOLD_MILLIS      = 1000;
72  const uint16_t MAX_OVERLOAD_TIME_THRESHOLD_MILLIS  = 500;
73  const uint16_t MAX_OVERLOAD_EVENT_COUNT            = 10;
74  const uint16_t MAX_OVERLOAD_RESTART_COUNT          = 10;
75
76  const uint16_t DEF_START_TIME_THRESHOLD_MILLIS     = 1000;
77  const uint16_t DEF_STOP_TIME_THRESHOLD_MILLIS      = 500;
78  const uint16_t DEF_OVERLOAD_TIME_THRESHOLD_MILLIS  = 300;
79  const uint16_t DEF_OVERLOAD_EVENT_COUNT            = 10;
80  const uint16_t DEF_OVERLOAD_RESTART_COUNT          = 10;
81
82  //-------------------------------------------------------------------------------------------------------------
83  // Track state machine state definitions. See the track state machine routine for an explanation of the
84  // individual states.
85  //
86  //-------------------------------------------------------------------------------------------------------------
87  enum DccTrackState : uint8_t {
88
89      TRACK_POWER_OFF        = 0,
90      TRACK_POWER_ON         = 1,
91      TRACK_POWER_OVERLOAD   = 2,
92      TRACK_POWER_START1     = 3,
93      TRACK_POWER_START2     = 4,
94      TRACK_POWER_STOP1      = 5,
95      TRACK_POWER_STOP2      = 6
96  };
97
98  //-------------------------------------------------------------------------------------------------------------
```

```
99    // Utility routine for number range checks.
100   //
101   //---------------------------------------------------------------------------------------------------------------------
102   bool isInRangeU( uint8_t val, uint8_t lower, uint8_t upper ) {
103
104       return (( val >= lower ) && ( val <= upper ));
105   }
106
107   //---------------------------------------------------------------------------------------------------------------------
108   // Conversion functions between milliAmps and digit values as report4de by the analog to digital converter
109   // hardware. For a better precision, the formula uses 32 bit computation and stores the result back in a
110   // 16 bit quantity.
111   //
112   //---------------------------------------------------------------------------------------------------------------------
113   uint16_t milliAmpToDigitValue( uint16_t milliAmp, uint16_t digitsPerAmp ) {
114
115       #if 0
116       uint32_t mA = milliAmp;
117       uint32_t dPA = digitsPerAmp;
118       return (( uint16_t ) ( mA * dPA / 1000 ));
119       #endif
120
121       return ((uint16_t) ((((uint32_t) milliAmp ) * ((uint32_t) digitsPerAmp )) / 1000 ));
122   }
123
124   uint16_t digitValueToMilliAmp( uint16_t digitValue, uint16_t digitsPerAmp ) {
125
126       #if 0
127       uint32_t dV = digitValue;
128       uint32_t dPA = digitsPerAmp;
129       return ((uint16_t)( dV * 1000 / dPA ));
130       #endif
131
132       return ((uint16_t) ((((uint32_t) digitValue ) * 1000 ) / ((uint32_t) digitsPerAmp )));
133   }
134
135   }; // namespace
136
137
138   //=====================================================================================================================
139   //=====================================================================================================================
140   //
141   // Object part.
142   //
143   //=====================================================================================================================
144   //=====================================================================================================================
145
146
147   //---------------------------------------------------------------------------------------------------------------------
148   // Object instance section. The DccTrack constructor. Nothing to do so far.
149   //
150   //---------------------------------------------------------------------------------------------------------------------
151   LcsBlockTrack::LcsBlockTrack( ) { }
152
153
154   //---------------------------------------------------------------------------------------------------------------------
155   // "setupDccTrack" performs the setup tasks for the DCC track. We will configure the hardware, the DCC
156   // packet options such as preamble and postamble length, the initial state machine state current consumption
157   // limit and load the initial packet into the active buffer. There is quite a list of parameters and options
158   // that can be set. This routine does the following checking:
159   //
160   //    - the pins used in the CDC layer must be a pair ( for atmega controllers ).
161   //    - the sensePin must be an analog input pin.
162   //    - if the track is a service track, cutout and RailCom are not supported.
163   //    - if RailCom is set, Cutout must be set too.
164   //    - the initial current limit consumption setting must be less than the current limit setting.
165   //    - the current limit setting must be less than the maximum current limit setting.
166   //
167   // Once the DCC track object is initialized, the last thing to do is to remember the object instance in the
168   // file static variables. This is necessary for the interrupt handlers to work. If any of the checks fails,
169   // the flag field will have the error bit set.
170   //
171   //---------------------------------------------------------------------------------------------------------------------
172   uint8_t LcsBlockTrack::setupBlockTrack( LcsBlockTrackDesc* trackDesc ) {
173
174       if ((  trackDesc -> selPin1     == CDC::UNDEFINED_PIN ) ||
175           (  trackDesc -> selPin2     == CDC::UNDEFINED_PIN ) ||
176           (  trackDesc -> sensePin    == CDC::UNDEFINED_PIN ) ||
177           (  trackDesc -> uartRxPin   == CDC::UNDEFINED_PIN )) {
178
179           flags = BT_F_CONFIG_ERROR;
180           return ( ERR_PIN_CONFIG );
181       }
182
183       if (( trackDesc -> initCurrentMilliAmp  > trackDesc -> limitCurrentMilliAmp )               ||
184           ( trackDesc -> limitCurrentMilliAmp > trackDesc -> maxCurrentMilliAmp )                 ||
185           ( trackDesc -> startTimeThresholdMillis > MAX_START_TIME_THRESHOLD_MILLIS )             ||
186           ( trackDesc -> stopTimeThresholdMillis > MAX_STOP_TIME_THRESHOLD_MILLIS )               ||
187           ( trackDesc -> overloadTimeThresholdMillis > MAX_OVERLOAD_TIME_THRESHOLD_MILLIS )        ||
188           ( trackDesc -> overloadEventThreshold > MAX_OVERLOAD_EVENT_COUNT )                      ||
189           ( trackDesc -> overloadRestartThreshold > MAX_OVERLOAD_RESTART_COUNT )
190           ) {
191
192           flags = BT_F_CONFIG_ERROR;
193           return ( ERR_TRACK_CONFIG );
194       }
195
196       trackState                    = TRACK_POWER_OFF;
197       flags                         = BT_F_DEFAULT_SETTING;
```

