TCD1304 Controller

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Chapter 1

Firwmare for the TCD1304 using FlexPWM

This directory contains an Arduino sketch file and libraries to operate the TCD1304 Sensor using the Teensy 4 in either the two board system, the TCD1304 SPI board plus Teensy 4 Controller Rev 3 or the All-In-One board with FlexPWM support.

In this version we add ring buffering. Regard this as experimental for the time being. In preliminary testing with an Intel I5 host running Linux, it seems to work well. We want to test more extensively on a wider range of host platforms.

To setup your system to install the firmware, see the `Teensyduino website and setup instructions`

See the `Python directory in this repo` for an interactive user utility with real time graphics. The Python program uses Python3, Numpy, Matplotlib, PySerial and SciPY.

In the interactive user utility, use the command "help" to see a list of commands.

1.0.1 In this directory:

The file TCD1304Device2.h is a header only library for the TCD1304 using the NXP iMXRT1060 FlexPWM.

The file TCD1304Device_Controller_251208.ino implements the user command interface and instantiates the ring buffer system.

The files parselib2.cpp and parselib2.h provides an api for parsing commands and is used in the controller code to implement the command language for the device.

The ring buffer system is implemented in the controller code, using the frame completion callback interface provide by the TCD1304Device class along with a frame structure also provided in the device library.

Chapter 2

Class Index

2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 3

File Index

3.1 File List

Here is a list of all files with brief descriptions:

Chapter 4

Class Documentation

4.1 TCD1304Device::Frame_Header_struct Struct Reference

`#include <TCD1304Device2.h>`

Public Attributes

- uint16_t * buffer
- unsigned int nbuffer
- unsigned int avgdummy
- float offset
- float frame_elapsed_secs
- float frame_exposure_secs
- float timer_elapsed_secs
- float timer_difference_secs
- float trigger_elapsed_secs
- float trigger_difference_secs
- unsigned int frame_counter
- unsigned int frameset_counter
- unsigned int trigger_counter
- TCD1304_Mode_t mode
- bool trigger_mode
- bool error_flag
- bool oops_flag
- bool frames_completed
- bool framesets_completed
- bool ready_for_send

4.1.1 Member Data Documentation

4.1.1.1 avgdummy

`unsigned int TCD1304Device::Frame_Header_struct::avgdummy`

4.1.1.2 buffer

```
uint16_t* TCD1304Device::Frame_Header_struct::buffer
```

4.1.1.3 error_flag

```
bool TCD1304Device::Frame_Header_struct::error_flag
```

4.1.1.4 frame_counter

```
unsigned int TCD1304Device::Frame_Header_struct::frame_counter
```

4.1.1.5 frame_elapsed_secs

```
float TCD1304Device::Frame_Header_struct::frame_elapsed_secs
```

4.1.1.6 frame_exposure_secs

```
float TCD1304Device::Frame_Header_struct::frame_exposure_secs
```

4.1.1.7 frames_completed

```
bool TCD1304Device::Frame_Header_struct::frames_completed
```

4.1.1.8 frameset_counter

```
unsigned int TCD1304Device::Frame_Header_struct::frameset_counter
```

4.1.1.9 framesets_completed

```
bool TCD1304Device::Frame_Header_struct::framesets_completed
```

4.1.1.10 mode

```
TCD1304_Mode_t TCD1304Device::Frame_Header_struct::mode
```

4.1.1.11 nbuffer

```
unsigned int TCD1304Device::Frame_Header_struct::nbuffer
```

4.1.1.12 offset

```
float TCD1304Device::Frame_Header_struct::offset
```

4.1.1.13 oops_flag

```
bool TCD1304Device::Frame_Header_struct::oops_flag
```

4.1.1.14 ready_for_send

```
bool TCD1304Device::Frame_Header_struct::ready_for_send
```

4.1.1.15 timer_difference_secs

```
float TCD1304Device::Frame_Header_struct::timer_difference_secs
```

4.1.1.16 timer_elapsed_secs

```
float TCD1304Device::Frame_Header_struct::timer_elapsed_secs
```

4.1.1.17 trigger_counter

```
unsigned int TCD1304Device::Frame_Header_struct::trigger_counter
```

4.1.1.18 trigger_difference_secs

```
float TCD1304Device::Frame_Header_struct::trigger_difference_secs
```

4.1.1.19 trigger_elapsed_secs

```
float TCD1304Device::Frame_Header_struct::trigger_elapsed_secs
```

4.1.1.20 trigger_mode

```
bool TCD1304Device::Frame_Header_struct::trigger_mode
```

The documentation for this struct was generated from the following file:

- TCD1304Device2.h

4.2 TCD1304Device::SubModule Struct Reference

`#include <TCD1304Device2.h>`

Public Member Functions

- SubModule (const char *name_, uint8_t submod_, uint8_t mask_, uint8_t pinA_, uint8_t muxvalA_, uint8_t pinB_, uint8_t muxvalB_, IRQ_NUMBER_t irq_, IMXRT_FLEXPWM_t *flexpwm_)

Public Attributes

- const char * name
- const uint8_t submod
- const uint8_t mask
- const uint8_t pinA
- const uint8_t muxvalA
- const uint8_t pinB
- const uint8_t muxvalB
- IRQ_NUMBER_t irq
- IMXRT_FLEXPWM_t * flexpwm
- uint16_t period_counts = 0
- uint16_t onA_counts = 0
- uint16_t offA_counts = 0
- uint16_t onB_counts = 0
- uint16_t offB_counts = 0
- uint16_t ctrl2_mask = 0
- uint16_t intena_mask = 0
- uint16_t divider = 1
- uint8_t prescale = 0
- uint8_t filler = 0
- float period_secs = 0
- bool invertA = false
- bool invertB = false
- bool newvals = false
- void(* isr)() = nullptr
- uint16_t inten_mask = 0

4.2.1 Constructor & Destructor Documentation

4.2.1.1 SubModule()

```
TCD1304Device::SubModule::SubModule (
            const char * name_,
            uint8_t submod_,
            uint8_t mask_,
            uint8_t pinA_,
            uint8_t muxvalA_,
            uint8_t pinB_,
            uint8_t muxvalB_,
            IRQ_NUMBER_t irq_,
            IMXRT_FLEXPWM_t * flexpwm_)  [inline]
```

4.2.2 Member Data Documentation

4.2.2.1 ctrl2_mask

```
uint16_t TCD1304Device::SubModule::ctrl2_mask = 0
```

4.2.2.2 divider

```
uint16_t TCD1304Device::SubModule::divider = 1
```

4.2.2.3 filler

```
uint8_t TCD1304Device::SubModule::filler = 0
```

4.2.2.4 flexpwm

```
IMXRT_FLEXPWM_t* TCD1304Device::SubModule::flexpwm
```

4.2.2.5 inten_mask

```
uint16_t TCD1304Device::SubModule::inten_mask = 0
```

4.2.2.6 intena_mask

```
uint16_t TCD1304Device::SubModule::intena_mask = 0
```

4.2.2.7 invertA

```
bool TCD1304Device::SubModule::invertA = false
```

4.2.2.8 invertB

```
bool TCD1304Device::SubModule::invertB = false
```

4.2.2.9 irq

```
IRQ_NUMBER_t TCD1304Device::SubModule::irq
```

4.2.2.10 isr

```
void(* TCD1304Device::SubModule::isr) () = nullptr
```

4.2.2.11 mask

```
const uint8_t TCD1304Device::SubModule::mask
```

4.2.2.12 muxvalA

```
const uint8_t TCD1304Device::SubModule::muxvalA
```

4.2.2.13 muxvalB

```
const uint8_t TCD1304Device::SubModule::muxvalB
```

4.2.2.14 name

```
const char* TCD1304Device::SubModule::name
```

4.2.2.15 newvals

```
bool TCD1304Device::SubModule::newvals = false
```

4.2.2.16 offA_counts

```
uint16_t TCD1304Device::SubModule::offA_counts = 0
```

4.2.2.17 offB_counts

```
uint16_t TCD1304Device::SubModule::offB_counts = 0
```

4.2.2.18 onA_counts

```
uint16_t TCD1304Device::SubModule::onA_counts = 0
```

4.2.2.19 onB_counts

```
uint16_t TCD1304Device::SubModule::onB_counts = 0
```

4.2.2.20 period_counts

```
uint16_t TCD1304Device::SubModule::period_counts = 0
```

4.2.2.21 period_secs

```
float TCD1304Device::SubModule::period_secs = 0
```

4.2.2.22 pinA

```
const uint8_t TCD1304Device::SubModule::pinA
```

4.2.2.23 pinB

```
const uint8_t TCD1304Device::SubModule::pinB
```

4.2.2.24 prescale

```
uint8_t TCD1304Device::SubModule::prescale = 0
```

4.2.2.25 submod

```
const uint8_t TCD1304Device::SubModule::submod
```

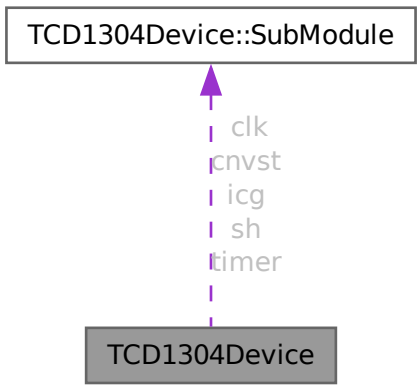
The documentation for this struct was generated from the following file:

- TCD1304Device2.h

4.3 TCD1304Device Class Reference

`#include <TCD1304Device2.h>`

Collaboration diagram for TCD1304Device:



Classes

- struct Frame_Header_struct
- struct SubModule

Public Types

- typedef struct TCD1304Device::Frame_Header_struct Frame_Header

Public Member Functions

- TCD1304Device (unsigned int period=CLK_DEFAULT)
- void stop_all ()
- bool read (uint nframes, float exposure, uint16_t *bufferp, void(*frame_callbackf)(), void(*frameset_callbackf)(), void(*completion_callbackf)(), void(*setup_callbackf)(), bool start=true)
- bool read (uint nframes, float exposure, float frame_interval, uint16_t *bufferp, void(*frame_callbackf)(), void(*frameset_callbackf)(), void(*completion_callbackf)(), void(*setup_callbackf)(), bool start=true)
- bool start_read ()
- bool wait_read (float timeout=0., float timestep=0.01, bool verbose=false)
- bool triggered_read (uint ntriggers, uint nframes, float exposure, uint16_t *bufferp, void(*frame_callbackf)(), void(*frameset_callbackf)(), void(*completion_callbackf)(), void(*setup_callbackf)(), bool start=true)
- bool triggered_read (uint ntriggers, uint nframes, float exposure, float interval, uint16_t *bufferp, void(*frame_↩ callbackf)(), void(*frameset_callbackf)(), void(*completion_callbackf)(), void(*setup_callbackf)(), bool start=true)

- bool wait_triggered_read (float timeout=1., float timestep=0.01, bool verbose=false)
- void print_submodule (SubModule *p)
- bool check_submodule (SubModule *p)
- bool print_and_check_submodule (SubModule *p)
- void load_submodule (SubModule *p)
- bool setup_submodule (SubModule *p, uint8_t prescale, uint16_t period_counts, uint16_t onA_counts, uint16_t offA_counts, bool invertA, uint16_t onB_counts, uint16_t offB_counts, bool invertB, uint16_t ctrl2_mask)
- void attach_isr (SubModule *p, uint16_t cmpf_mask, void(*isrf)())
- void clear_frames_completed_callback ()
- void load_frames_completed_callback (void(*callback)(), unsigned int nframes=0)
- void clear_framesets_completed_callback ()
- void load_framesets_completed_callback (void(*callback)(), unsigned int nsets=0)
- bool flexpwm_wait (float timeout_=1., float timestep_=0.01, bool verbose=false)
- bool setup_pulse (float clk_secs, float sh_secs, float sh_offset_secs, float icg_secs, float icg_offset_secs, uint16_t *buffer, unsigned int nbuffer, void(*callbackf)())
- bool setup_frameset (float clk_secs, float sh_secs, float sh_offset_secs, float icg_secs, float icg_offset_secs, float exposure_secs, float frame_interval_secs, unsigned int nframes, uint16_t *buffer, unsigned int nbuffer, void(*callbackf)())
- bool timer_wait (float timeout_=1., float timestep_=0.01, bool verbose=false)
- bool setup_timer (float exposure_secs, float exposure_offset_secs, unsigned int ncounts=0)
- bool start_triggers ()
- bool wait_triggers (float timeout_=1., float timestep_=0.01, bool verbose=false)
- bool setup_triggers (unsigned int ncounts=0)
- void set_clock_master (uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)

  Low level functions for command line register access.
- void set_clock_master (SubModule *p)
- void set_clock_slave (uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_clock_slave (SubModule *p)
- void set_clock_sync (uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_clock_sync (SubModule *p)
- void clear_ldok (uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_ldok (uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm)
- void clear_run (uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_run (uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm)
- void force (uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_prescale (uint8_t submod, uint8_t prescale=0, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_init (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val0 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val1 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val2 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val3 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val4 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- void set_val5 (uint8_t submod, uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm)
- uint16_t set_outen (uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm)
- uint16_t set_outen_on (uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm)
- uint16_t set_outen_off (uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm)
- uint16_t set_outenA_on (uint8_t mask8, IMXRT_FLEXPWM_t *q=flexpwm)
- void printbits16_ (uint16_t u16, int bits)
- void register_dump (IMXRT_FLEXPWM_t *const q=flexpwm, uint8_t mask=0xFF)

Static Public Member Functions

- static void stop_runs_only ()
- static void disable_irqs ()
- static void stop_with_irqs ()
- static void clear_error_flags ()
- static void clear_mode ()
- static void clear_sync_busy_pins ()
- static void toggle_busypin ()
- static void toggle_syncpin ()
- static void clear_busypin ()
- static void clear_syncpin ()
- static void update_read_buffer (uint16_t *buffer)
- static void fill_frame_header (Frame_Header *p)
- static uint64_t cycles64 ()
- static double sh_elapsed_secs ()
- static double sh_difference_secs ()
- static double sh_exposure_secs ()
- static double timer_elapsed_secs ()
- static double timer_difference_secs ()
- static double trigger_elapsed_secs ()
- static double trigger_difference_secs ()
- static void print_errormsg (const char *name, const char *errmsg)
- static void print_errormsg (SubModule *p, const char *errmsg)
- static void print_counters ()
- static void flexpwm_start ()
- static void flexpwm_stop ()
- static void pulse_sh_isr ()
- static void pulse_icg_isr ()
- static void pulse_cnvst_isr ()
- static void pulse_start ()
- static void pulse_arm ()
- static void pulse_init_frames ()
- static void pulse_init_frameset ()
- static void frameset_sh_isr ()
- static void frameset_icg_isr ()
- static void frameset_cnvst_isr ()
- static void frameset_start ()
- static void frameset_arm ()
- static void frameset_init_frames ()
- static void frameset_init_frameset ()
- static void timer_isr ()
- static void timer_start ()
- static void timer_stop ()
- static void timer_stop_with_irq ()
- static void trigger_isr ()
- static void stop_triggers ()
- static void setup_digital_pins ()
- static void close ()

Static Public Attributes

- static uint64_t sh_cyccnt64_start = 0
- static uint64_t sh_cyccnt64_now = 0
- static uint64_t sh_cyccnt64_prev = 0
- static uint64_t sh_cyccnt64_exposure = 0
- static uint64_t timer_cyccnt64_start = 0
- static uint64_t timer_cyccnt64_now = 0
- static uint64_t timer_cyccnt64_prev = 0
- static uint64_t trigger_cyccnt64_start = 0
- static uint64_t trigger_cyccnt64_now = 0
- static uint64_t trigger_cyccnt64_prev = 0
- static TCD1304_Mode_t mode = NOTCONFIGURED
- static bool trigger_mode = false
- static bool trigger_attached = false
- static unsigned int sh_counter = 0
- static unsigned int icg_counter = 0
- static unsigned int cnvst_counter = 0
- static unsigned int sh_counts_per_icg = 0
- static unsigned int sh_clearing_counts = SH_CLEARING_DEFAULT
- static unsigned int sh_clearing_counter = 0
- static unsigned int sh_short_period_counts = 0
- static unsigned int read_counter = 0
- static unsigned int read_counts = 0
- static uint16_t * read_buffer = 0
- static uint16_t * read_pointer = 0
- static void(* read_callback)()=0
- static unsigned int frame_counter = 0
- static unsigned int frame_counts = 0
- static void(* frames_completed_callback)()=0
- static unsigned int frameset_counter = 0
- static unsigned int frameset_counts = 0
- static void(* framesets_completed_callback)()=0
- static unsigned int timer_inner_counter = 0
- static unsigned int timer_inner_counts = 0
- static unsigned int timer_outer_counter = 0
- static unsigned int timer_outer_counts = 0
- static void(* timer_callback)()=0
- static float timer_interframe_min_secs = 0.
- static float timer_period_secs = 0
- static float timer_interval_secs = .0
- static unsigned int trigger_counter = 0
- static unsigned int trigger_counts = 1
- static void(* trigger_callback)()=0
- static uint8_t trigger_pin = TRIGGER_PIN
- static uint8_t trigger_edge_mode = RISING
- static uint8_t trigger_pin_mode = INPUT
- static uint16_t cnvst_extra_delay_counts = 1
- static bool skip_one = false
- static bool skip_one_reload = false
- static bool busytoggled = false