```
198          options                    = trackDesc -> options;
199          selPin1                    = trackDesc -> selPin1;
200          selPin2                    = trackDesc -> selPin2;
201          sensePin                   = trackDesc -> sensePin;
202          uartRxPin                  = trackDesc -> uartRxPin;
203          pwmFrequency               = trackDesc -> pwmFrequency;
204          initCurrentMilliAmp        = trackDesc -> initCurrentMilliAmp;
205          limitCurrentMilliAmp       = trackDesc -> limitCurrentMilliAmp;
206          maxCurrentMilliAmp         = trackDesc -> maxCurrentMilliAmp;
207          startTimeThreshold         = trackDesc -> startTimeThresholdMillis;
208          stopTimeThreshold          = trackDesc -> stopTimeThresholdMillis;
209          overloadTimeThreshold      = trackDesc -> overloadTimeThresholdMillis;
210          overloadEventThreshold     = trackDesc -> overloadEventThreshold;
211          overloadRestartThreshold   = trackDesc -> overloadRestartThreshold;
212
213          // ??? MILLI_VOLT_PER_DIGIT is actually 4,72V / 1024 = 4,6 mV. How to make this more precise ?
214
215          milliVoltPerAmp            = trackDesc -> milliVoltPerAmp;
216          digitsPerAmp               = milliVoltPerAmp / MILLI_VOLT_PER_DIGIT;
217
218          limitCurrentDigitValue     = milliAmpToDigitValue( initCurrentMilliAmp, digitsPerAmp );
219          actualCurrentDigitValue    = 0;
220          totalPwrSamplesTaken       = 0;
221          lastPwrSamplePerSecTaken   = 0;
222          pwrSamplesPerSec           = 0;
223
224          CDC::configurePwm( selPin1, pwmFrequency );
225          CDC::configurePwm( selPin2, pwmFrequency );
226          CDC::configureAdc( sensePin );
227
228          CDC::writePwm( selPin1, 0 );
229          CDC::writePwm( selPin1, 0 );
230
231          if ( trackDesc -> options & BT_OPT_RAILCOM ) {
232
233              flags |= BT_F_RAILCOM_MODE_ON;
234              if ( CDC::configureUart( uartRxPin, CDC::UNDEFINED_PIN, 250000, CDC::UART_MODE_8N1 ) != ALL_OK ) {
235
236                  flags = BT_F_CONFIG_ERROR;
237                  return ( ERR_TRACK_CONFIG );
238              }
239          }
240
241          return ( ALL_OK );
242  }
243
244  //-------------------------------------------------------------------------------------------------------------------
245  // DCC track power is not just a matter of turning power on or off. To address all the requirements of the
246  // standard, the track is managed by a state machine that implements the start and stop sequences. It is also
247  // important that we do not really block the progress of the entire base station, so any timing calls are
248  // handled by timestamp comparison in state machine WAIT states. The track state machine routine is expected
249  // to be called very often.
250  //
251  //  TRACK_POWER_START1    - this is the first state of a start sequence. When the track should be powered
252  //                          on, the first activity is to set the status flags and enable the power module.
253  //                          We set the power module current consumption to the initial limit configured.
254  //                          The next state is TRACK_POWER_START2.
255  //
256  //  TRACK_POWER_START2    - we stay in this state until the threshold time has passed. Once the threshold
257  //                          is reached, the current consumption limit is set to the configured limit.
258  //                          Then we move on to TRACK_POWER_ON.
259  //
260  //  TRACK_POWER_ON        - this is the state when power is on and things are running normal. An overload
261  //                          situation is set by the current measurement routines through setting the
262  //                          overload status flag. We make sure that we have seen a couple of overloads
263  //                          in a row before taking action which is to turn power off and set the
264  //                          TRACK_POWER_OVERLOAD state. Otherwise we stay in this state.
265  //
266  //  TRACK_POWER_OVERLOAD  - with power turned off, we stay in this state until the threshold time has
267  //                          passed. If passed, the overload restart count is incremented and checked for
268  //                          its threshold. If reached, we have tried to restart several times and failed.
269  //                          The track state becomes TRACK_POWER_STOP1, something is wrong on the track.
270  //                          If not, we move on to TRACK_POWER_START1.
271  //
272  //  TRACK_POWER_STOP1     - this state initiates a shutdown sequence. We disable the power module, set
273  //                          status flags and advance to the TRACK_POWER_STOP2 state.
274  //
275  //  TRACK_POWER_STOP2     - we stay in this state until the configured threshold has passed. Then we move
276  //                          on to TRACK_POWER_OFF. The key reason for this time delay is to implement
277  //                          the requirement that track turned off and perhaps switched to another mode,
278  //                          should be powerless for one second. Switch track modes becomes simply a matter
279  //                          of stopping and then starting again.
280  //
281  //  TRACK_POWER_OFF       - the track is disabled. We just stay in this state until the state is set to
282  //                          a different state from outside.
283  //
284  // During the power on state, we also append the actual current measurement value to a circular buffer when
285  // the time interval for this kind of measurement has passed. The idea is to measure the samples at a more
286  // or less constant interval rate and compute the power consumption RMS value from the data in the buffer
287  // when requested. In the interest of minimizing the controller load, the calculation is done in digit values
288  // the result is presented in then in milliAmps.
289  //
290  //-------------------------------------------------------------------------------------------------------------------
291  void LcsBlockTrack::runDccTrackStateMachine( ) {
292
293      switch ( trackState ) {
294
295          case TRACK_POWER_START1: {
296
```

```
297              // ??? do we need a way to check for overload during this initial phase , just like we do when ON ?
298
299              trackTimeStamp           = CDC::getMillis( );
300              flags                   |= BT_F_POWER_ON;
301              flags                   &= ~BT_F_POWER_OVERLOAD;
302              flags                   &= ~BT_F_MEASUREMENT_ON;
303              limitCurrentDigitValue  = milliAmpToDigitValue( initCurrentMilliAmp , digitsPerAmp );
304
305              CDC::writePwm( selPin1 , 1 ); // ??? default is DCC ?
306              CDC::writePwm( selPin1 , 1 );
307              trackState = TRACK_POWER_START2;
308
309          }  break;
310
311          case TRACK_POWER_START2: {
312
313              if (( CDC::getMillis( ) - trackTimeStamp ) > startTimeThreshold ) {
314
315                  highWaterMarkDigitValue = 0;
316                  actualCurrentDigitValue = 0;
317                  overloadRestartCount   = 0;
318                  overloadEventCount     = 0;
319                  flags                 |= BT_F_POWER_ON | BT_F_MEASUREMENT_ON;
320                  limitCurrentDigitValue = milliAmpToDigitValue( limitCurrentMilliAmp , digitsPerAmp );
321
322                  CDC::writePwm( selPin1 , 1 ); // ??? default is DCC ?
323                  CDC::writePwm( selPin1 , 1 );
324                  trackState = TRACK_POWER_ON;
325              }
326
327          } break;
328
329          case TRACK_POWER_ON: {
330
331              if (( CDC::getMillis( ) - lastPwrSampleTimeStamp ) > PWR_SAMPLE_TIME_INTERVAL_MILLIS ) {
332
333                  pwrSampleBuf[ pwrSampleBufIndex % TRACK_POWER_ON ] = actualCurrentDigitValue;
334                  pwrSampleBufIndex ++;
335                  lastPwrSampleTimeStamp = CDC::getMillis( );
336              }
337
338              if (( CDC::getMillis( ) - lastPwrSamplePerSecTimeStamp ) > 1000 ) {
339
340                  pwrSamplesPerSec         = totalPwrSamplesTaken - lastPwrSamplePerSecTaken;
341                  lastPwrSamplePerSecTaken  = totalPwrSamplesTaken;
342                  lastPwrSamplePerSecTimeStamp = CDC::getMillis( );
343              }
344
345              if ( flags & BT_F_POWER_OVERLOAD ) {
346
347                  overloadEventCount  ++;
348
349                  if ( overloadEventCount > overloadEventThreshold ) {
350
351                      if (( debugMask & DBG_BC_CONFIG ) && ( debugMask & DBG_BC_TRACK_POWER_MGMT )) {
352
353                          printf( "Overload detected: " );
354
355                          #if 0
356                          printf( "(hwm(mA): %d : limit(mA): %d )\n",
357                                  digitValueToMilliAmp( highWaterMarkDigitValue , digitsPerAmp ),
358                                  digitValueToMilliAmp( limitCurrentDigitValue , digitsPerAmp ));
359
360                          #else
361                          printf( "(hwm(dVal): %d  : limit(dVal): %d )\n", highWaterMarkDigitValue , limitCurrentDigitValue );
362                          #endif
363                      }
364
365                      trackTimeStamp  = CDC::getMillis( );
366                      flags           |= BT_F_POWER_OVERLOAD;
367                      flags           &= ~BT_F_POWER_ON;
368                      flags           &= ~BT_F_MEASUREMENT_ON;
369
370                      CDC::writePwm( selPin1 , 0 );
371                      CDC::writePwm( selPin1 , 0 );
372                      trackState = TRACK_POWER_OVERLOAD;
373                  }
374              }
375
376          }  break;
377
378          case TRACK_POWER_OVERLOAD: {
379
380              if ( CDC::getMillis( ) - trackTimeStamp > overloadTimeThreshold ) {
381
382                  overloadRestartCount ++;
383
384                  if ( overloadRestartCount > overloadRestartThreshold ) {
385
386                      if (( debugMask & DBG_BC_CONFIG ) && ( debugMask & DBG_BC_TRACK_POWER_MGMT )) {
387
388                          printf( "Overload restart failed, Cnt:%d\n", overloadRestartCount );
389                      }
390
391                      trackState = TRACK_POWER_STOP1;
392                  }
393                  else trackState = TRACK_POWER_START1;
394              }
395
```

```
396            }  break;
397
398            case TRACK_POWER_STOP1: {
399
400                 trackTimeStamp  = CDC::getMillis( );
401                 flags          &= ~BT_F_POWER_ON;
402                 flags          &= ~BT_F_POWER_OVERLOAD;
403                 flags          &= ~BT_F_MEASUREMENT_ON;
404
405                 CDC::writePwm( selPin1, 0 );
406                 CDC::writePwm( selPin1, 0 );
407                 trackState = TRACK_POWER_STOP2;
408
409            }  break;
410
411            case TRACK_POWER_STOP2: {
412
413                 if ( CDC::getMillis( ) - trackTimeStamp > stopTimeThreshold ) trackState = TRACK_POWER_OFF;
414
415            } break;
416
417            case TRACK_POWER_OFF: {
418
419            } break;
420        }
421 }
422
423 //----------------------------------------------------------------------------------------------------------
424 // Some getter functions. Straightforward.
425 //
426 //----------------------------------------------------------------------------------------------------------
427 uint16_t LcsBlockTrack::getFlags( ) {
428
429      return ( flags );
430 }
431
432 uint16_t LcsBlockTrack::getOptions( ) {
433
434      return ( options );
435 }
436
437 uint32_t LcsBlockTrack::getPwrSamplesTaken( ) {
438
439      return ( totalPwrSamplesTaken );
440 }
441
442 uint16_t LcsBlockTrack::getPwrSamplesPerSec( ) {
443
444      return ( pwrSamplesPerSec );
445 }
446
447 bool LcsBlockTrack::isPowerOn( ) {
448
449      return ( flags & BT_F_POWER_ON );
450 }
451
452 bool LcsBlockTrack::isPowerOverload( ) {
453
454      return ( flags & BT_F_POWER_OVERLOAD );
455 }
456
457 bool LcsBlockTrack::isRailComOn( ) {
458
459      return ( flags & BT_F_RAILCOM_MODE_ON );
460 }
461
462 //----------------------------------------------------------------------------------------------------------
463 // Track power management functions. The actual state of track power is kept in the track status field
464 // and can be queried or set by setting the respective flag. Starting and stopping track power is done by
465 // setting the respective START or STOP state.
466 //
467 //----------------------------------------------------------------------------------------------------------
468 void LcsBlockTrack::powerStart( ) {
469
470      trackState = TRACK_POWER_START1;
471 }
472
473 void LcsBlockTrack::powerStop( ) {
474
475      trackState = TRACK_POWER_STOP1;
476 }
477
478 void LcsBlockTrack::railComOn( ) {
479
480      flags |= BT_F_RAILCOM_MODE_ON;
481 }
482
483 void LcsBlockTrack::railComOff( ) {
484
485      flags &= ~BT_F_RAILCOM_MODE_ON;
486 }
487
488 //----------------------------------------------------------------------------------------------------------
489 // Power Consumption Management. There are two key values. The first is the actual current consumption as
490 // measured by the ADC hardware on each ZERO DCC bit. This value is used to do the power overload checking.
491 // The second value is the high water mark built from these measurements. This values is used for the DCC
492 // decoder programming logic. The high water mark will be set to zero before collecting measurements. All
493 // measurement values are actually ADC digit values for performance reason. Only on limit setting and external
494 // data access are these values converted from and to milliAmps.
```