- static uint8_t sync_pin = SYNC_PIN
- static bool synctoggled = false
- static bool sync_enabled = true
- static IMXRT_FLEXPWM_t *const flexpwm = &IMXRT_FLEXPWM2
- static SubModule clk = {"clk",CLK_SUBMODULE, CLK_MASK, CLK_PIN,CLK_MUXVAL, 0xFF,0, CLK_IRQ, &IMXRT_FLEXPWM2}
- static SubModule sh = {"sh", SH_SUBMODULE, SH_MASK, SH_PIN,SH_MUXVAL, 0xFF,0, SH_IRQ, &IMXRT↩ _FLEXPWM2}
- static SubModule icg = {"icg", ICG_SUBMODULE, ICG_MASK, ICG_PIN,ICG_MUXVAL, 0xFF,0, ICG_IRQ, &IMXRT_FLEXPWM2}
- static SubModule cnvst = {"cnvst", CNVST_SUBMODULE, CNVST_MASK, 0xFF,0, 0xFF,0, CNVST_IRQ, &IMXRT_FLEXPWM2}
- static IMXRT_FLEXPWM_t *const timerflexpwm = &IMXRT_FLEXPWM4
- static SubModule timer = {"timer", TIMER_SUBMODULE, TIMER_MASK, 0xFF,0, TIMER_PIN,TIMER_MUXVAL, TIMER_IRQ, &IMXRT_FLEXPWM4}
- static bool error_flag = false
- static bool oops_flag = false
- static float read_expected_time = 0.
- static bool flexpwm_running = false
- static bool pulse_armed = false

  Configure the flexpwm for single pulse, use this with a timer.
- static bool frameset_armed = false
- static bool timer_first_time_flag = true
- static bool timer_running = false
- static bool trigger_busy = false

4.3.1 Member Typedef Documentation

4.3.1.1 Frame_Header

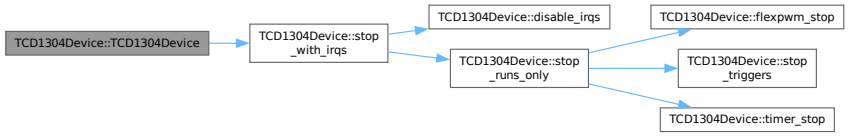
```
typedef struct TCD1304Device::Frame_Header_struct TCD1304Device::Frame_Header
```

4.3.2 Constructor & Destructor Documentation

4.3.2.1 TCD1304Device()

```
TCD1304Device::TCD1304Device (
            unsigned int period = CLK_DEFAULT)  [inline]
```

Here is the call graph for this function:

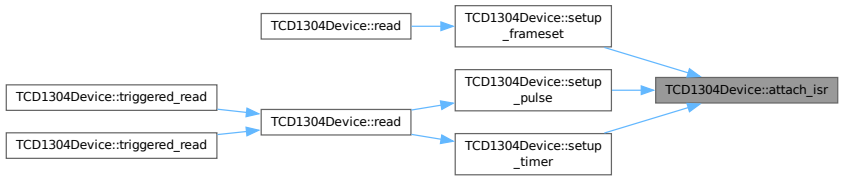


4.3.3 Member Function Documentation

4.3.3.1 attach_isr()

```
void TCD1304Device::attach_isr (
            SubModule * p,
            uint16_t cmpf_mask,
            void(* isrf )())  [inline]
```

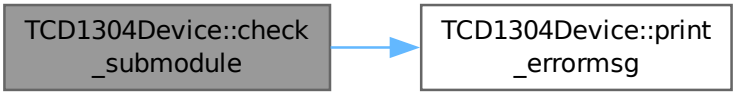
Here is the caller graph for this function:



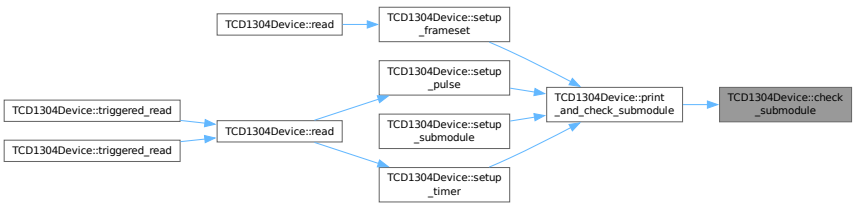
4.3.3.2 check_submodule()

```
bool TCD1304Device::check_submodule (
            SubModule * p)  [inline]
```

Here is the call graph for this function:



Here is the caller graph for this function:



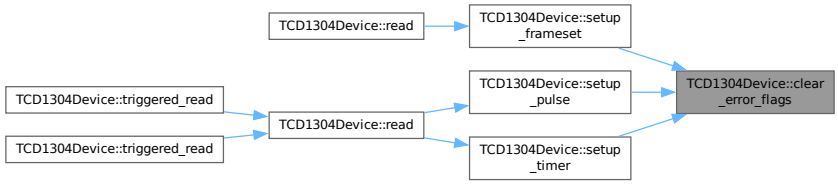
4.3.3.3 clear_busypin()

```
static void TCD1304Device::clear_busypin ()  [inline], [static]
```

4.3.3.4 clear_error_flags()

```
static void TCD1304Device::clear_error_flags ()  [inline], [static]
```

Here is the caller graph for this function:



4.3.3.5 clear_frames_completed_callback()

```
void TCD1304Device::clear_frames_completed_callback ()  [inline]
```

4.3.3.6 clear_framesets_completed_callback()

```
void TCD1304Device::clear_framesets_completed_callback ()  [inline]
```

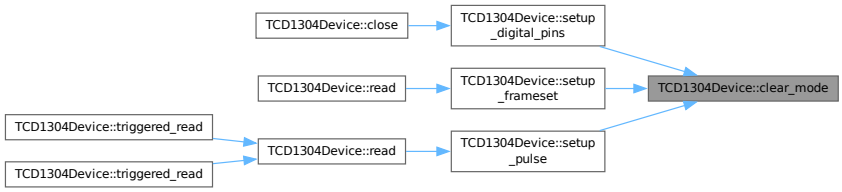
4.3.3.7 clear_ldok()

```
void TCD1304Device::clear_ldok (
            uint8_t mask,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.8 clear_mode()

```
static void TCD1304Device::clear_mode ()  [inline], [static]
```

Here is the caller graph for this function:



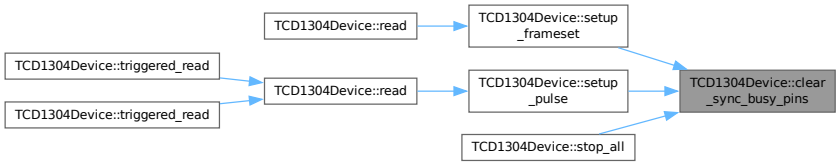
4.3.3.9 clear_run()

```
void TCD1304Device::clear_run (
            uint8_t mask,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.10 clear_sync_busy_pins()

```
static void TCD1304Device::clear_sync_busy_pins ()  [inline], [static]
```

Here is the caller graph for this function:



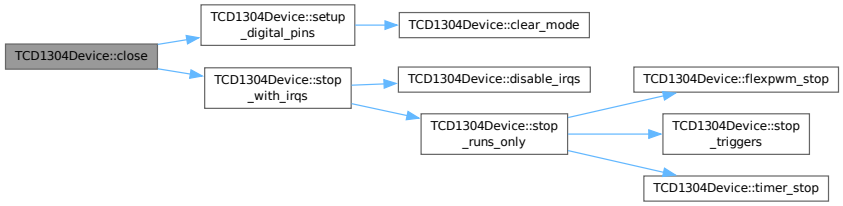
4.3.3.11 clear_syncpin()

```
static void TCD1304Device::clear_syncpin ()  [inline], [static]
```

4.3.3.12 close()

```
static void TCD1304Device::close ()  [inline], [static]
```

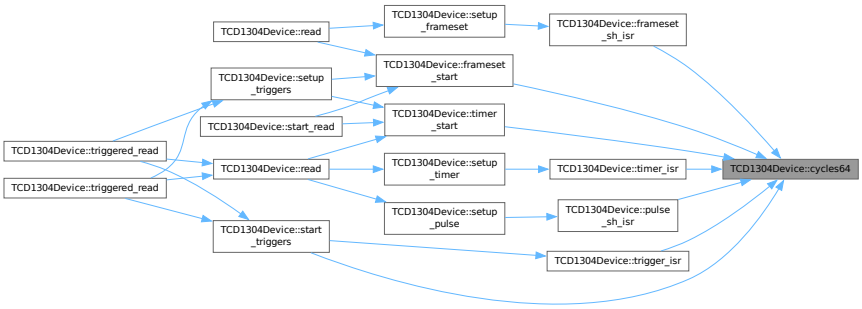
Here is the call graph for this function:



4.3.3.13 cycles64()

```
static uint64_t TCD1304Device::cycles64 ()  [inline], [static]
```

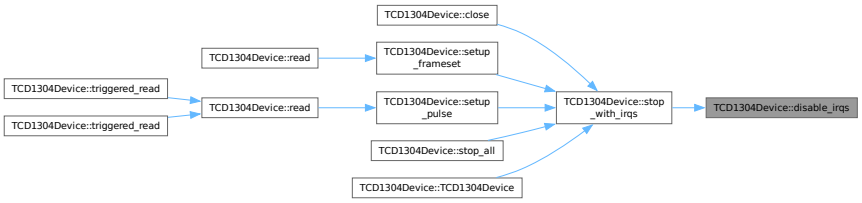
Here is the caller graph for this function:



4.3.3.14 disable_irqs()

```
static void TCD1304Device::disable_irqs ()  [inline], [static]
```

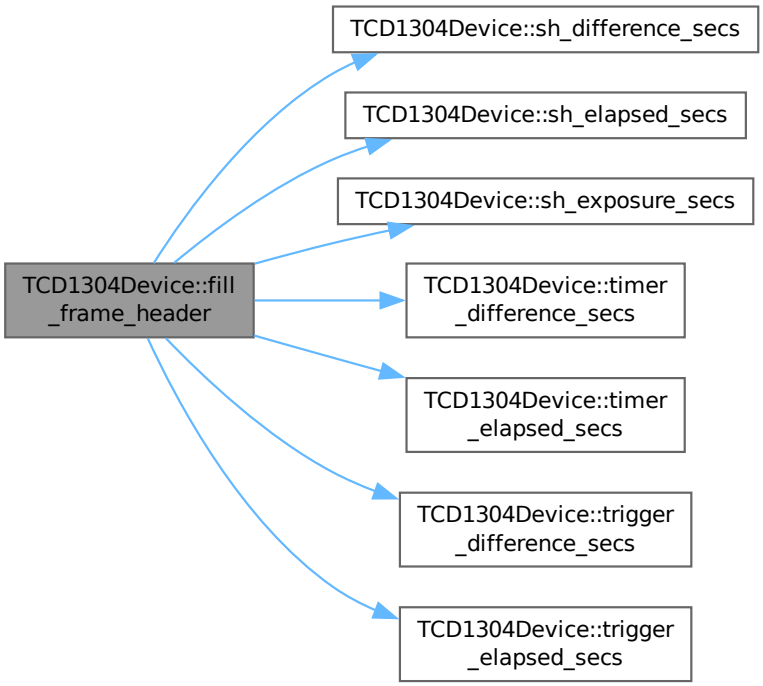
Here is the caller graph for this function:



4.3.3.15 fill_frame_header()

```
static void TCD1304Device::fill_frame_header (
            Frame_Header * p)  [inline], [static]
```

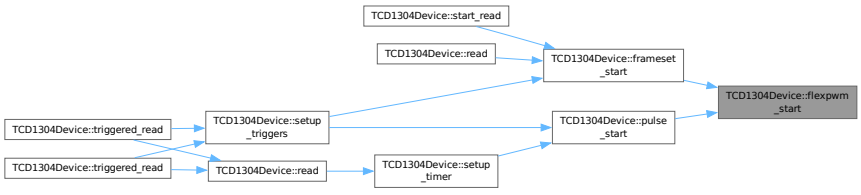
Here is the call graph for this function:



4.3.3.16 flexpwm_start()

```
static void TCD1304Device::flexpwm_start ()  [inline], [static]
```

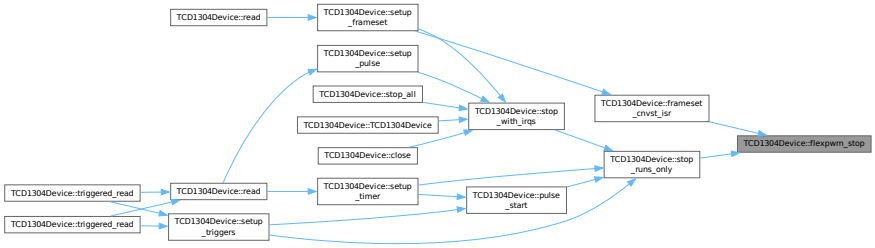
Here is the caller graph for this function:



4.3.3.17 flexpwm_stop()

```
static void TCD1304Device::flexpwm_stop ()  [inline], [static]
```

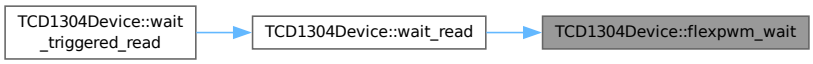
Here is the caller graph for this function:



4.3.3.18 flexpwm_wait()

```
bool TCD1304Device::flexpwm_wait (
            float timeout_ = 1.,
            float timestep_ = 0.01,
            bool verbose = false)  [inline]
```

Here is the caller graph for this function:



4.3.3.19 force()

```
void TCD1304Device::force (
            uint8_t submod,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.20 frameset_arm()

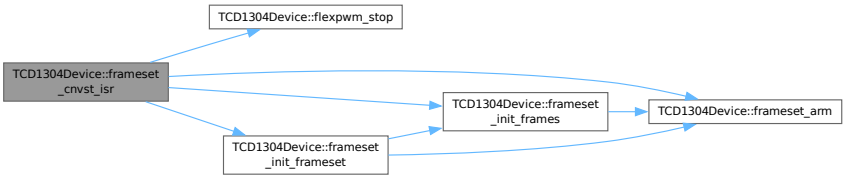
```
static void TCD1304Device::frameset_arm ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.21 frameset_cnvst_isr()

```
static void TCD1304Device::frameset_cnvst_isr ()  [inline], [static]
```

Here is the call graph for this function:



Here is the caller graph for this function:

4.3.3.22 frameset_icg_isr()

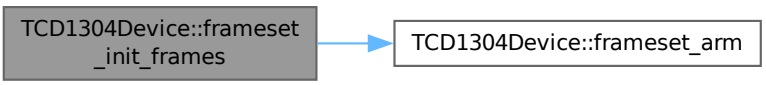
```
static void TCD1304Device::frameset_icg_isr ()  [inline], [static]
```

Here is the caller graph for this function:

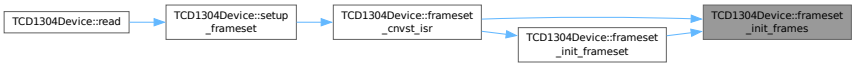
4.3.3.23 frameset_init_frames()

```
static void TCD1304Device::frameset_init_frames ()  [inline], [static]
```

Here is the call graph for this function:



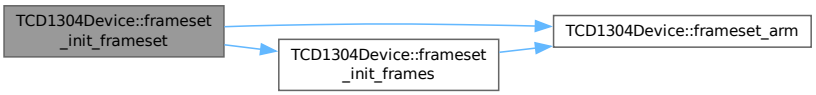
Here is the caller graph for this function:



4.3.3.24 frameset_init_frameset()

```
static void TCD1304Device::frameset_init_frameset ()  [inline], [static]
```

Here is the call graph for this function:

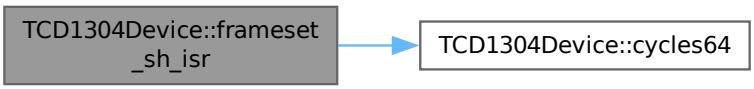


Here is the caller graph for this function:

4.3.3.25 frameset_sh_isr()

```
static void TCD1304Device::frameset_sh_isr ()  [inline], [static]
```

Here is the call graph for this function:

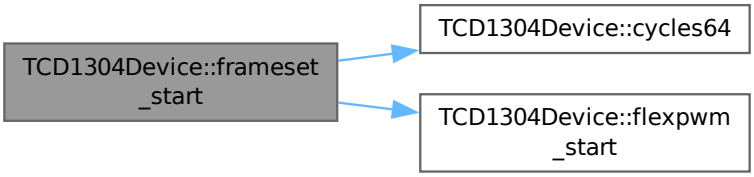


Here is the caller graph for this function:

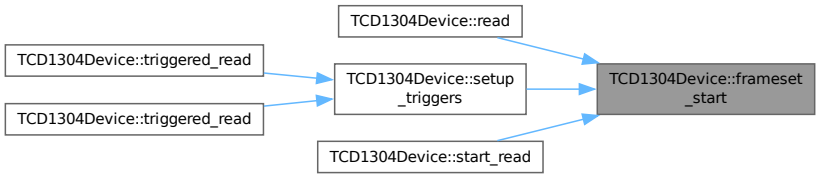
4.3.3.26 frameset_start()

```
static void TCD1304Device::frameset_start ()  [inline], [static]
```

Here is the call graph for this function:



Here is the caller graph for this function:



4.3.3.27 load_frames_completed_callback()

```
void TCD1304Device::load_frames_completed_callback (
            void(* callback )(),
            unsigned int nframes = 0)  [inline]
```

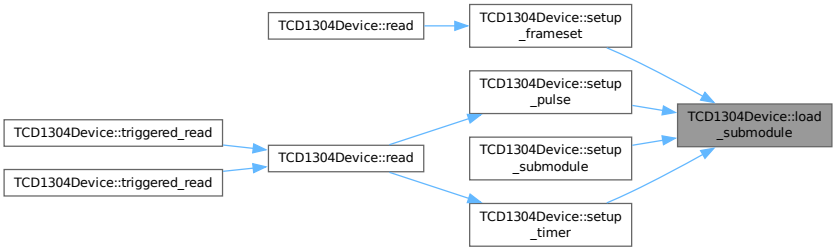
4.3.3.28 load_framesets_completed_callback()

```
void TCD1304Device::load_framesets_completed_callback (
            void(* callback )(),
            unsigned int nsets = 0)  [inline]
```

4.3.3.29 load_submodule()

```
void TCD1304Device::load_submodule (
            SubModule * p)  [inline]
```

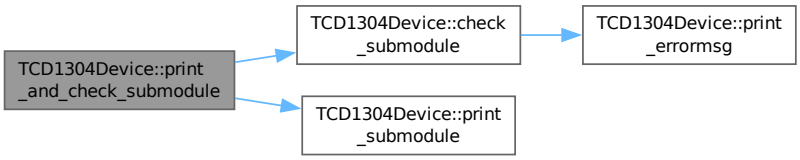
Here is the caller graph for this function:



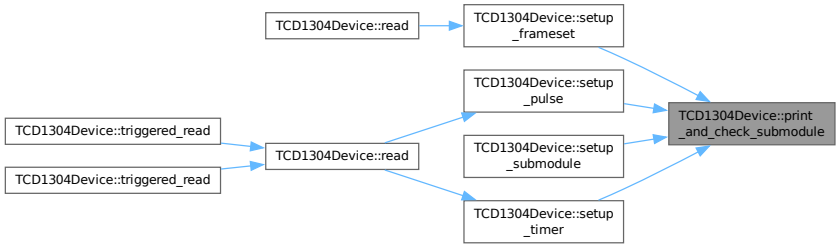
4.3.3.30 print_and_check_submodule()

```
bool TCD1304Device::print_and_check_submodule (
            SubModule * p)  [inline]
```

Here is the call graph for this function:



Here is the caller graph for this function:



4.3.3.31 print_counters()

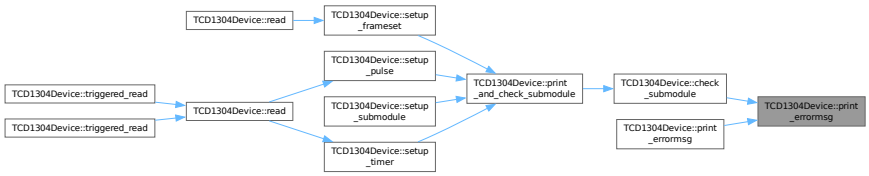
```
static void TCD1304Device::print_counters ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.32 print_errormsg() [1/2]

```
static void TCD1304Device::print_errormsg (
            const char * name,
            const char * errmsg)  [inline], [static]
```

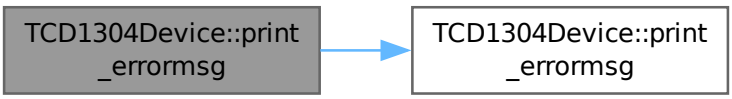
Here is the caller graph for this function:



4.3.3.33 print_errormsg() [2/2]

```
static void TCD1304Device::print_errormsg (
            SubModule * p,
            const char * errmsg)  [inline], [static]
```

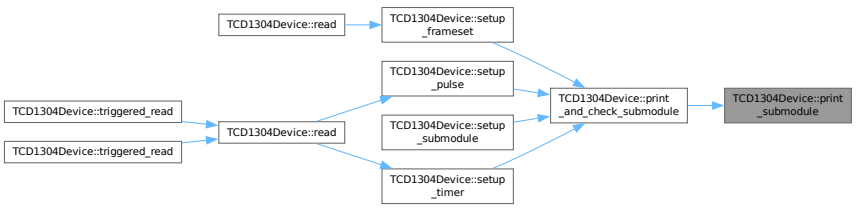
Here is the call graph for this function:



4.3.3.34 print_submodule()

```
void TCD1304Device::print_submodule (
            SubModule * p)  [inline]
```

Here is the caller graph for this function:



4.3.3.35 printbits16_()

```
void TCD1304Device::printbits16_ (
            uint16_t u16,
            int bits)  [inline]
```

Here is the caller graph for this function:

4.3.3.36 pulse_arm()

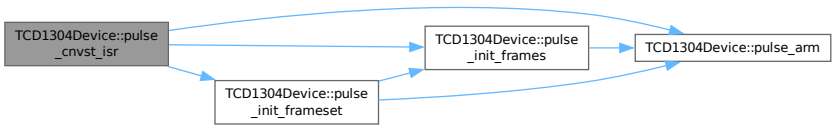
```
static void TCD1304Device::pulse_arm ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.37 pulse_cnvst_isr()

```
static void TCD1304Device::pulse_cnvst_isr ()  [inline], [static]
```

Here is the call graph for this function:



Here is the caller graph for this function:

4.3.3.38 pulse_icg_isr()

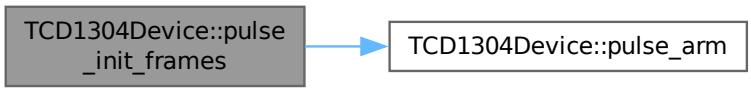
```
static void TCD1304Device::pulse_icg_isr ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.39 pulse_init_frames()

```
static void TCD1304Device::pulse_init_frames ()  [inline], [static]
```

Here is the call graph for this function:

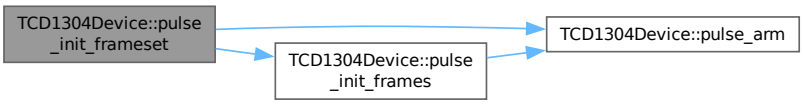


Here is the caller graph for this function:

4.3.3.40 pulse_init_frameset()

```
static void TCD1304Device::pulse_init_frameset ()  [inline], [static]
```

Here is the call graph for this function:

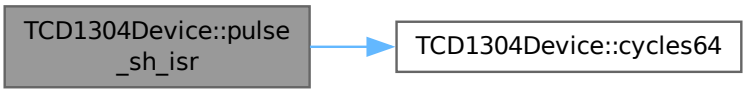


Here is the caller graph for this function:

4.3.3.41 pulse_sh_isr()

```
static void TCD1304Device::pulse_sh_isr ()  [inline], [static]
```

Here is the call graph for this function:

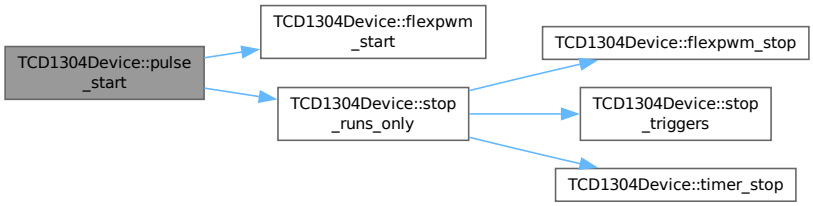


Here is the caller graph for this function:

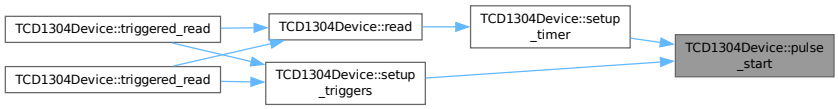
4.3.3.42 pulse_start()

```
static void TCD1304Device::pulse_start ()  [inline], [static]
```

Here is the call graph for this function:



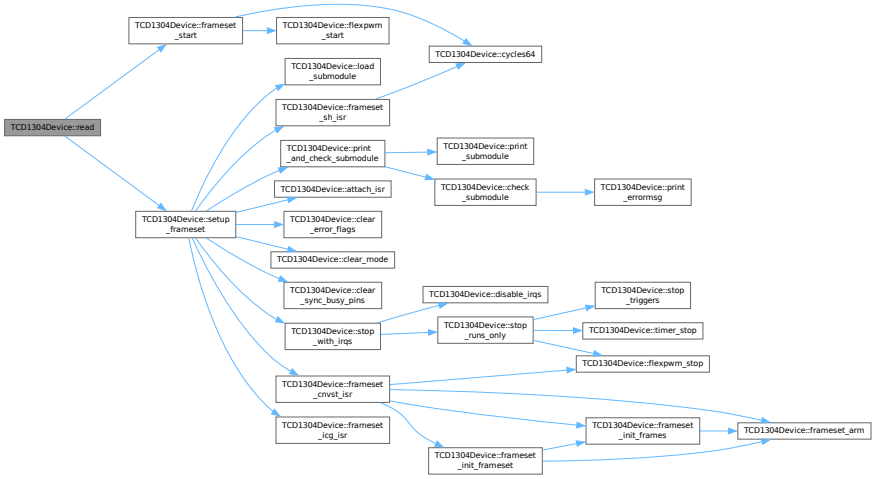
Here is the caller graph for this function:



4.3.3.43 read() [1/2]

```
bool TCD1304Device::read (
            uint nframes,
            float exposure,
            float frame_interval,
            uint16_t * bufferp,
            void(* frame_callbackf )(),
            void(* frameset_callbackf )(),
            void(* completion_callbackf )(),
            void(* setup_callbackf )(),
            bool start = true)  [inline]
```

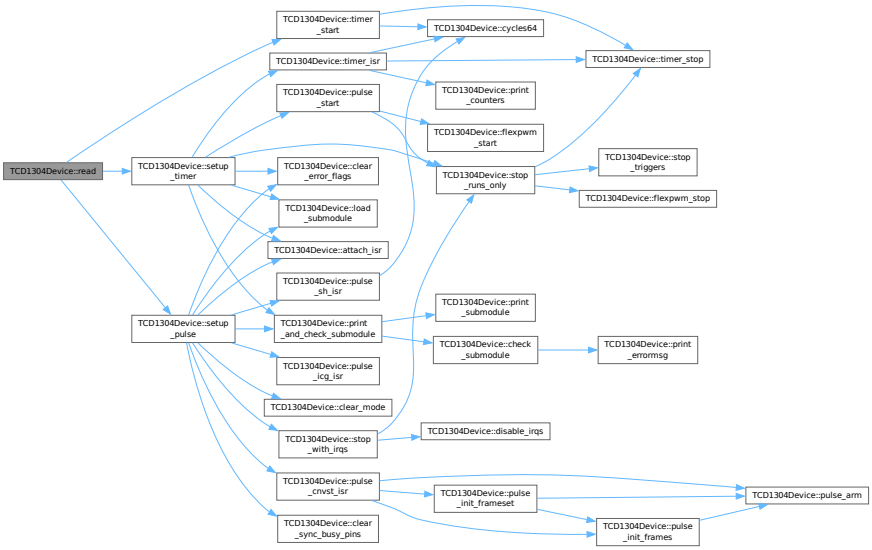
Here is the call graph for this function:



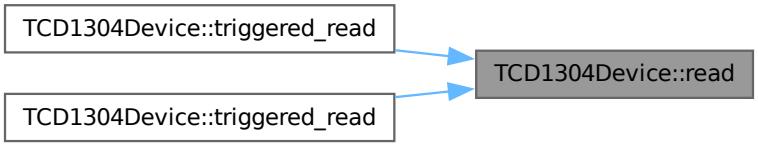
4.3.3.44 read() [2/2]

```
bool TCD1304Device::read (
            uint nframes,
            float exposure,
            uint16_t * bufferp,
            void(* frame_callbackf )(),
            void(* frameset_callbackf )(),
            void(* completion_callbackf )(),
            void(* setup_callbackf )(),
            bool start = true)  [inline]
```

Here is the call graph for this function:



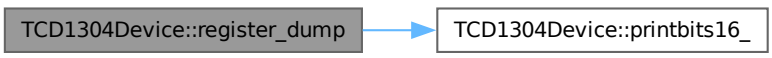
Here is the caller graph for this function:



4.3.3.45 register_dump()

```
void TCD1304Device::register_dump (
            IMXRT_FLEXPWM_t *const q = flexpwm,
            uint8_t mask = 0xFF)  [inline]
```

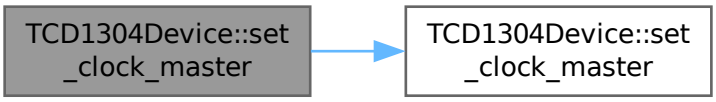
Here is the call graph for this function:



4.3.3.46 set_clock_master() [1/2]

```
void TCD1304Device::set_clock_master (
            SubModule * p)  [inline]
```

Here is the call graph for this function:

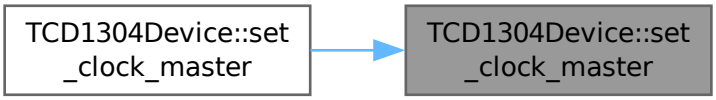


4.3.3.47 set_clock_master() [2/2]

```
void TCD1304Device::set_clock_master (
            uint8_t submod,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

Low level functions for command line register access.