```
495  //
496  //-----------------------------------------------------------------------------------------------------------
497  uint16_t LcsBlockTrack::getLimitCurrent( ) {
498
499      return ( limitCurrentMilliAmp );
500  }
501
502  uint16_t LcsBlockTrack::getActualCurrent( ) {
503
504      return ( digitValueToMilliAmp( actualCurrentDigitValue, digitsPerAmp ));
505  }
506
507  uint16_t LcsBlockTrack::getInitCurrent( ) {
508
509      return ( initCurrentMilliAmp );
510  }
511
512  uint16_t LcsBlockTrack::getMaxCurrent( ) {
513
514      return ( maxCurrentMilliAmp );
515  }
516
517  void LcsBlockTrack::setLimitCurrent( uint16_t val ) {
518
519      if      ( val < initCurrentMilliAmp )  val = initCurrentMilliAmp;
520      else if ( val > maxCurrentMilliAmp  )  val = maxCurrentMilliAmp;
521
522      limitCurrentMilliAmp    = val;
523      limitCurrentDigitValue  = milliAmpToDigitValue( val, digitsPerAmp );
524  }
525
526  //-----------------------------------------------------------------------------------------------------------
527  // The "getRMSCurrent" function returns the power consumption based on the samples taken and stored in the
528  // sample buffer. The function computes the square root of the sum of the squares of the array elements. The
529  // result is returned in milliAmps. Note that our measurement is based on unsigned 16-bit quantities that come
530  // from the controller ADC converter. We compute the RMS based on 16-bit unsigned integers, which compared
531  // to floating point computation is not really precise. However, for our purpose to just show a rough power
532  // consumption, the error should be not a big issue. We will not use RMS values for power overload detection
533  // or decoder ACK detection.
534  //
535  //-----------------------------------------------------------------------------------------------------------
536  uint16_t LcsBlockTrack::getRMSCurrent( ) {
537
538      uint32_t res = 0;
539
540      for ( uint8_t i = 0; i < PWR_SAMPLE_BUF_SIZE; i++ ) res += pwrSampleBuf[ i ] * pwrSampleBuf[ i ];
541
542      return ( digitValueToMilliAmp( sqrt( res / PWR_SAMPLE_BUF_SIZE ), digitsPerAmp ));
543  }
544
545  //-----------------------------------------------------------------------------------------------------------
546  // This function is called whenever a power measurement operation completes from the analog conversion
547  // interrupt handler. This typically takes place on the first half of the DCC "0" bit. If power measurement
548  // is enabled, we increment the number of samples taken, check the measured value for an overload situation
549  // and also set the high water mark accordingly. Since we are part of an interrupt handler, keep the amount
550  // work really short.
551  //
552  //-----------------------------------------------------------------------------------------------------------
553  void LcsBlockTrack::powerMeasurement( ) {
554
555      if ( flags & BT_F_MEASUREMENT_ON ) {
556
557          actualCurrentDigitValue = CDC::readAdc( sensePin );
558
559          totalPwrSamplesTaken ++;
560
561          if ( actualCurrentDigitValue > highWaterMarkDigitValue ) highWaterMarkDigitValue = actualCurrentDigitValue;
562          if ( actualCurrentDigitValue > limitCurrentDigitValue ) flags |= BT_F_POWER_OVERLOAD;
563      }
564  }
565
566  //-----------------------------------------------------------------------------------------------------------
567  // Print out the DCC Track configuration data. For debugging purposes.
568  //
569  //-----------------------------------------------------------------------------------------------------------
570  void LcsBlockTrack::printTrackConfig( ) {
571
572      printf( "DccTrack Config: " );
573
574      printf( " Config options: ( 0x%x ) -> ", flags );
575
576      if ( options & BT_OPT_RAILCOM ) printf( "Railcom " );
577      printf( "\n" );
578
579      printf( " Current Initial(mA): %d Current Limit(mA): %d Current Max(mA): %d\n",
580              getInitCurrent( ), getLimitCurrent( ), getMaxCurrent( ));
581      printf( " milliVoltPerAmp: %d\n", milliVoltPerAmp );
582      printf( " digitsPerAmp: %d\n", digitsPerAmp );
583      printf( " Limit Digit Value: %d\n", limitCurrentDigitValue );
584
585      printf( " Sel1 Pin: %d, Sel2 Pin: %d, Sensor Pin: %d, RailCom Pin: %d\n",
586              selPin1, selPin2, sensePin, uartRxPin );
587  }
588
589  //-----------------------------------------------------------------------------------------------------------
590  // Print out the DCC Track status.
591  //
592  //-----------------------------------------------------------------------------------------------------------
593  void LcsBlockTrack::printTrackStatus( ) {
```

```
594
595        printf( ", Track Status: ( 0x%x ) -> ", flags );
596
597        if ( flags & BT_F_POWER_ON          ) printf( "PowerOn " );
598        if ( flags & BT_F_POWER_OVERLOAD    ) printf( "PowerOverload " );
599        if ( flags & BT_F_MEASUREMENT_ON    ) printf( "PowerMeasOn " );
600        if ( flags & BT_F_RAILCOM_MODE_ON   ) printf( "RailcomOn " );
601        if ( flags & BT_F_CONFIG_ERROR      ) printf( "ConfigError " );
602        printf( "\n" );
603
604        printf( "Total Power Samples: %d\n", totalPwrSamplesTaken );
605        printf( "Power Samples per Sec: %d\n", pwrSamplesPerSec );
606        printf( "Power consumption (RMS): %d\n", getRMSCurrent( ));
607        printf( "\n" );
608 }
```

```cpp
//-----------------------------------------------------------------------------------------------------------
//
// LCS Block Controller - RailCom Support
//
//-----------------------------------------------------------------------------------------------------------
//
// LCS Block Controller
// Copyright (C) 2019 - 2024  Helmut Fieres
//
// This program is free software: you can redistribute it and/or modify it under the terms of the GNU General
// Public License as published by the Free Software Foundation, either version 3 of the License, or (at your
// option) any later version.
//
// This program is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the
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// You should have received a copy of the GNU General Public License along with this program. If not, see
// http://www.gnu.org/licenses
//
//  GNU General Public License:  http://opensource.org/licenses/GPL-3.0
//
//-----------------------------------------------------------------------------------------------------------

// ??? to work on ...

#if 0


//-----------------------------------------------------------------------------------------------------------
// Utility function to map a DCC address to a railcom decoder type.
//
//-----------------------------------------------------------------------------------------------------------
inline uint8_t mapDccAdrToRailComDatagramType( uint16_t adr ) {

    if      (( adr >= 1 )   && ( adr <= 127 ))  return ( RC_DG_TYPE_MOB );
    else if (( adr >= 128 ) && ( adr <= 191 ))  return ( RC_DG_TYPE_STAT );
    else if (( adr >= 192 ) && ( adr <= 231 ))  return ( RC_DG_TYPE_MOB );
    else                                        return ( RX_DG_TYPE_UNDEFINED );
}


//-----------------------------------------------------------------------------------------------------------
// RailCom decoder table. The Railcom communication will send raw bytes where only four bits are "one" in
// a byte ( hamming weight 4 ). The first two bytes are labelled "channel1" and the remaining six bytes
// are labelled "channel2". The actual data is then encode using the table below. Each raw byte will be
// translated to a 6 bits of data for the datagram to assemble. In total there are therefore a maximum
// of 48bits that are transmitted in a railcom message.
//
//-----------------------------------------------------------------------------------------------------------
enum RailComDataBytes : uint8_t {

    INV   = 0xff,
    BUSY  = 0xfe,
    ACK   = 0xfd,
    NACK  = 0xfc,
    RSV1  = 0xfa,
    RSV2  = 0xf9,
    RSV3  = 0xf8
};

const uint8_t railComDecode[256] = {

    INV,    INV,    INV,    INV,    INV,    INV,    INV,    INV,    // 0
    INV,    INV,    INV,    INV,    INV,    INV,    INV,    ACK,

    INV,    INV,    INV,    INV,    INV,    INV,    INV,    0x33,   // 1
    INV,    INV,    INV,    0x34,   INV,    0x35,   0x36,   INV,

    INV,    INV,    INV,    INV,    INV,    INV,    INV,    0x3A,   // 2
    INV,    INV,    INV,    0x3B,   INV,    0x3C,   0x37,   INV,

    INV,    INV,    INV,    0x3F,   INV,    0x3D,   0x38,   INV,    // 3
    INV,    0x3E,   0x39,   INV,    NACK,   INV,    INV,    INV,

    INV,    INV,    INV,    INV,    INV,    INV,    INV,    0x24,   // 4
    INV,    INV,    INV,    0x23,   INV,    0x22,   0x21,   INV,

    INV,    INV,    INV,    0x1F,   INV,    0x1E,   0x20,   INV,    // 5
    INV,    0x1D,   0x1C,   INV,    0x1B,   INV,    INV,    INV,

    INV,    INV,    INV,    0x19,   INV,    0x18,   0x1A,   INV,    // 6
    INV,    0x17,   0x16,   INV,    0x15,   INV,    INV,    INV,

    INV,    0x25,   0x14,   INV,    0x13,   INV,    INV,    INV,    // 7
    0x32,   INV,    INV,    INV,    INV,    INV,    INV,    INV,

    INV,    INV,    INV,    INV,    INV,    INV,    INV,    RSV2,   // 8
    INV,    INV,    INV,    0x0E,   INV,    0x0D,   0x0C,   INV,

    INV,    INV,    INV,    0x0A,   INV,    0x09,   0x0B,   INV,    // 9
    INV,    0x08,   0x07,   INV,    0x06,   INV,    INV,    INV,

    INV,    INV,    INV,    0x04,   INV,    0x03,   0x05,   INV,    // a
    INV,    0x02,   0x01,   INV,    0x00,   INV,    INV,    INV,

    INV,    0x0F,   0x10,   INV,    0x11,   INV,    INV,    INV,    // b
    0x12,   INV,    INV,    INV,    INV,    INV,    INV,    INV,
```

```
 99
100      INV ,      INV ,      INV ,      RSV1 ,      INV ,      0x2B ,      0x30 ,      INV ,      // c
101      INV ,      0x2A ,      0x2F ,      INV ,      0x31 ,      INV ,      INV ,      INV ,
102
103      INV ,      0x29 ,      0x2E ,      INV ,      0x2D ,      INV ,      INV ,      INV ,      // d
104      0x2C ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,
105
106      INV ,      RSV3 ,      0x28 ,      INV ,      0x27 ,      INV ,      INV ,      INV ,      // e
107      0x26 ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,
108
109      ACK ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      // f
110      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,      INV ,
111 };
112
113 //-----------------------------------------------------------------------------------------------------
114 // Railcom datagrams are sent from a mobile or a stationary decoder.
115 //
116 //-----------------------------------------------------------------------------------------------------
117 enum railComDatagramType : uint8_t {
118
119      RX_DG_TYPE_UNDEFINED  = 0,
120      RC_DG_TYPE_MOB        = 1,
121      RC_DG_TYPE_STAT       = 2
122 };
123
124 //-----------------------------------------------------------------------------------------------------
125 // Each mobile decoder railcom datagram will start with an ID field of four bits. Channel one will use only
126 // the ADR_HIG and ADR_LOW Ids. All IDs can be used for channel 2. Since decoders answer on channel one
127 // for each DCC packet they receive, here is a good chance that channel 1 will contains nonsense data. This
128 // is different for channel two, where only the addressed decoder explicitly answers. To decide whether
129 // a railcom message is valid, you should perhaps ignore channel 1 data and just check channel 2 for this
130 // purpose. A RC datagram starts with the 4-bit ID and an 8 to 32bit payload.
131 //
132 //      RC_DG_MOB_ID_POM        ( 0  )  - 12bit
133 //      RC_DG_MOB_ID_ADR_HIGH   ( 1  )  - 12bit
134 //      RC_DG_MOB_ID_ADR_LOW    ( 2  )  - 12bit
135 //      RC_DG_MOB_ID_APP_EXT    ( 3  )  - 18bit
136 //      RC_DG_MOB_ID_APP_DYN    ( 7  )  - 18bit
137 //      RC_DG_MOB_ID_XPOM_1     ( 8  )  - 36bit
138 //      RC_DG_MOB_ID_XPOM_2     ( 9  )  - 36bit
139 //      RC_DG_MOB_ID_XPOM_3     ( 10 )  - 36bit
140 //      RC_DG_MOB_ID_XPOM_4     ( 11 )  - 36bit
141 //      RC_DG_MOB_ID_TEST       ( 12 )  - ignore
142 //      RC_DG_MOB_ID_SEARCH     ( 14 )  - 48bit
143 //
144 // A datagram with the ID 14 is a DDC-A datagram and all 8 datagram bytes are combined to an 48bit datagram.
145 // A datagram packet can also contain more than one datagram. For example there could be two 18-bit length
146 // datagram in one packet or 3 12-bit packets and so on. Finally, unused bytes in channel two could contain
147 // an ACK to fill them up.
148 //
149 //-----------------------------------------------------------------------------------------------------
150 enum railComDatagramMobId : uint8_t {
151
152      RC_DG_MOB_ID_POM        = 0,
153      RC_DG_MOB_ID_ADR_HIGH   = 1,
154      RC_DG_MOB_ID_ADR_LOW    = 2,
155      RC_DG_MOB_ID_APP_EXT    = 3,
156      RC_DG_MOB__IDAPP_DYN    = 7,
157      RC_DG_MOB_ID_XPOM_1     = 8,
158      RC_DG_MOB_ID_XPOM_2     = 9,
159      RC_DG_MOB_ID_XPOM_3     = 10,
160      RC_DG_MOB_ID_XPOM_4     = 11,
161      RC_DG_MOB_ID_TEST       = 12,
162      RC_DG_MOB_ID_SEARCH     = 14
163 };
164
165 //-----------------------------------------------------------------------------------------------------
166 // Similar to the mobile decode, a stationary decoder datagram will start an ID field of four bits. Stationary
167 // decoders also define a datagram with "SRQ" and no ID field to request service from the base station.
168 //
169 // ??? to fill in ...
170 //
171 //      RC_DG_STAT_ID_SRQ       ( 0  )  - 12bit
172 //      RC_DG_STAT_ID_POM       ( 1  )  - 12bit
173 //      RC_DG_STAT_ID_STAT1     ( 4  )  - 12bit
174 //      RC_DG_STAT_ID_TIME      ( 5  )  - xxbit
175 //      RC_DG_STAT_ID_ERR       ( 6  )  - xxbit
176 //      RC_DG_STAT_ID_XPOM_1    ( 8  )  - 36bit
177 //      RC_DG_STAT_ID_XPOM_2    ( 9  )  - 36bit
178 //      RC_DG_STAT_ID_XPOM_3    ( 10 )  - 36bit
179 //      RC_DG_STAT_ID_XPOM_4    ( 11 )  - 36bit
180 //      RC_DG_STAT_ID_TEST      ( 12 )  - ignore
181 //
182 //-----------------------------------------------------------------------------------------------------
183 enum railComDatagramStatId : uint8_t {
184
185      RC_DG_STAT_ID_SRQ       = 0,
186      RC_DG_STAT_ID_POM       = 1,
187      RC_DG_STAT_ID_STAT1     = 4,
188      RC_DG_STAT_ID_TIME      = 5,
189      RC_DG_STAT_ID_ERR       = 6,
190      RC_DG_STAT_ID_DYN       = 7,
191      RC_DG_STAT_ID_XPOM_1    = 8,
192      RC_DG_STAT_ID_XPOM_2    = 9,
193      RC_DG_STAT_ID_XPOM_3    = 10,
194      RC_DG_STAT_ID_XPOM_4    = 11,
195      RC_DG_STAT_ID_TEST      = 12
196 };
197
```