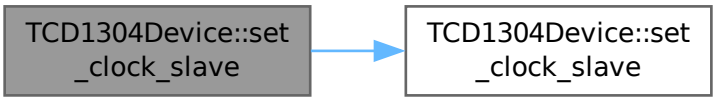
Here is the caller graph for this function:



4.3.3.48 set_clock_slave() [1/2]

```
void TCD1304Device::set_clock_slave (
            SubModule * p)  [inline]
```

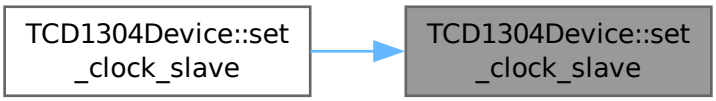
Here is the call graph for this function:



4.3.3.49 set_clock_slave() [2/2]

```
void TCD1304Device::set_clock_slave (
            uint8_t submod,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

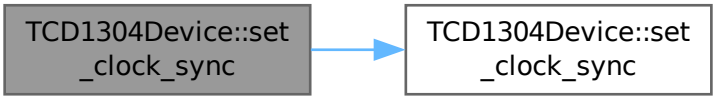
Here is the caller graph for this function:



4.3.3.50 set_clock_sync() [1/2]

```
void TCD1304Device::set_clock_sync (
            SubModule * p)  [inline]
```

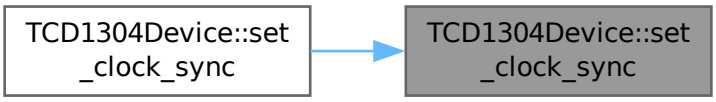
Here is the call graph for this function:



4.3.3.51 set_clock_sync() [2/2]

```
void TCD1304Device::set_clock_sync (
            uint8_t submod,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

Here is the caller graph for this function:



4.3.3.52 set_init()

```
void TCD1304Device::set_init (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.53 set_ldok()

```
void TCD1304Device::set_ldok (
            uint8_t mask,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.54 set_outen()

```
uint16_t TCD1304Device::set_outen (
            uint16_t mask16,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.55 set_outen_off()

```
uint16_t TCD1304Device::set_outen_off (
            uint16_t mask16,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.56 set_outen_on()

```
uint16_t TCD1304Device::set_outen_on (
            uint16_t mask16,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.57 set_outenA_on()

```
uint16_t TCD1304Device::set_outenA_on (
            uint8_t mask8,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.58 set_prescale()

```
void TCD1304Device::set_prescale (
            uint8_t submod,
            uint8_t prescale = 0,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.59 set_run()

```
void TCD1304Device::set_run (
            uint8_t mask,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.60 set_val0()

```
void TCD1304Device::set_val0 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.61 set_val1()

```
void TCD1304Device::set_val1 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.62 set_val2()

```
void TCD1304Device::set_val2 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.63 set_val3()

```
void TCD1304Device::set_val3 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

4.3.3.64 set_val4()

```
void TCD1304Device::set_val4 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

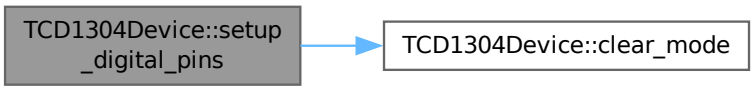
4.3.3.65 set_val5()

```
void TCD1304Device::set_val5 (
            uint8_t submod,
            uint16_t value,
            IMXRT_FLEXPWM_t * q = flexpwm)  [inline]
```

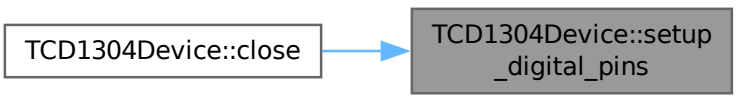
4.3.3.66 setup_digital_pins()

```
static void TCD1304Device::setup_digital_pins ()  [inline], [static]
```

Here is the call graph for this function:



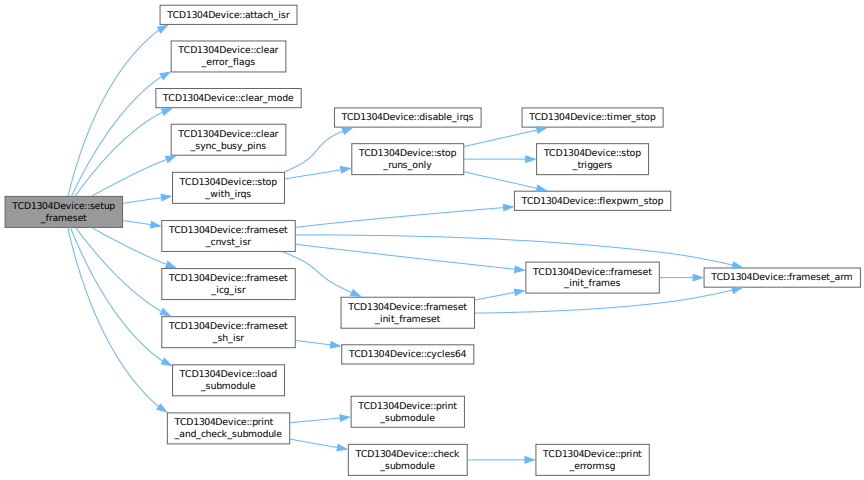
Here is the caller graph for this function:



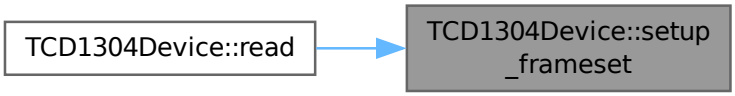
4.3.3.67 setup_frameset()

```
bool TCD1304Device::setup_frameset (
            float clk_secs,
            float sh_secs,
            float sh_offset_secs,
            float icg_secs,
            float icg_offset_secs,
            float exposure_secs,
            float frame_interval_secs,
            unsigned int nframes,
            uint16_t * buffer,
            unsigned int nbuffer,
            void(* callbackf )())  [inline]
```

Here is the call graph for this function:



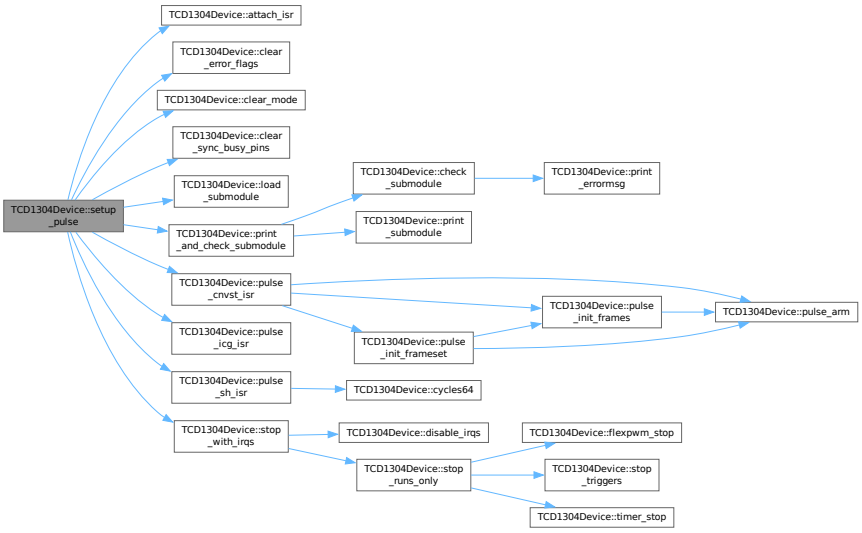
Here is the caller graph for this function:



4.3.3.68 setup_pulse()

```
bool TCD1304Device::setup_pulse (
            float clk_secs,
            float sh_secs,
            float sh_offset_secs,
            float icg_secs,
            float icg_offset_secs,
            uint16_t * buffer,
            unsigned int nbuffer,
            void(* callbackf )())  [inline]
```

Here is the call graph for this function:



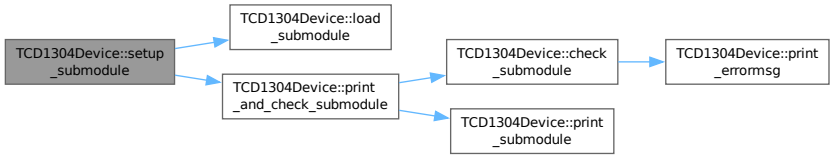
Here is the caller graph for this function:

4.3.3.69 setup_submodule()

```
bool TCD1304Device::setup_submodule (
            SubModule * p,
```

```
            uint8_t prescale,
            uint16_t period_counts,
            uint16_t onA_counts,
            uint16_t offA_counts,
            bool invertA,
            uint16_t onB_counts,
            uint16_t offB_counts,
            bool invertB,
            uint16_t ctrl2_mask)  [inline]
```

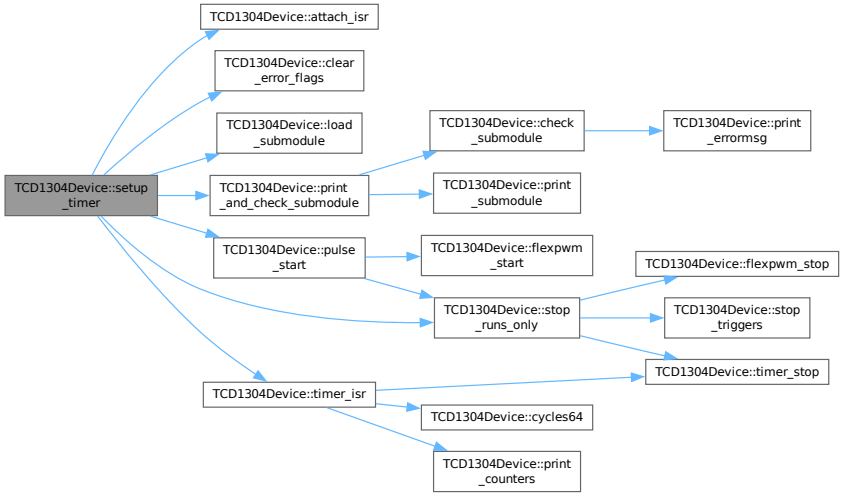
Here is the call graph for this function:



4.3.3.70 setup_timer()

```
bool TCD1304Device::setup_timer (
            float exposure_secs,
            float exposure_offset_secs,
            unsigned int ncounts = 0)  [inline]
```

Here is the call graph for this function:

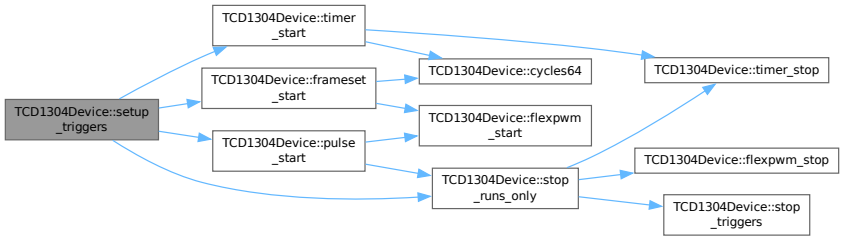


Here is the caller graph for this function:

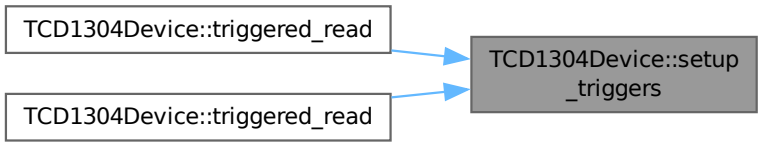
4.3.3.71 setup_triggers()

```
bool TCD1304Device::setup_triggers (
            unsigned int ncounts = 0)  [inline]
```

Here is the call graph for this function:



Here is the caller graph for this function:



4.3.3.72 sh_difference_secs()

```
static double TCD1304Device::sh_difference_secs ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.73 sh_elapsed_secs()

```
static double TCD1304Device::sh_elapsed_secs ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.74 sh_exposure_secs()

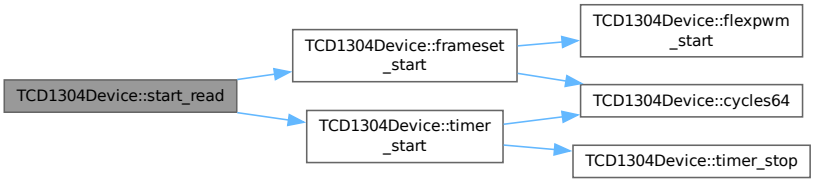
```
static double TCD1304Device::sh_exposure_secs ()  [inline], [static]
```

Here is the caller graph for this function:

4.3.3.75 start_read()

```
bool TCD1304Device::start_read ()  [inline]
```

Here is the call graph for this function:

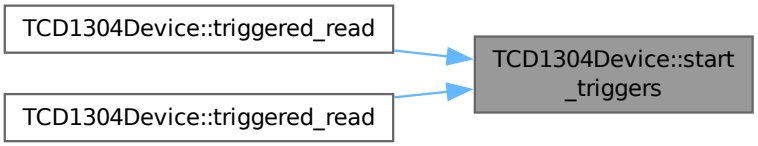


4.3.3.76 start_triggers()

```
bool TCD1304Device::start_triggers ()  [inline]
```

Here is the call graph for this function:

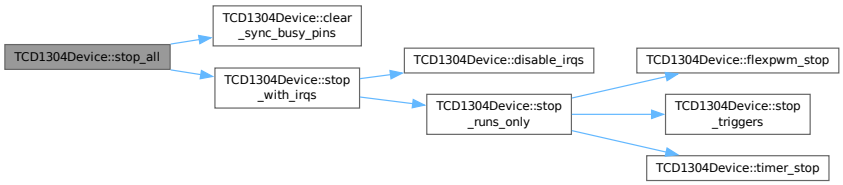
Here is the caller graph for this function:



4.3.3.77 stop_all()

```
void TCD1304Device::stop_all ()  [inline]
```

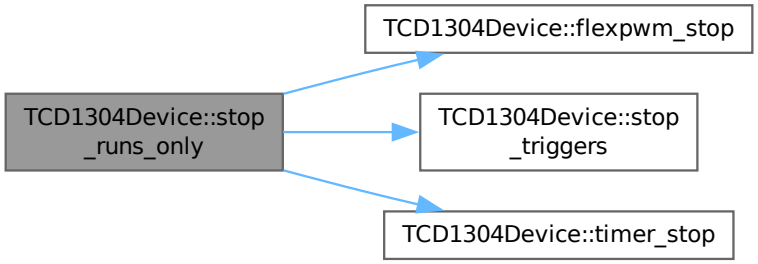
Here is the call graph for this function:



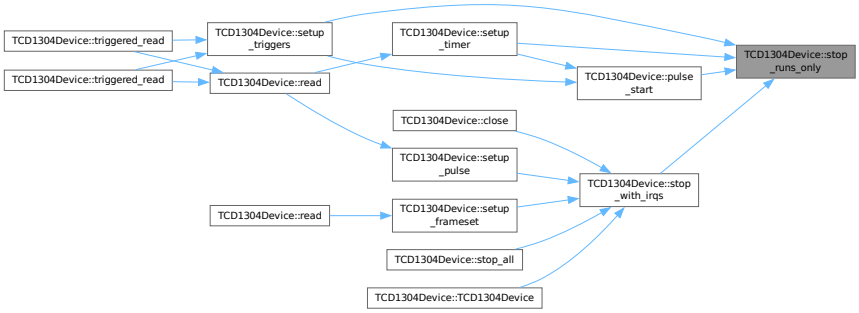
4.3.3.78 stop_runs_only()

```
static void TCD1304Device::stop_runs_only ()  [inline], [static]
```

Here is the call graph for this function:



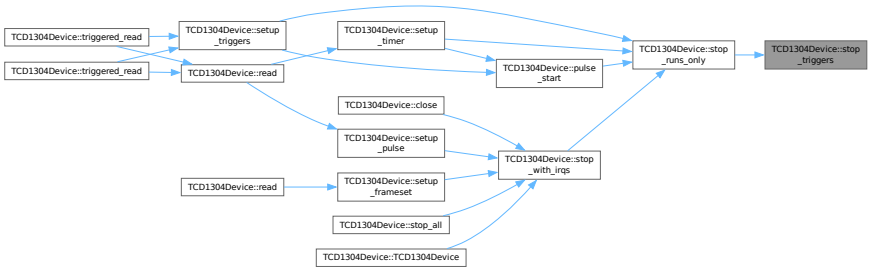
Here is the caller graph for this function:



4.3.3.79 stop_triggers()

```
static void TCD1304Device::stop_triggers ()  [inline], [static]
```

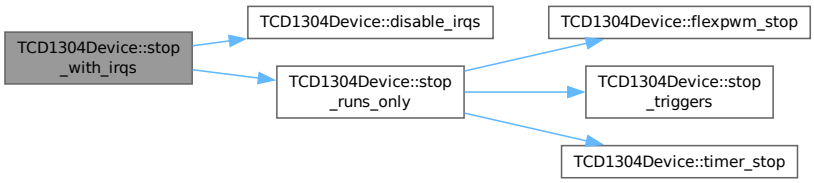
Here is the caller graph for this function:



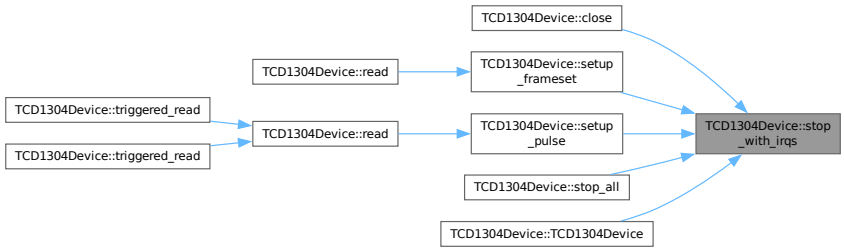
4.3.3.80 stop_with_irqs()

```
static void TCD1304Device::stop_with_irqs ()  [inline], [static]
```

Here is the call graph for this function:



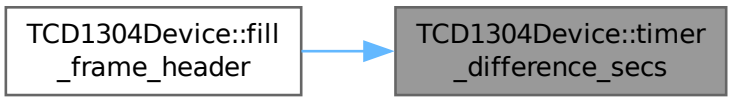
Here is the caller graph for this function:



4.3.3.81 timer_difference_secs()

```
static double TCD1304Device::timer_difference_secs ()  [inline], [static]
```

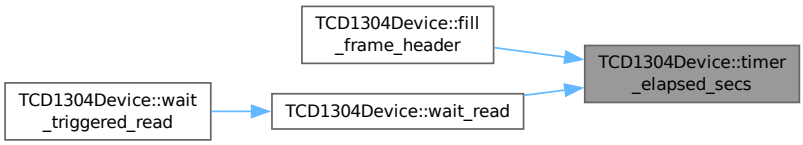
Here is the caller graph for this function:



4.3.3.82 timer_elapsed_secs()

```
static double TCD1304Device::timer_elapsed_secs ()  [inline], [static]
```

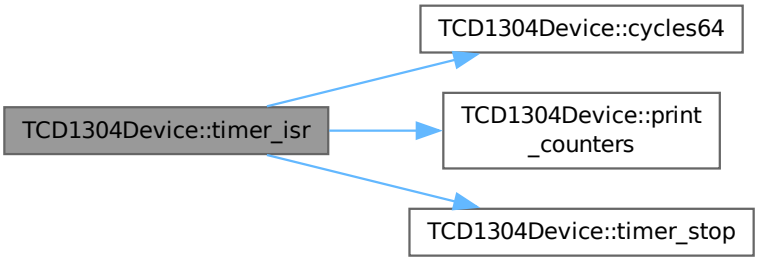
Here is the caller graph for this function:



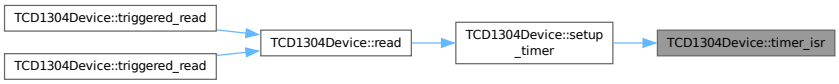
4.3.3.83 timer_isr()

```
static void TCD1304Device::timer_isr ()  [inline], [static]
```

Here is the call graph for this function:



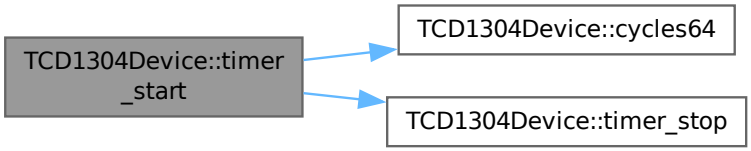
Here is the caller graph for this function:



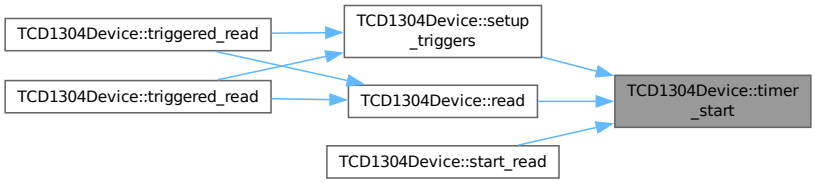
4.3.3.84 timer_start()

```
static void TCD1304Device::timer_start ()  [inline], [static]
```

Here is the call graph for this function:



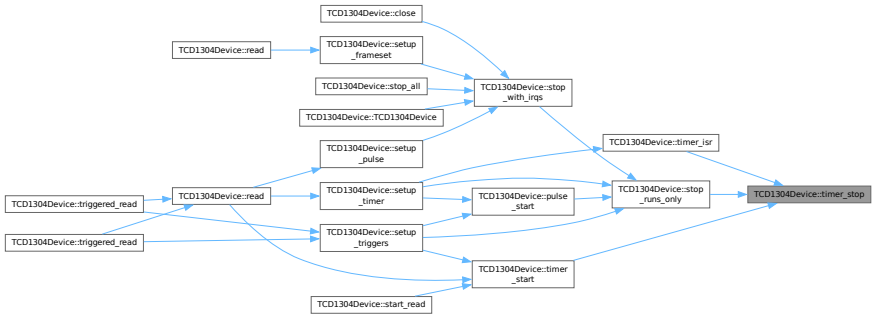
Here is the caller graph for this function:



4.3.3.85 timer_stop()

```
static void TCD1304Device::timer_stop ()  [inline], [static]
```

Here is the caller graph for this function:



4.3.3.86 timer_stop_with_irq()

```
static void TCD1304Device::timer_stop_with_irq ()  [inline], [static]
```

4.3.3.87 timer_wait()

```
bool TCD1304Device::timer_wait (
            float timeout_ = 1.,
            float timestep_ = 0.01,
            bool verbose = false)  [inline]
```

Here is the caller graph for this function:

4.3.3.88 toggle_busypin()

```
static void TCD1304Device::toggle_busypin ()  [inline], [static]
```

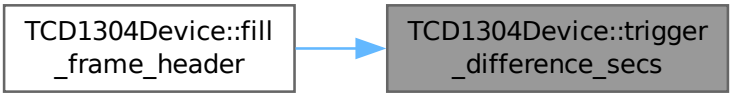
4.3.3.89 toggle_syncpin()

```
static void TCD1304Device::toggle_syncpin ()  [inline], [static]
```

4.3.3.90 trigger_difference_secs()

```
static double TCD1304Device::trigger_difference_secs ()  [inline], [static]
```

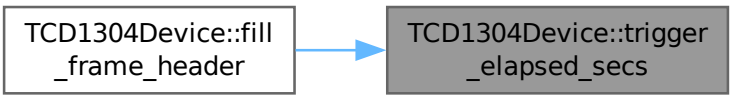
Here is the caller graph for this function:



4.3.3.91 trigger_elapsed_secs()

```
static double TCD1304Device::trigger_elapsed_secs ()  [inline], [static]
```

Here is the caller graph for this function:

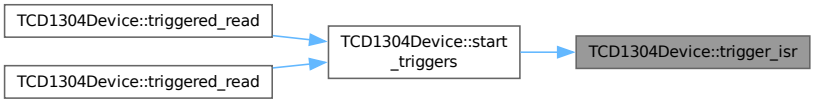


4.3.3.92 trigger_isr()

```
static void TCD1304Device::trigger_isr ()  [inline], [static]
```

Here is the call graph for this function:

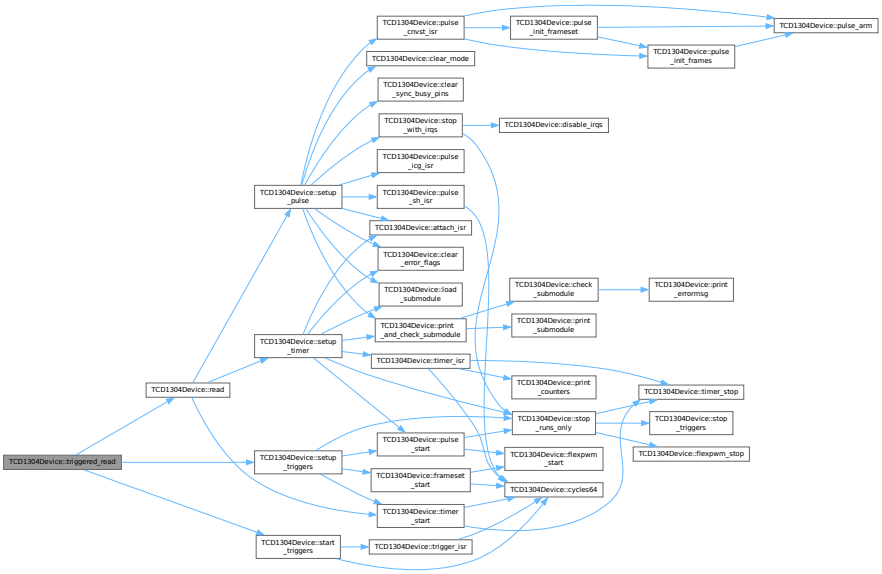
Here is the caller graph for this function:



4.3.3.93 triggered_read() [1/2]

```
bool TCD1304Device::triggered_read (
            uint ntriggers,
            uint nframes,
            float exposure,
            float interval,
            uint16_t * bufferp,
            void(* frame_callbackf )(),
            void(* frameset_callbackf )(),
            void(* completion_callbackf )(),
            void(* setup_callbackf )(),
            bool start = true)  [inline]
```

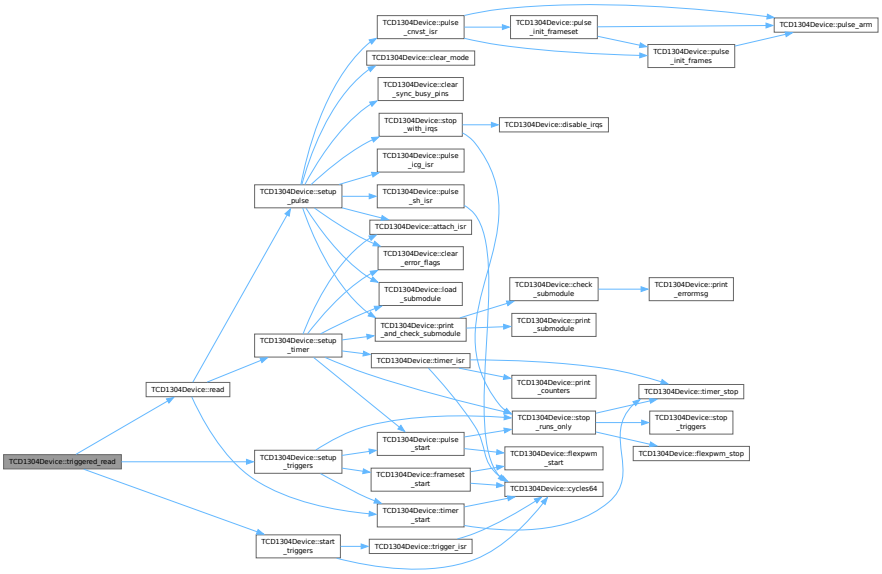
Here is the call graph for this function:



4.3.3.94 triggered_read() [2/2]

```
bool TCD1304Device::triggered_read (
            uint ntriggers,
            uint nframes,
            float exposure,
            uint16_t * bufferp,
            void(* frame_callbackf )(),
            void(* frameset_callbackf )(),
            void(* completion_callbackf )(),
            void(* setup_callbackf )(),
            bool start = true)  [inline]
```

Here is the call graph for this function:



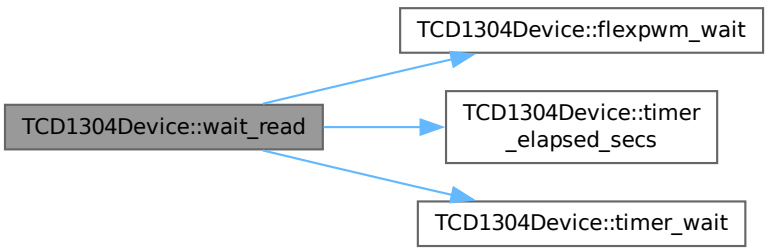
4.3.3.95 update_read_buffer()

```
static void TCD1304Device::update_read_buffer (
            uint16_t * buffer)  [inline], [static]
```

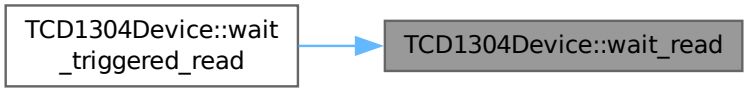
4.3.3.96 wait_read()

```
bool TCD1304Device::wait_read (
            float timeout = 0.,
            float timestep = 0.01,
            bool verbose = false)  [inline]
```

Here is the call graph for this function:



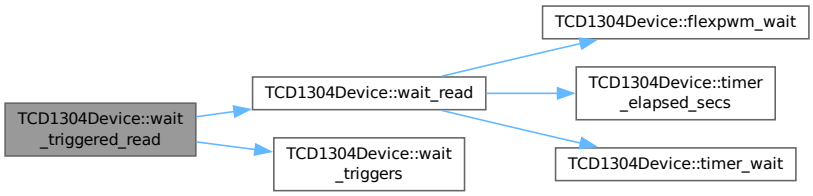
Here is the caller graph for this function:



4.3.3.97 wait_triggered_read()

```
bool TCD1304Device::wait_triggered_read (
            float timeout = 1.,
            float timestep = 0.01,
            bool verbose = false)  [inline]
```

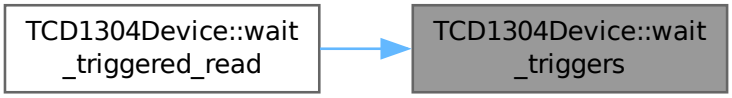
Here is the call graph for this function:



4.3.3.98 wait_triggers()

```
bool TCD1304Device::wait_triggers (
            float timeout_ = 1.,
            float timestep_ = 0.01,
            bool verbose = false)  [inline]
```

Here is the caller graph for this function:



4.3.4 Member Data Documentation

4.3.4.1 busytoggled

```
bool TCD1304Device::busytoggled = false  [inline], [static]
```

4.3.4.2 clk

```
SubModule TCD1304Device::clk = {"clk",CLK_SUBMODULE, CLK_MASK, CLK_PIN,CLK_MUXVAL, 0xFF,0, CLK_IRQ,
&IMXRT_FLEXPWM2}  [inline], [static]
```

4.3.4.3 cnvst

```
SubModule TCD1304Device::cnvst = {"cnvst", CNVST_SUBMODULE, CNVST_MASK, 0xFF,0, 0xFF,0, CNVST_IRQ,
&IMXRT_FLEXPWM2}  [inline], [static]
```

4.3.4.4 cnvst_counter

```
unsigned int TCD1304Device::cnvst_counter = 0  [inline], [static]
```

4.3.4.5 cnvst_extra_delay_counts

```
uint16_t TCD1304Device::cnvst_extra_delay_counts = 1  [inline], [static]
```

4.3.4.6 error_flag

```
bool TCD1304Device::error_flag = false  [inline], [static]
```

4.3.4.7 flexpwm

```
IMXRT_FLEXPWM_t* const TCD1304Device::flexpwm = &IMXRT_FLEXPWM2  [inline], [static]
```

4.3.4.8 flexpwm_running

```
bool TCD1304Device::flexpwm_running = false  [inline], [static]
```

4.3.4.9 frame_counter

```
unsigned int TCD1304Device::frame_counter = 0  [inline], [static]
```

4.3.4.10 frame_counts

```
unsigned int TCD1304Device::frame_counts = 0  [inline], [static]
```

4.3.4.11 frames_completed_callback

```
void(* TCD1304Device::frames_completed_callback) ()=0  [inline], [static]
```

4.3.4.12 frameset_armed

```
bool TCD1304Device::frameset_armed = false  [inline], [static]
```

4.3.4.13 frameset_counter

```
unsigned int TCD1304Device::frameset_counter = 0  [inline], [static]
```

4.3.4.14 frameset_counts

```
unsigned int TCD1304Device::frameset_counts = 0  [inline], [static]
```

4.3.4.15 framesets_completed_callback

```
void(* TCD1304Device::framesets_completed_callback) ()=0  [inline], [static]
```

4.3.4.16 icg

```
SubModule TCD1304Device::icg = {"icg", ICG_SUBMODULE, ICG_MASK, ICG_PIN,ICG_MUXVAL, 0xFF,0, ICG_IRQ,
&IMXRT_FLEXPWM2}  [inline], [static]
```

4.3.4.17 icg_counter

```
unsigned int TCD1304Device::icg_counter = 0  [inline], [static]
```

4.3.4.18 mode

```
TCD1304_Mode_t TCD1304Device::mode = NOTCONFIGURED  [inline], [static]
```

4.3.4.19 oops_flag

```
bool TCD1304Device::oops_flag = false  [inline], [static]
```

4.3.4.20 pulse_armed

```
bool TCD1304Device::pulse_armed = false  [inline], [static]
```

Configure the flexpwm for single pulse, use this with a timer.

4.3.4.21 read_buffer

```
uint16_t* TCD1304Device::read_buffer = 0  [inline], [static]
```

4.3.4.22 read_callback

```
void(* TCD1304Device::read_callback) ()=0  [inline], [static]
```

4.3.4.23 read_counter

```
unsigned int TCD1304Device::read_counter = 0  [inline], [static]
```

4.3.4.24 read_counts

```
unsigned int TCD1304Device::read_counts = 0  [inline], [static]
```

4.3.4.25 read_expected_time

```
float TCD1304Device::read_expected_time = 0.  [inline], [static]
```

4.3.4.26 read_pointer

```
uint16_t* TCD1304Device::read_pointer = 0  [inline], [static]
```

4.3.4.27 sh

```
SubModule TCD1304Device::sh = {"sh", SH_SUBMODULE, SH_MASK, SH_PIN,SH_MUXVAL, 0xFF,0, SH_IRQ,
&IMXRT_FLEXPWM2}  [inline], [static]
```

4.3.4.28 sh_clearing_counter

```
unsigned int TCD1304Device::sh_clearing_counter = 0  [inline], [static]
```

4.3.4.29 sh_clearing_counts

```
unsigned int TCD1304Device::sh_clearing_counts = SH_CLEARING_DEFAULT  [inline], [static]
```

4.3.4.30 sh_counter