```
198
199
200   //------------------------------------------------------------------------------------------------------------
201   // The RailCom buffer size. During the cutout period up to eight bytes of raw data are sent by the decoder if
202   // the Railcom option is enabled.
203   //
204   //------------------------------------------------------------------------------------------------------------
205   const uint8_t    RAILCOM_BUF_SIZE = 8;
206
207
208
209   //------------------------------------------------------------------------------------------------------------
210   // Railcom. If the cutout period and the RailCom feature is enabled, the signal state machine will also start
211   // and stop the UART reader for RailCom data. The final message is then to handle that message. In the cutout
212   // period, a decoder sends 8 data bytes. They are divided into two channels, 2bytes and another 6 bytes. The
213   // bytes themselves are encoded such that each byte has four bits set, i.e. a hamming weight of 4. The first
214   // channel is used to just send the locomotive address when the decoder is addressed. The second channel is
215   // used only when the decoder is explicitly addressed via a CV operation command to provide the answer to the
216   // request.
217   //
218   // The received datagrams are also recorded in the DCC_LOG, if enabled.
219   //
220   // ??? under construction....
221   // ??? we could store the last loco address in some global variable.
222   // ??? we could store the channel 2 datagram in the corresponding session.
223   // ??? still, both pieces of data needs to go somewhere before the next message is received...