```
unsigned int TCD1304Device::sh_counter = 0  [inline], [static]
```

4.3.4.31 sh_counts_per_icg

```
unsigned int TCD1304Device::sh_counts_per_icg = 0  [inline], [static]
```

4.3.4.32 sh_cyccnt64_exposure

```
uint64_t TCD1304Device::sh_cyccnt64_exposure = 0  [inline], [static]
```

4.3.4.33 sh_cyccnt64_now

```
uint64_t TCD1304Device::sh_cyccnt64_now = 0  [inline], [static]
```

4.3.4.34 sh_cyccnt64_prev

```
uint64_t TCD1304Device::sh_cyccnt64_prev = 0  [inline], [static]
```

4.3.4.35 sh_cyccnt64_start

```
uint64_t TCD1304Device::sh_cyccnt64_start = 0  [inline], [static]
```

4.3.4.36 sh_short_period_counts

```
unsigned int TCD1304Device::sh_short_period_counts = 0  [inline], [static]
```

4.3.4.37 skip_one

```
bool TCD1304Device::skip_one = false  [inline], [static]
```

4.3.4.38 skip_one_reload

```
bool TCD1304Device::skip_one_reload = false  [inline], [static]
```

4.3.4.39 sync_enabled

```
bool TCD1304Device::sync_enabled = true  [inline], [static]
```

4.3.4.40 sync_pin

```
uint8_t TCD1304Device::sync_pin = SYNC_PIN  [inline], [static]
```

4.3.4.41 synctoggled

```
bool TCD1304Device::synctoggled = false  [inline], [static]
```

4.3.4.42 timer

```
SubModule TCD1304Device::timer = {"timer", TIMER_SUBMODULE, TIMER_MASK, 0xFF,0, TIMER_PIN,TIMER_MUXVAL,
TIMER_IRQ, &IMXRT_FLEXPWM4}  [inline], [static]
```

4.3.4.43 timer_callback

```
void(* TCD1304Device::timer_callback) ()=0  [inline], [static]
```

4.3.4.44 timer_cyccnt64_now

```
uint64_t TCD1304Device::timer_cyccnt64_now = 0  [inline], [static]
```

4.3.4.45 timer_cyccnt64_prev

```
uint64_t TCD1304Device::timer_cyccnt64_prev = 0  [inline], [static]
```

4.3.4.46 timer_cyccnt64_start

```
uint64_t TCD1304Device::timer_cyccnt64_start = 0  [inline], [static]
```

4.3.4.47 timer_first_time_flag

```
bool TCD1304Device::timer_first_time_flag = true  [inline], [static]
```

4.3.4.48 timer_inner_counter

```
unsigned int TCD1304Device::timer_inner_counter = 0  [inline], [static]
```

4.3.4.49 timer_inner_counts

```
unsigned int TCD1304Device::timer_inner_counts = 0  [inline], [static]
```

4.3.4.50 timer_interframe_min_secs

```
float TCD1304Device::timer_interframe_min_secs = 0.  [inline], [static]
```

4.3.4.51 timer_interval_secs

```
float TCD1304Device::timer_interval_secs = .0  [inline], [static]
```

4.3.4.52 timer_outer_counter

```
unsigned int TCD1304Device::timer_outer_counter = 0  [inline], [static]
```

4.3.4.53 timer_outer_counts

```
unsigned int TCD1304Device::timer_outer_counts = 0  [inline], [static]
```

4.3.4.54 timer_period_secs

```
float TCD1304Device::timer_period_secs = 0  [inline], [static]
```

4.3.4.55 timer_running

```
bool TCD1304Device::timer_running = false  [inline], [static]
```

4.3.4.56 timerflexpwm

```
IMXRT_FLEXPWM_t* const TCD1304Device::timerflexpwm = &IMXRT_FLEXPWM4  [inline], [static]
```

4.3.4.57 trigger_attached

```
bool TCD1304Device::trigger_attached = false  [inline], [static]
```

4.3.4.58 trigger_busy

```
bool TCD1304Device::trigger_busy = false  [inline], [static]
```

4.3.4.59 trigger_callback

```
void(* TCD1304Device::trigger_callback) ()=0  [inline], [static]
```

4.3.4.60 trigger_counter

```
unsigned int TCD1304Device::trigger_counter = 0  [inline], [static]
```

4.3.4.61 trigger_counts

```
unsigned int TCD1304Device::trigger_counts = 1  [inline], [static]
```

4.3.4.62 trigger_cyccnt64_now

```
uint64_t TCD1304Device::trigger_cyccnt64_now = 0  [inline], [static]
```

4.3.4.63 trigger_cyccnt64_prev

```
uint64_t TCD1304Device::trigger_cyccnt64_prev = 0  [inline], [static]
```

4.3.4.64 trigger_cyccnt64_start

```
uint64_t TCD1304Device::trigger_cyccnt64_start = 0  [inline], [static]
```

4.3.4.65 trigger_edge_mode

```
uint8_t TCD1304Device::trigger_edge_mode = RISING  [inline], [static]
```

4.3.4.66 trigger_mode

```
bool TCD1304Device::trigger_mode = false  [inline], [static]
```

4.3.4.67 trigger_pin

```
uint8_t TCD1304Device::trigger_pin = TRIGGER_PIN  [inline], [static]
```

4.3.4.68 trigger_pin_mode

```
uint8_t TCD1304Device::trigger_pin_mode = INPUT  [inline], [static]
```

The documentation for this class was generated from the following file:

- TCD1304Device2.h

4.4 usb_string_descriptor_struct_manufacturer Struct Reference

Public Attributes

- uint8_t bLength
- uint8_t bDescriptorType
- uint16_t wString [thisMANUFACTURER_NAME_LEN]

4.4.1 Member Data Documentation

4.4.1.1 bDescriptorType

```
uint8_t usb_string_descriptor_struct_manufacturer::bDescriptorType
```

4.4.1.2 bLength

```
uint8_t usb_string_descriptor_struct_manufacturer::bLength
```

4.4.1.3 wString

```
uint16_t usb_string_descriptor_struct_manufacturer::wString[thisMANUFACTURER_NAME_LEN]
```

The documentation for this struct was generated from the following file:

- TCD1304Device_Controller_251208.ino

4.5 usb_string_descriptor_struct_product Struct Reference

Public Attributes

- uint8_t bLength
- uint8_t bDescriptorType
- uint16_t wString [thisPRODUCT_NAME_LEN]

4.5.1 Member Data Documentation

4.5.1.1 bDescriptorType

```
uint8_t usb_string_descriptor_struct_product::bDescriptorType
```

4.5.1.2 bLength

```
uint8_t usb_string_descriptor_struct_product::bLength
```

4.5.1.3 wString

```
uint16_t usb_string_descriptor_struct_product::wString[thisPRODUCT_NAME_LEN]
```

The documentation for this struct was generated from the following file:

- TCD1304Device_Controller_251208.ino

4.6 usb_string_descriptor_struct_serial_number Struct Reference

Public Attributes

- uint8_t bLength
- uint8_t bDescriptorType
- uint16_t wString [thisPRODUCT_SERIAL_NUMBER_LEN]

4.6.1 Member Data Documentation

4.6.1.1 bDescriptorType

```
uint8_t usb_string_descriptor_struct_serial_number::bDescriptorType
```

4.6.1.2 bLength

```
uint8_t usb_string_descriptor_struct_serial_number::bLength
```

4.6.1.3 wString

```
uint16_t usb_string_descriptor_struct_serial_number::wString[thisPRODUCT_SERIAL_NUMBER_LEN]
```

The documentation for this struct was generated from the following file:

- TCD1304Device_Controller_251208.ino

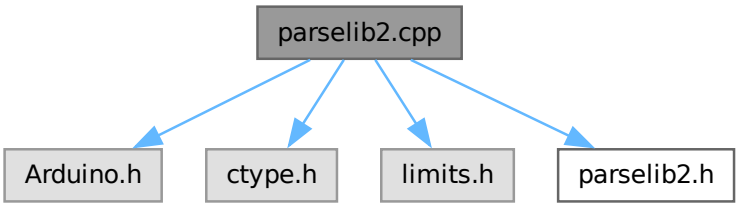
Chapter 5

File Documentation

5.1 parselib2.cpp File Reference

```
#include "Arduino.h"
#include <ctype.h>
#include <limits.h>
#include "parselib2.h"
```

Include dependency graph for parselib2.cpp:



Functions

- int serialPrintf (const char *format,...)
- int serialPrintlnf (const char *format,...)
- char * eow (char *s)
- char * eos (char *s)
- unsigned int wordLength (char *s)
- char * nextWord (char *s)
- char * basenamef (const char *cs)
- unsigned int countWords (char *s)
- bool strMatch (const char *cs, const char *key, char **next)

- bool strBool (const char *cs, bool *b, char **next)
- bool strUint8lim (const char *cs, uint8_t *u, char **next, uint8_t ulim)
- bool strUint8 (const char *cs, uint8_t *u, char **next)
- bool strUint (const char *cs, unsigned int *u, char **next)
- bool strUint16 (const char *cs, uint16_t *u, char **next)
- bool strUint32 (const char *cs, uint32_t *u, char **next)
- char * scaling (float *f, char *s)
- bool strFlt (const char *cs, float *p, char **next)
- unsigned int strUints (const char *cs, unsigned int *p, unsigned int nmax, char **next)
- unsigned int strUint32s (const char *cs, uint32_t *p, unsigned int nmax, char **next)
- unsigned int strFlts (const char *pc, float *p, unsigned int nmax, char **next)

Variables

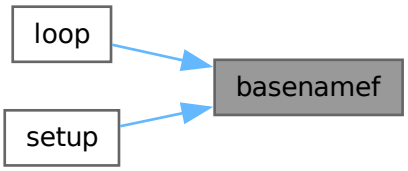
- char printbuffer [256]
- unsigned int nprintbuffer = 0

5.1.1 Function Documentation

5.1.1.1 basenamef()

```
char * basenamef (
            const char * cs)
```

Here is the caller graph for this function:



5.1.1.2 countWords()

```
unsigned int countWords (
            char * s)
```

Here is the call graph for this function:

5.1.1.3 eos()

```
char * eos (
            char * s)
```

5.1.1.4 eow()

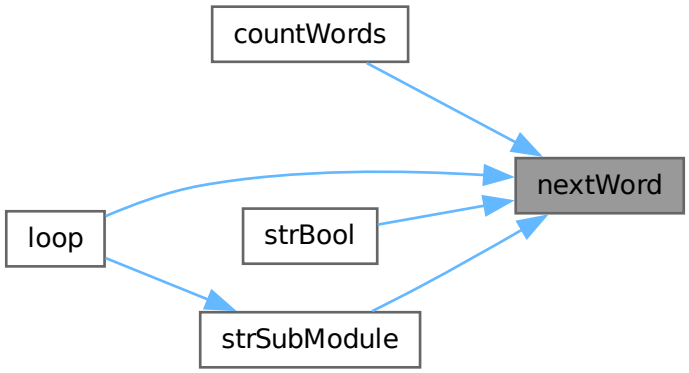
```
char * eow (
            char * s)
```

Here is the caller graph for this function:

5.1.1.5 nextWord()

```
char * nextWord (
            char * s)
```

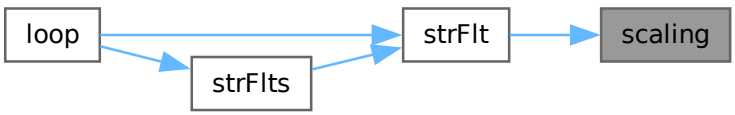
Here is the caller graph for this function:



5.1.1.6 scaling()

```
char * scaling (
            float * f,
            char * s)
```

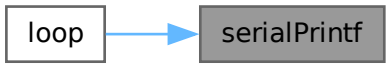
Here is the caller graph for this function:



5.1.1.7 serialPrintf()

```
int serialPrintf (
             const char * format,
              ...)
```

Here is the caller graph for this function:



5.1.1.8 serialPrintlnf()

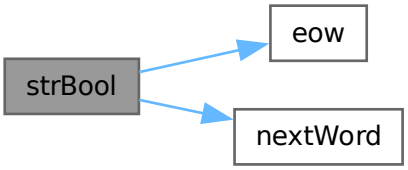
```
int serialPrintlnf (
             const char * format,
              ...)
```

Here is the caller graph for this function:

5.1.1.9 strBool()

```
bool strBool (
             const char * cs,
             bool * b,
             char ** next)
```

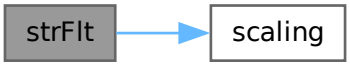
Here is the call graph for this function:



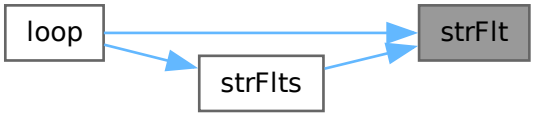
5.1.1.10 strFlt()

```
bool strFlt (
            const char * cs,
            float * p,
            char ** next)
```

Here is the call graph for this function:



Here is the caller graph for this function:

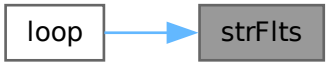


5.1.1.11 strFlts()

```
unsigned int strFlts (
            const char * pc,
            float * p,
            unsigned int nmax,
            char ** next)
```

Here is the call graph for this function:

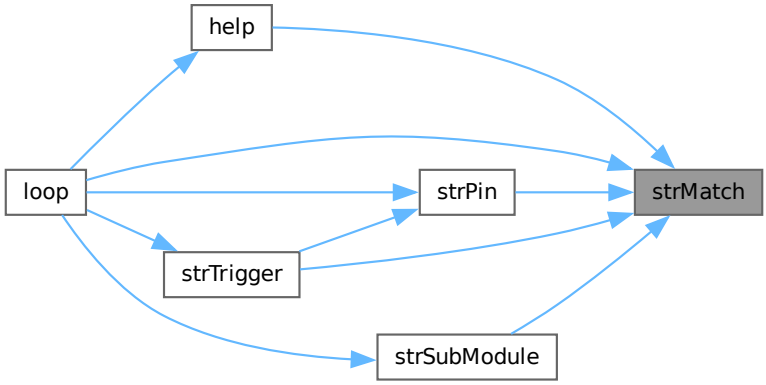
Here is the caller graph for this function:



5.1.1.12 strMatch()

```
bool strMatch (
            const char * cs,
            const char * key,
            char ** next)
```

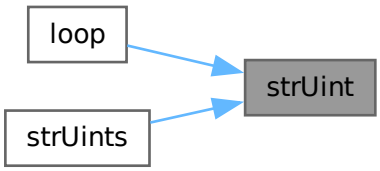
Here is the caller graph for this function:



5.1.1.13 strUint()

```
bool strUint (
            const char * cs,
            unsigned int * u,
            char ** next)
```

Here is the caller graph for this function:

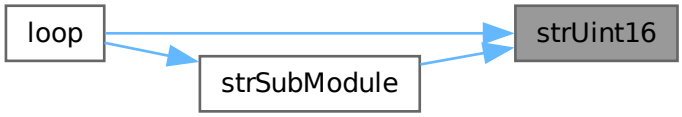


5.1.1.14 strUint16()

```
bool strUint16 (
            const char * cs,
```

```
            uint16_t * u,
            char ** next)
```

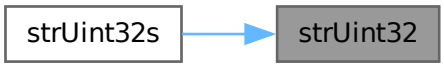
Here is the caller graph for this function:



5.1.1.15 strUint32()

```
bool strUint32 (
            const char * cs,
            uint32_t * u,
            char ** next)
```

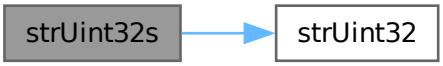
Here is the caller graph for this function:



5.1.1.16 strUint32s()

```
unsigned int strUint32s (
            const char * cs,
            uint32_t * p,
            unsigned int nmax,
            char ** next)
```

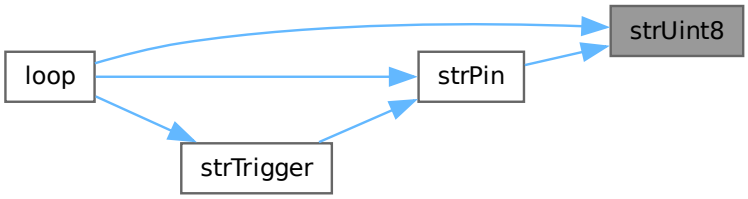
Here is the call graph for this function:



5.1.1.17 strUint8()

```
bool strUint8 (
            const char * cs,
            uint8_t * u,
            char ** next)
```

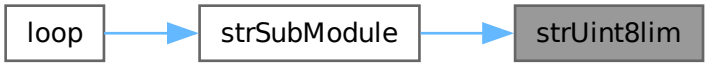
Here is the caller graph for this function:



5.1.1.18 strUint8lim()

```
bool strUint8lim (
            const char * cs,
            uint8_t * u,
            char ** next,
            uint8_t ulim)
```

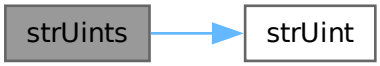
Here is the caller graph for this function:



5.1.1.19 strUints()

```
unsigned int strUints (
            const char * cs,
            unsigned int * p,
            unsigned int nmax,
            char ** next)
```

Here is the call graph for this function:



5.1.1.20 wordLength()

```
unsigned int wordLength (
            char * s)
```

5.1.2 Variable Documentation

5.1.2.1 nprintbuffer

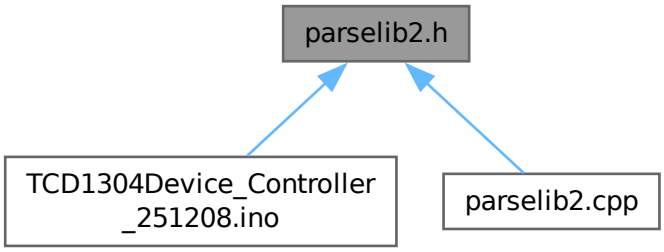
```
unsigned int nprintbuffer = 0
```

5.1.2.2 printbuffer

```
char printbuffer[256]
```

5.2 parselib2.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- #define PARSELIB_H

Functions

- int serialPrintf (const char *fmt,...)
- int serialPrintlnf (const char *fmt,...)
- unsigned int wordLength (char *s)
- char * nextWord (char *s)
- unsigned int countWords (char *s)
- char * basenamef (const char *cs)
- bool strMatch (const char *s, const char *key, char **next)
- bool strBool (const char *s, bool *b, char **next=0)
- bool strUint8 (const char *s, uint8_t *u, char **next)
- bool strUint8lim (const char *s, uint8_t *u, char **next, uint8_t ulim)
- bool strUint (const char *s, unsigned int *u, char **next)
- bool strUint16 (const char *s, uint16_t *u, char **next)
- bool strUint32 (const char *s, uint32_t *u, char **next)
- bool strFlt (const char *s, float *p, char **next)
- unsigned int strUints (const char *pc, unsigned int *p, unsigned int nmax, char **next)
- unsigned int strUint32s (const char *pc, uint32_t *p, unsigned int nmax, char **next)
- unsigned int strFlts (const char *pc, float *p, unsigned int nmax, char **next)

5.2.1 Macro Definition Documentation

5.2.1.1 PARSELIB_H

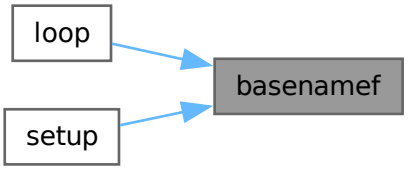
```
#define PARSELIB_H
```

5.2.2 Function Documentation

5.2.2.1 basenamef()

```
char * basenamef (
            const char * cs)
```

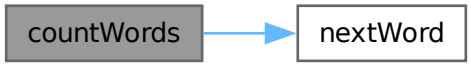
Here is the caller graph for this function:



5.2.2.2 countWords()

```
unsigned int countWords (
            char * s)
```

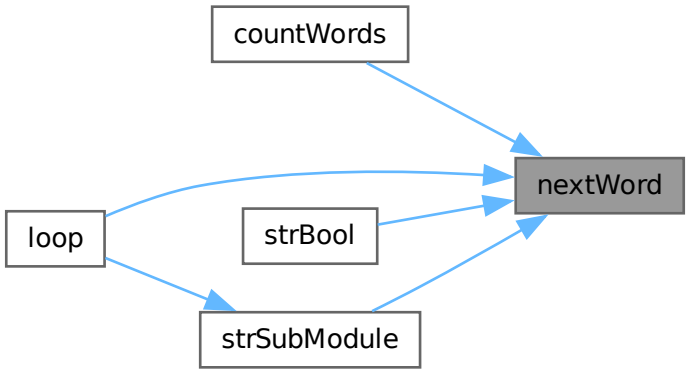
Here is the call graph for this function:



5.2.2.3 nextWord()

```
char * nextWord (
            char * s)
```

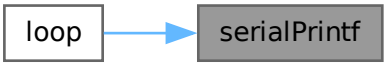
Here is the caller graph for this function:



5.2.2.4 serialPrintf()

```
int serialPrintf (
            const char * fmt,
             ...)
```

Here is the caller graph for this function:



5.2.2.5 serialPrintlnf()

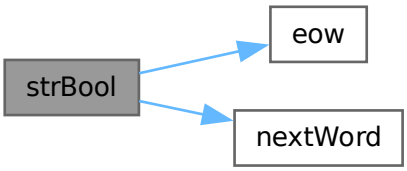
```
int serialPrintlnf (
            const char * fmt,
             ...)
```

Here is the caller graph for this function:

5.2.2.6 strBool()

```
bool strBool (
            const char * s,
            bool * b,
            char ** next = 0)
```

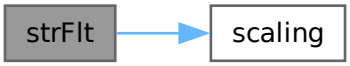
Here is the call graph for this function:



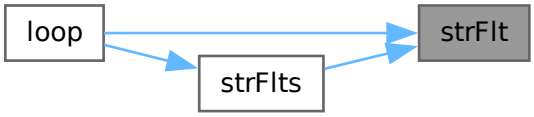
5.2.2.7 strFlt()

```
bool strFlt (
            const char * s,
            float * p,
            char ** next)
```

Here is the call graph for this function:



Here is the caller graph for this function:

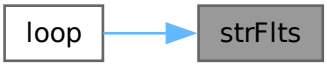


5.2.2.8 strFlts()

```
unsigned int strFlts (
            const char * pc,
            float * p,
            unsigned int nmax,
            char ** next)
```

Here is the call graph for this function:

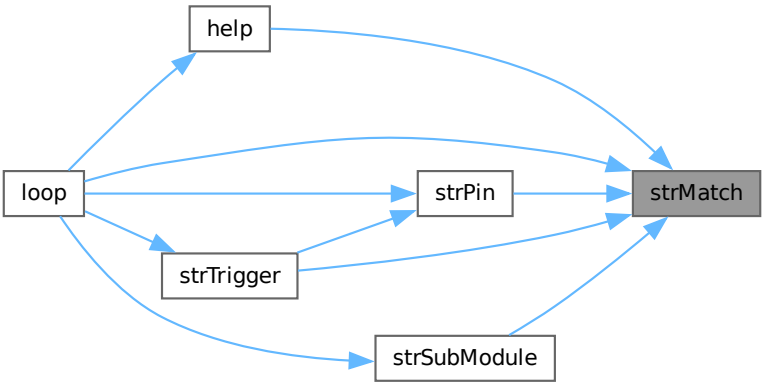
Here is the caller graph for this function:



5.2.2.9 strMatch()

```
bool strMatch (
            const char * s,
            const char * key,
            char ** next)
```

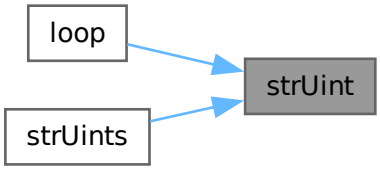
Here is the caller graph for this function:



5.2.2.10 strUint()

```
bool strUint (
            const char * s,
            unsigned int * u,
            char ** next)
```

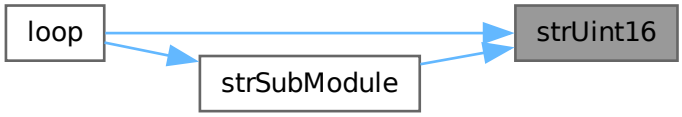
Here is the caller graph for this function:



5.2.2.11 strUint16()

```
bool strUint16 (
            const char * s,
            uint16_t * u,
            char ** next)
```

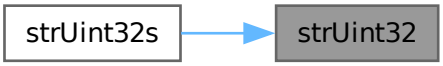
Here is the caller graph for this function:



5.2.2.12 strUint32()

```
bool strUint32 (
            const char * s,
            uint32_t * u,
            char ** next)
```

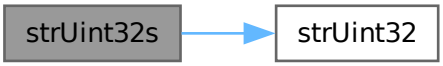
Here is the caller graph for this function:



5.2.2.13 strUint32s()

```
unsigned int strUint32s (
            const char * pc,
            uint32_t * p,
            unsigned int nmax,
            char ** next)
```

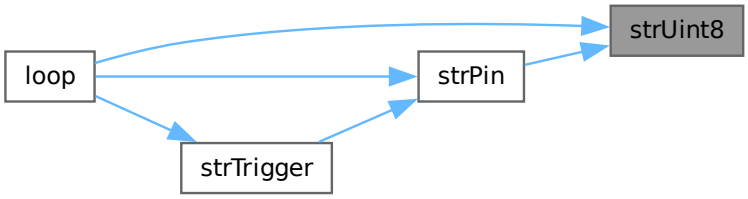
Here is the call graph for this function:



5.2.2.14 strUint8()

```
bool strUint8 (
            const char * s,
            uint8_t * u,
            char ** next)
```

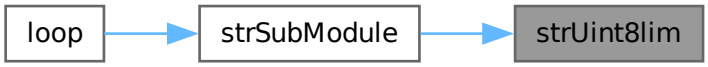
Here is the caller graph for this function:



5.2.2.15 strUint8lim()

```
bool strUint8lim (
            const char * s,
            uint8_t * u,
            char ** next,
            uint8_t ulim)
```

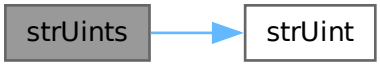
Here is the caller graph for this function:



5.2.2.16 strUints()

```
unsigned int strUints (
            const char * pc,
            unsigned int * p,
            unsigned int nmax,
            char ** next)
```

Here is the call graph for this function:



5.2.2.17 wordLength()

```
unsigned int wordLength (
            char * s)
```

5.3 parselib2.h

Go to the documentation of this file.

```
00001 /* ================================================================
00002    Parse srings for words, numbers, etc
00003
00004    Apart from wordLength(), these return a pointer to the
00005    next character in the string, or null if they fail
00006
00007 */
00008
00009 #ifndef PARSELIB_h
00010 #define PARSELIB_H
00011
00012 /*
00013 #ifdef __cplusplus
00014 extern "C" {
00015 #endif
00016 */
00017
00018 int serialPrintf( const char *fmt, ... );
00019 int serialPrintlnf( const char *fmt, ... );
00020
00021 unsigned int wordLength( char *s );
00022
00023 char *nextWord( char *s );
00024
00025 unsigned int countWords( char *s );
00026
00027 char *basenamef(const char *cs);
00028
00029 bool strMatch(const char *s, const char *key, char **next);
00030
00031 bool strBool(const char *s, bool *b, char **next=0);
00032
00033 bool strUint8(const char *s, uint8_t *u, char **next );
00034
00035 bool strUint8lim(const char *s, uint8_t *u, char **next, uint8_t ulim);
00036
00037 bool strUint(const char *s, unsigned int *u, char **next);
00038
00039 bool strUint16(const char *s, uint16_t *u, char **next);
00040
00041 bool strUint32(const char *s, uint32_t *u, char **next);
00042
```

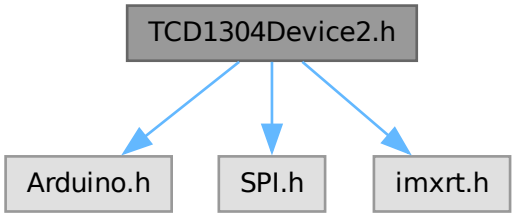
```
00043 bool strFlt(const char *s, float *p, char **next);
00044
00045 unsigned int strUints(const char *pc, unsigned int *p, unsigned int nmax, char **next);
00046
00047 unsigned int strUint32s(const char *pc, uint32_t *p, unsigned int nmax, char **next);
00048
00049 unsigned int strFlts(const char *pc, float *p, unsigned int nmax, char **next);
00050
00051 /*
00052   #ifdef __cplusplus
00053   }
00054   #endif
00055 */
00056
00057 #endif
```

5.4 README.md File Reference

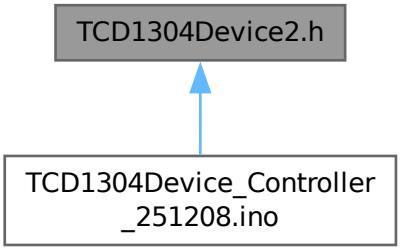
5.5 TCD1304Device2.h File Reference

```
#include "Arduino.h"
#include <SPI.h>
#include "imxrt.h"
```

Include dependency graph for TCD1304Device2.h:



This graph shows which files directly or indirectly include this file:



Classes

- class TCD1304Device
- struct TCD1304Device::SubModule
- struct TCD1304Device::Frame_Header_struct

Macros

- #define PINPULLS
- #define TCD1304_MAXCLKHZ 4.E6
- #define TCD1304_MINCLKHZ 0.8E6
- #define TDIFF(a, b)
- #define SH_STOP_IN_READ
- #define SH_CLEARING_DEFAULT 0
- #define ROUNDUP(a, b)
- #define ROUNDTO(a, b)
- #define ROUNDTOMOD(a, b, c)
- #define CYCCNT2SECS(a)
- #define PWM_CTRL2_CLOCK_MASTER FLEXPWM_SMCTRL2_FRCEN
- #define PWM_CTRL2_CLOCK_SLAVE (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | (FLEXPWM_SMCTRL2_↩ FRCEN | FLEXPWM_SMCTRL2_FORCE_SEL(0X3)))
- #define PWM_CTRL2_CLOCK_SYNC (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | FLEXPWM_SMCTRL2_↩ FRCEN)
- #define CMPF_MASKA_ON (1<<2)
- #define CMPF_MASKA_OFF (1<<3)
- #define CMPF_MASKA_ON_OFF (CMPF_MASKA_ON|CMPF_MASKA_OFF)
- #define CMPF_MASKB_ON (1<<4)
- #define CMPF_MASKB_OFF (1<<5)
- #define CMPF_MASKB_ON_OFF (CMPF_MASKB_ON|CMPF_MASKB_OFF)
- #define CLK_DEFAULT 64
- #define CLK_SUBMODULE 0
- #define CLK_MASK 0x1

- #define CLK_CHANNEL 1
- #define CLK_PIN 4
- #define CLK_MUXVAL 1
- #define CLK_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
- #define CLK_IRQ IRQ_FLEXPWM2_0
- #define CLK_CMPF_MASK CMPF_MASKA_ON
- #define ICG_SUBMODULE 1
- #define ICG_MASK 0x2
- #define ICG_CHANNEL 1
- #define ICG_PIN 5
- #define ICG_MUXVAL 1
- #define ICG_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
- #define ICG_IRQ IRQ_FLEXPWM2_1
- #define ICG_CMPF_MASK (CMPF_MASKA_OFF|CMPF_MASKB_ON_OFF)
- #define SH_SUBMODULE 2
- #define SH_MASK 0x4
- #define SH_CHANNEL 1
- #define SH_PIN 6
- #define SH_MUXVAL 2
- #define SH_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
- #define SH_IRQ IRQ_FLEXPWM2_2
- #define SH_CMPF_MASK CMPF_MASKA_ON_OFF
- #define CNVST_SUBMODULE 3
- #define CNVST_MASK 0x8
- #define CNVST_CHANNEL 1
- #define CNVST_CTRL2_MASK PWM_CTRL2_CLOCK_SYNC
- #define CNVST_IRQ IRQ_FLEXPWM2_3
- #define CNVST_CMPF_MASK CMPF_MASKA_OFF
- #define TIMER_SUBMODULE 2
- #define TIMER_MASK 0x4
- #define TIMER_CHANNEL 2
- #define TIMER_PIN 3
- #define TIMER_MUXVAL 1
- #define TIMER_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
- #define TIMER_IRQ IRQ_FLEXPWM4_2
- #define TIMER_CMPF_MASK CMPF_MASKB_ON
- #define CNVST_PIN 10
- #define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
- #define CNVST_PULSE_SECS 630.E-9
- #define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
- #define CLK_MONITOR_PIN 3
- #define SYNC_PIN 0
- #define BUSY_PIN 1
- #define TRIGGER_PIN 2
- #define SYNC_PIN_DEFAULT LOW
- #define BUSY_PIN_DEFAULT HIGH
- #define NREADOUT 3694
- #define DATASTART 16
- #define DATASTOP 3680
- #define NPIXELS (DATASTOP-DATASTART)
- #define NBYTES (NPIXELS∗2)

- #define NBYTES32 (NPIXELS∗4)
- #define NDARK 13
- #define NBITS 16
- #define VFS (0.6)
- #define VPERBIT (VFS/(1<<NBITS))
- #define SHUTTERMIN 5
- #define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
- #define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
- #define USBSPEED 480.0E6
- #define USBTRANSFERSECS ((float)NREADOUT∗(16/USBSPEED))
- #define COUNTER_MAX_SECS ((float)(65535 ∗ 128) / F_BUS_ACTUAL)
- #define DEBUGPRINTF(...)

Enumerations

- enum TCD1304_Mode_t { NOTCONFIGURED , PULSE , FRAMESET , TIMER }

5.5.1 Macro Definition Documentation

5.5.1.1 BUSY_PIN