224   //------------------------------------------------------------------------------------------------------------
225   void LcsBaseStationDccTrack::startRailComIO( ) {
226
227       CDC::startUartRead( uartRxPin );
228   }
229
230   void LcsBaseStationDccTrack::stopRailComIO( ) {
231
232       CDC::stopUartRead( uartRxPin );
233   }
234
235   uint8_t LcsBaseStationDccTrack::handleRailComMsg( ) {
236
237       railComBufIndex = CDC::getUartBuffer( uartRxPin, railComMsgBuf, sizeof( railComMsgBuf ));
238
239       writeLogData( LOG_DCC_RCM, railComMsgBuf, railComBufIndex );
240
241       for ( uint8_t i = 0; i < railComBufIndex; i++ ) {
242
243           uint8_t dataByte = railComDecode[ railComMsgBuf[ i ]];
244
245           if      ( dataByte == ACK ) ;
246           else if ( dataByte == NACK ) ;
247           else if ( dataByte == BUSY ) ;
248           else if ( dataByte < 64 ) {
249
250               // ??? valid
251               // ??? a railCom message can have multiple datagrams
252               // we would need to handle each datagram, one at a time or fill them into a kind of structure
253               // that has a slot for the up to maximum 4 datagrams per railCom cutout period.
254           }
255           else {
256
257               // ??? invalid packet ... if this is channel2, discard the entire message.
258           }
259
260           railComMsgBuf[ i ] = dataByte;
261       }
262
263       flags &= ~ DT_F_RAILCOM_MSG_PENDING;
264       return ( ALL_OK );
265   }
266
267   // ??? not very useful, but good for debugging and initial testing .... and it works like a champ :-)
268
269   uint8_t LcsBaseStationDccTrack::getRailComMsg( uint8_t *buf, uint8_t bufLen ) {
270
271       if (( railComBufIndex > 0 ) && ( bufLen > 0 )) {
272
273           uint8_t i = 0;
274
275           do {
276
277               buf[ i ] = railComMsgBuf[ i ];
278               i++;
279
280           } while (( i < railComBufIndex ) && ( i < bufLen ));
281
282           return ( i );
283
284       } else return ( 0 );
285   }
286
287   #endif
```
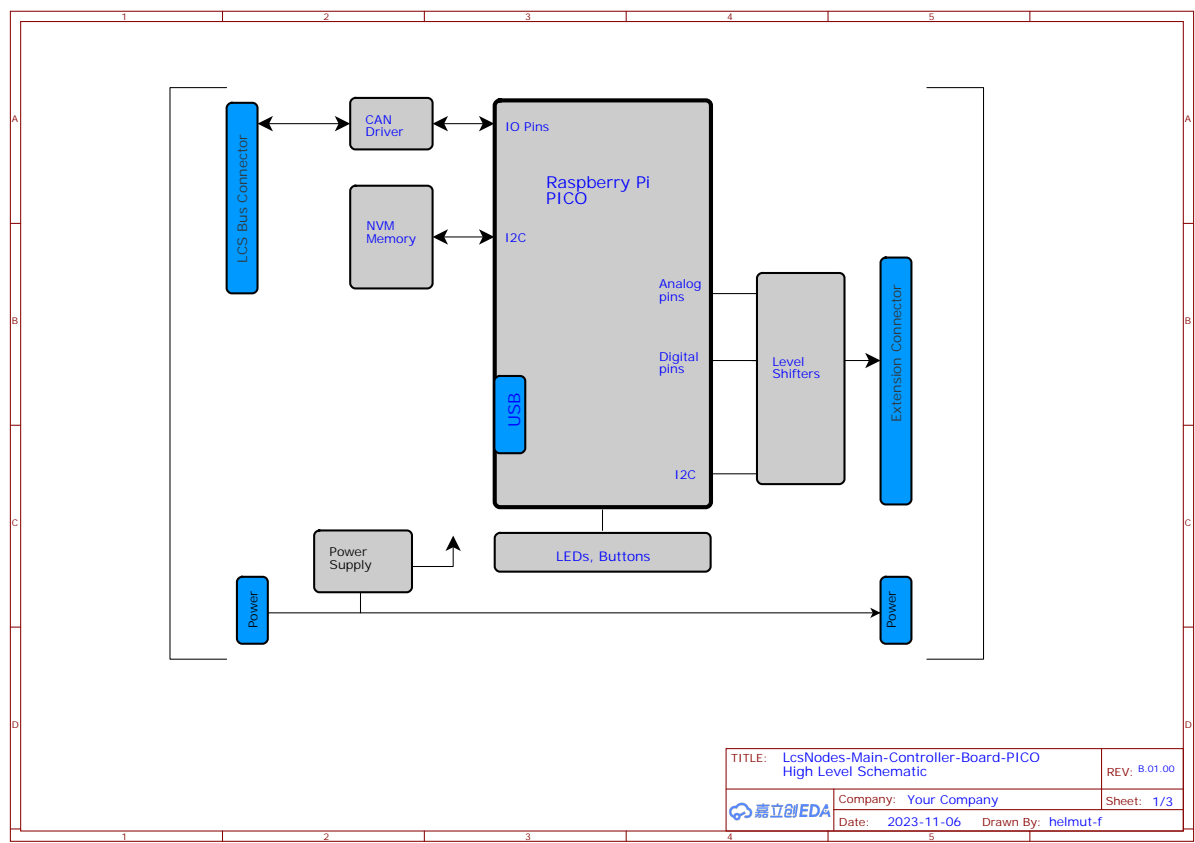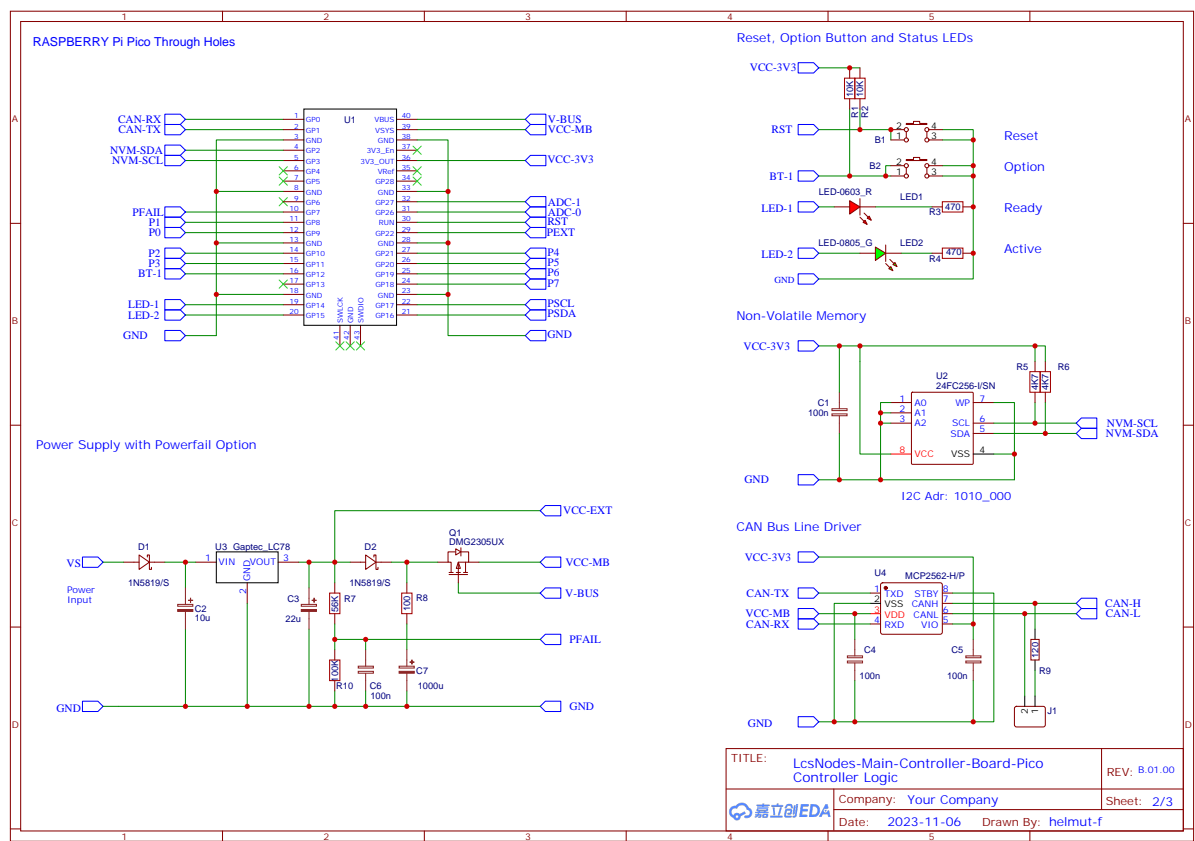
B   Tests

B.1   Schematics

float barrier command to ensure that text stays close to the picture but no text from after the picture.
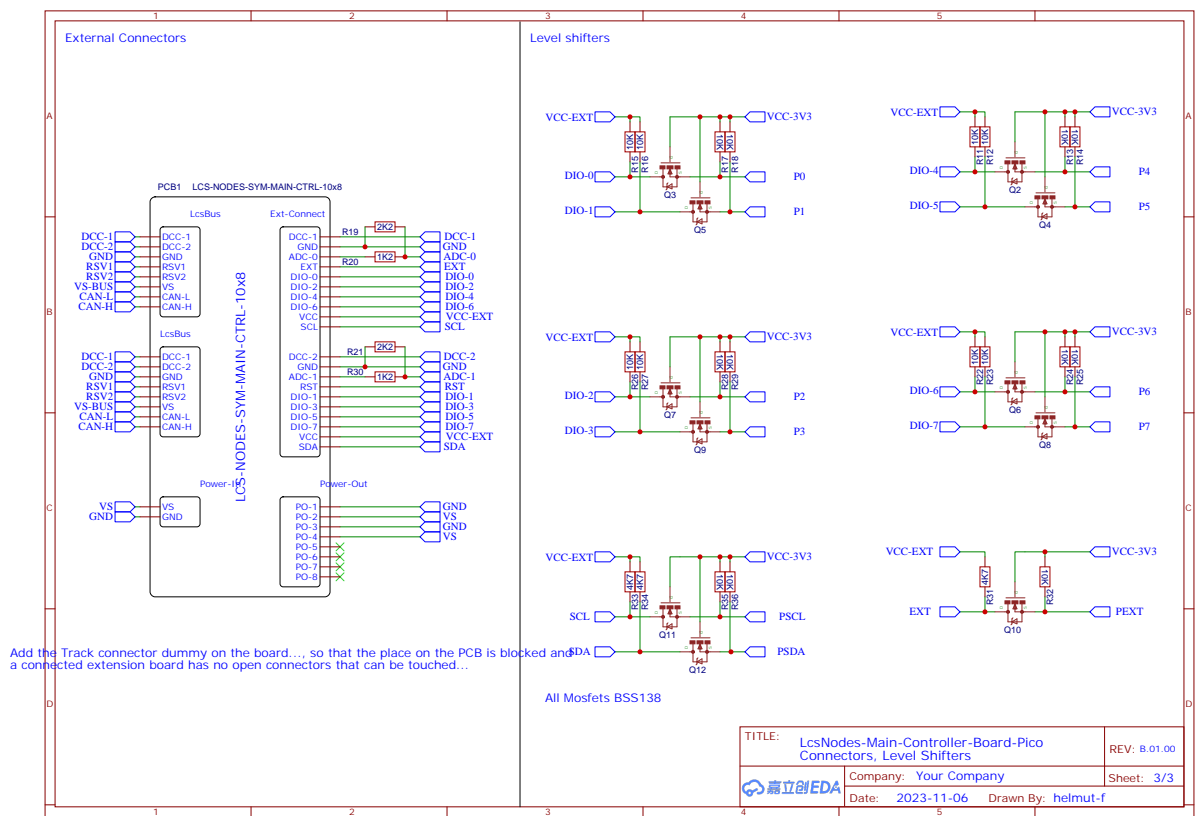
B.1.1   part 1

B.1.2   part 2

B.1.3 part 3

External Connectors

Level shifters

PCB1 LCS-NODES-SYM-MAIN-CTRL-10x8

TITLE: LcsNodes-Main-Controller-Board-Pico Connectors, Level Shifters

REV: B.01.00

Company: Your Company

Sheet: 3/3

Date: 2023-11-06 Drawn By: helmut-f

All Mosfets BSS138

Add the Track connector dummy on the board..., so that the place on the PCB is blocked and a connected extension board has no open connectors that can be touched...

B.2   Lists

B.2.1   A simple list

- First bullet point

- Second bullet point

- Third bullet point

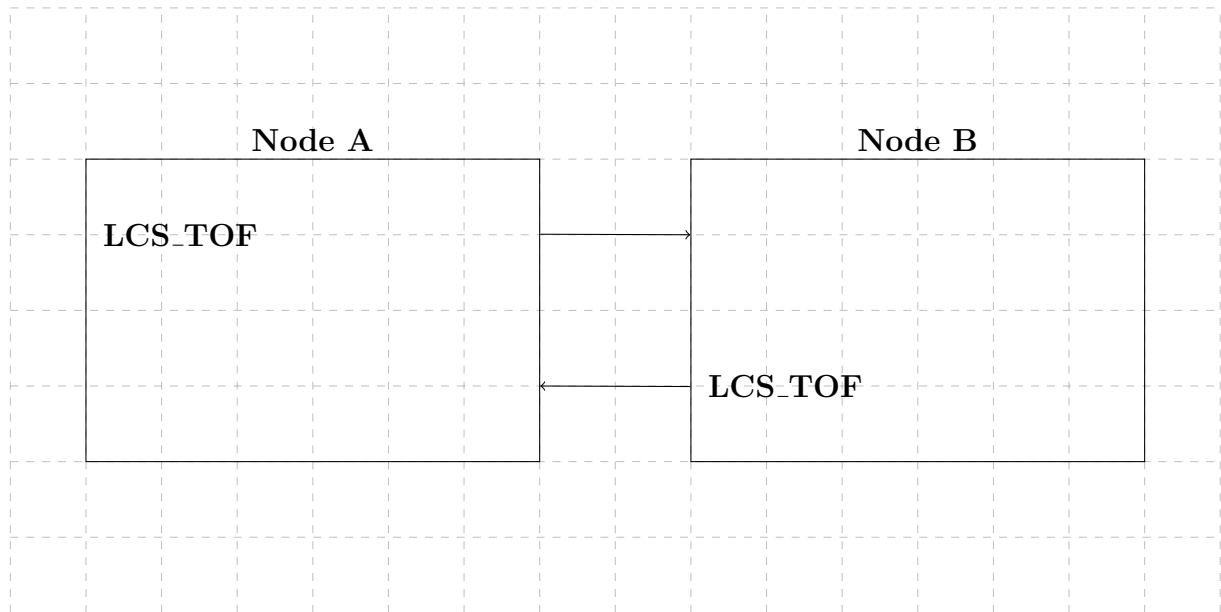### B.2.2   An instruction word layout

A little test for an instruction word layout ... will be a bit fiddling work ...

1	3	6
Test		

B.3   Protocol boxes

A bit cumbersome and we would need to have text at defined locations. Perhaps keep the simple table in the protocol chapter.

B.4   Split rectangle

We would need the split rectangle for the runtime area maps....

B.5   Using tikzstyle

Another test with tikzstyle. It still is a lot of work to even make simple pictures look nice :-)