```
#define BUSY_PIN 1
```

5.5.1.2 BUSY_PIN_DEFAULT

```
#define BUSY_PIN_DEFAULT HIGH
```

5.5.1.3 CLEARCNVST [1/2]

```
#define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
```

5.5.1.4 CLEARCNVST [2/2]

```
#define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
```

5.5.1.5 CLK_CHANNEL

```
#define CLK_CHANNEL 1
```

5.5.1.6 CLK_CMPF_MASK

```
#define CLK_CMPF_MASK CMPF_MASKA_ON
```

5.5.1.7 CLK_CTRL2_MASK

```
#define CLK_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
```

5.5.1.8 CLK_DEFAULT

```
#define CLK_DEFAULT 64
```

5.5.1.9 CLK_IRQ

```
#define CLK_IRQ IRQ_FLEXPWM2_0
```

5.5.1.10 CLK_MASK

```
#define CLK_MASK 0x1
```

5.5.1.11 CLK_MONITOR_PIN

```
#define CLK_MONITOR_PIN 3
```

5.5.1.12 CLK_MUXVAL

```
#define CLK_MUXVAL 1
```

5.5.1.13 CLK_PIN

```
#define CLK_PIN 4
```

5.5.1.14 CLK_SUBMODULE

```
#define CLK_SUBMODULE 0
```

5.5.1.15 CMPF_MASKA_OFF

```
#define CMPF_MASKA_OFF (1<<3)
```

5.5.1.16 CMPF_MASKA_ON

```
#define CMPF_MASKA_ON (1<<2)
```

5.5.1.17 CMPF_MASKA_ON_OFF

```
#define CMPF_MASKA_ON_OFF (CMPF_MASKA_ON|CMPF_MASKA_OFF)
```

5.5.1.18 CMPF_MASKB_OFF

```
#define CMPF_MASKB_OFF (1<<5)
```

5.5.1.19 CMPF_MASKB_ON

```
#define CMPF_MASKB_ON (1<<4)
```

5.5.1.20 CMPF_MASKB_ON_OFF

```
#define CMPF_MASKB_ON_OFF (CMPF_MASKB_ON|CMPF_MASKB_OFF)
```

5.5.1.21 CNVST_CHANNEL

```
#define CNVST_CHANNEL 1
```

5.5.1.22 CNVST_CMPF_MASK

```
#define CNVST_CMPF_MASK CMPF_MASKA_OFF
```

5.5.1.23 CNVST_CTRL2_MASK

```
#define CNVST_CTRL2_MASK PWM_CTRL2_CLOCK_SYNC
```

5.5.1.24 CNVST_IRQ

```
#define CNVST_IRQ IRQ_FLEXPWM2_3
```

5.5.1.25 CNVST_MASK

```
#define CNVST_MASK 0x8
```

5.5.1.26 CNVST_PIN

```
#define CNVST_PIN 10
```

5.5.1.27 CNVST_PULSE_SECS

```
#define CNVST_PULSE_SECS 630.E-9
```

5.5.1.28 CNVST_SUBMODULE

```
#define CNVST_SUBMODULE 3
```

5.5.1.29 COUNTER_MAX_SECS

```
#define COUNTER_MAX_SECS ((float)(65535 * 128) / F_BUS_ACTUAL)
```

5.5.1.30 CYCCNT2SECS

```
#define CYCCNT2SECS(
              a)
```

Value:

```
((double)(a)/F_CPU)
```

5.5.1.31 DATASTART

```
#define DATASTART 16
```

5.5.1.32 DATASTOP

```
#define DATASTOP 3680
```

5.5.1.33 DEBUGPRINTF

```
#define DEBUGPRINTF(
              ...)
```

5.5.1.34 ICG_CHANNEL

```
#define ICG_CHANNEL 1
```

5.5.1.35 ICG_CMPF_MASK

```
#define ICG_CMPF_MASK (CMPF_MASKA_OFF|CMPF_MASKB_ON_OFF)
```

5.5.1.36 ICG_CTRL2_MASK

```
#define ICG_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
```

5.5.1.37 ICG_IRQ

```
#define ICG_IRQ IRQ_FLEXPWM2_1
```

5.5.1.38 ICG_MASK

```
#define ICG_MASK 0x2
```

5.5.1.39 ICG_MUXVAL

```
#define ICG_MUXVAL 1
```

5.5.1.40 ICG_PIN

```
#define ICG_PIN 5
```

5.5.1.41 ICG_SUBMODULE

```
#define ICG_SUBMODULE 1
```

5.5.1.42 NBITS

```
#define NBITS 16
```

5.5.1.43 NBYTES

```
#define NBYTES (NPIXELS*2)
```

5.5.1.44 NBYTES32

```
#define NBYTES32 (NPIXELS*4)
```

5.5.1.45 NDARK

```
#define NDARK 13
```

5.5.1.46 NPIXELS

```
#define NPIXELS (DATASTOP-DATASTART)
```

5.5.1.47 NREADOUT

```
#define NREADOUT 3694
```

5.5.1.48 PINPULLS

```
#define PINPULLS
```

5.5.1.49 PWM_CTRL2_CLOCK_MASTER

```
#define PWM_CTRL2_CLOCK_MASTER FLEXPWM_SMCTRL2_FRCEN
```

5.5.1.50 PWM_CTRL2_CLOCK_SLAVE

```
#define PWM_CTRL2_CLOCK_SLAVE (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | (FLEXPWM_SMCTRL2_FRCEN | FLEXPWM_↩
SMCTRL2_FORCE_SEL(0X3)))
```

5.5.1.51 PWM_CTRL2_CLOCK_SYNC

```
#define PWM_CTRL2_CLOCK_SYNC (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | FLEXPWM_SMCTRL2_FRCEN)
```

5.5.1.52 ROUNDTO

```
#define ROUNDTO(
              a,
              b)
```

Value:

```
((a/b)*b)
```

5.5.1.53 ROUNDTOMOD

```
#define ROUNDTOMOD(
              a,
              b,
              c)
```

Value:

```
(((a/b)*b)%c)
```

5.5.1.54 ROUNDUP

```
#define ROUNDUP(
                a,
                b)
```

Value:

```
(ceil((float)a/b)*b)
```

5.5.1.55 SETCNVST [1/2]

```
#define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
```

5.5.1.56 SETCNVST [2/2]

```
#define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
```

5.5.1.57 SH_CHANNEL

```
#define SH_CHANNEL 1
```

5.5.1.58 SH_CLEARING_DEFAULT

```
#define SH_CLEARING_DEFAULT 0
```

5.5.1.59 SH_CMPF_MASK

```
#define SH_CMPF_MASK CMPF_MASKA_ON_OFF
```

5.5.1.60 SH_CTRL2_MASK

```
#define SH_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
```

5.5.1.61 SH_IRQ

```
#define SH_IRQ IRQ_FLEXPWM2_2
```

5.5.1.62 SH_MASK

```
#define SH_MASK 0x4
```

5.5.1.63 SH_MUXVAL

```
#define SH_MUXVAL 2
```

5.5.1.64 SH_PIN

```
#define SH_PIN 6
```

5.5.1.65 SH_STOP_IN_READ

```
#define SH_STOP_IN_READ
```

5.5.1.66 SH_SUBMODULE

```
#define SH_SUBMODULE 2
```

5.5.1.67 SHUTTERMIN

```
#define SHUTTERMIN 5
```

5.5.1.68 SYNC_PIN

```
#define SYNC_PIN 0
```

5.5.1.69 SYNC_PIN_DEFAULT

```
#define SYNC_PIN_DEFAULT LOW
```

5.5.1.70 TCD1304_MAXCLKHZ

```
#define TCD1304_MAXCLKHZ 4.E6
```

5.5.1.71 TCD1304_MINCLKHZ

```
#define TCD1304_MINCLKHZ 0.8E6
```

5.5.1.72 TDIFF

```
#define TDIFF(
              a,
              b)
```

Value:

```
((double)(a-b)/F_CPU)
```

5.5.1.73 TIMER_CHANNEL

```
#define TIMER_CHANNEL 2
```

5.5.1.74 TIMER_CMPF_MASK

```
#define TIMER_CMPF_MASK CMPF_MASKB_ON
```

5.5.1.75 TIMER_CTRL2_MASK

```
#define TIMER_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
```

5.5.1.76 TIMER_IRQ

```
#define TIMER_IRQ IRQ_FLEXPWM4_2
```

5.5.1.77 TIMER_MASK

```
#define TIMER_MASK 0x4
```

5.5.1.78 TIMER_MUXVAL

```
#define TIMER_MUXVAL 1
```

5.5.1.79 TIMER_PIN

```
#define TIMER_PIN 3
```

5.5.1.80 TIMER_SUBMODULE

```
#define TIMER_SUBMODULE 2
```

5.5.1.81 TRIGGER_PIN

```
#define TRIGGER_PIN 2
```

5.5.1.82 USBSPEED

```
#define USBSPEED 480.0E6
```

5.5.1.83 USBTRANSFERSECS

```
#define USBTRANSFERSECS ((float)NREADOUT*(16/USBSPEED))
```

5.5.1.84 VFS

```
#define VFS (0.6)
```

5.5.1.85 VPERBIT

```
#define VPERBIT (VFS/(1<<NBITS))
```

5.5.2 Enumeration Type Documentation

5.5.2.1 TCD1304_Mode_t

```
enum TCD1304_Mode_t
```

Enumerator

NOTCONFIGURED	
PULSE	
FRAMESET	
TIMER	

5.6 TCD1304Device2.h

Go to the documentation of this file.

```
00001 /* tcd1304 flexpwm library
00002
00003    Author Mitchell C Nelson, PhD
00004    Copyright 2025
00005
00006    Free for non-commercial use.
00007
00008    No warranty and no representation of suitability for any purpose whatsoever
00009
00010 */
00011
00012 #ifndef TCD1304DEVICE_H
00013 #define TCD1304DEVICE_H
00014
00015 #include "Arduino.h"
00016 #include <SPI.h>
00017
00018 #include "imxrt.h"
00019
00020 // ========================================
00021 // All In One Board
00022
00023 //#define ALLINONEBOARD
00024
00025 // CONFIGURE PULLUPS/PULLDOWNS
00026 #define PINPULLS
00027
00028 // ========================================
00029
00030 #ifdef  ALLINONEBOARD
00031 #include <ADC.h>
00032 #include <ADC_util.h>
00033 extern ADC *adc;
00034 #define ANALOGPIN A0
00035 #define TCD1304_MAXCLKHZ 2.35E6
00036 #else
00037 #define TCD1304_MAXCLKHZ 4.E6
00038 #endif
00039 #define TCD1304_MINCLKHZ 0.8E6
00040
00041 // ========================================
00042
00043 #define TDIFF(a,b) ((double)(a-b)/F_CPU)
00044
00045 // debug statements in setup
00046 //#define DEBUG
00047
00048 // we'll comment this out for the new boards
00049 #define SH_STOP_IN_READ
00050
00051 // clearing pulses, leave at 0 as default
00052 #define SH_CLEARING_DEFAULT 0
00053
00054 #define ROUNDUP(a,b) (ceil((float)a/b)*b)
00055 #define ROUNDTO(a,b) ((a/b)*b)
00056 #define ROUNDTOMOD(a,b,c) (((a/b)*b)%c)
00057
00058 // cpu cycle counter values to seconds
00059 // usage
00060 #ifndef CYCCNT2SECS
00061 #define CYCCNT2SECS(a) ((double)(a)/F_CPU)
00062 #endif
00063
00064 // Clock and force configurations
00065 #define PWM_CTRL2_CLOCK_MASTER FLEXPWM_SMCTRL2_FRCEN
00066 #define PWM_CTRL2_CLOCK_SLAVE (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | (FLEXPWM_SMCTRL2_FRCEN |
      FLEXPWM_SMCTRL2_FORCE_SEL(0X3)))
00067 #define PWM_CTRL2_CLOCK_SYNC (FLEXPWM_SMCTRL2_CLK_SEL(0x2) | FLEXPWM_SMCTRL2_FRCEN)
00068
00069 // Flexpwm compare interrupts
00070 #define CMPF_MASKA_ON (1«2)
00071 #define CMPF_MASKA_OFF (1«3)
00072 #define CMPF_MASKA_ON_OFF (CMPF_MASKA_ON|CMPF_MASKA_OFF)
00073
00074 #define CMPF_MASKB_ON (1«4)
```

```
00075 #define CMPF_MASKB_OFF (1<<5)
00076 #define CMPF_MASKB_ON_OFF (CMPF_MASKB_ON|CMPF_MASKB_OFF)
00077
00078 //#define CLK_DEFAULT 48
00079 #define CLK_DEFAULT 64
00080 //#define CLK_DEFAULT 96
00081 //#define CLK_DEFAULT 128
00082
00083 #define CLK_SUBMODULE 0
00084 #define CLK_MASK 0x1
00085 #define CLK_CHANNEL 1
00086 #define CLK_PIN 4
00087 #define CLK_MUXVAL 1
00088 #define CLK_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
00089 #define CLK_IRQ IRQ_FLEXPWM2_0
00090 #define CLK_CMPF_MASK CMPF_MASKA_ON
00091
00092 #define ICG_SUBMODULE 1
00093 #define ICG_MASK 0x2
00094 #define ICG_CHANNEL 1
00095 #define ICG_PIN 5
00096 #define ICG_MUXVAL 1
00097 #define ICG_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
00098 #define ICG_IRQ IRQ_FLEXPWM2_1
00099 #define ICG_CMPF_MASK (CMPF_MASKA_OFF|CMPF_MASKB_ON_OFF)
00100
00101 #define SH_SUBMODULE 2
00102 #define SH_MASK 0x4
00103 #define SH_CHANNEL 1
00104 #define SH_PIN 6
00105 #define SH_MUXVAL 2
00106 #define SH_CTRL2_MASK PWM_CTRL2_CLOCK_SLAVE
00107 #define SH_IRQ IRQ_FLEXPWM2_2
00108 #define SH_CMPF_MASK CMPF_MASKA_ON_OFF
00109
00110 #define CNVST_SUBMODULE 3
00111 #define CNVST_MASK 0x8
00112 #define CNVST_CHANNEL 1
00113 #define CNVST_CTRL2_MASK PWM_CTRL2_CLOCK_SYNC
00114 #define CNVST_IRQ IRQ_FLEXPWM2_3
00115 #define CNVST_CMPF_MASK CMPF_MASKA_OFF
00116
00117 // this one is for PWM4
00118 #define TIMER_SUBMODULE 2
00119 #define TIMER_MASK 0x4
00120 #define TIMER_CHANNEL 2
00121 #define TIMER_PIN 3
00122 #define TIMER_MUXVAL 1
00123 #define TIMER_CTRL2_MASK PWM_CTRL2_CLOCK_MASTER
00124 #define TIMER_IRQ IRQ_FLEXPWM4_2
00125 #define TIMER_CMPF_MASK CMPF_MASKB_ON
00126
00127 /* Note that we do not configure the flexPWM to use this pin (CNVST_PIN),
00128    It is not on the mux list for this module,
00129    We operate this pin using digitalwrite, from the isr.
00130 */
00131 #define CNVST_PIN 10
00132 #define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
00133
00134 #define CNVST_PULSE_SECS 630.E-9
00135 //#define CNVST_OFFSET_CLOCKS 1
00136
00137 #define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
00138
00139 #define CLK_MONITOR_PIN 3
00140
00141 #define SYNC_PIN 0
00142 #define BUSY_PIN 1
00143 #define TRIGGER_PIN 2
00144 //#define SPARE_PIN 3
00145
00146 #define SYNC_PIN_DEFAULT LOW
00147 #define BUSY_PIN_DEFAULT HIGH
00148
00149 // Fast nofrills BUSY pin set, lear, flip state
00150 /*
00151 #define SETBUSYPIN (CORE_PIN1_PORTSET = CORE_PIN1_BITMASK)
00152 #define CLEARBUSYPIN (CORE_PIN1_PORTCLEAR = CORE_PIN1_BITMASK)
00153 #define TOGGLEBUSYPIN (CORE_PIN1_PORTTOGGLE = CORE_PIN1_BITMASK)
00154 */
00155
```

```
00156 // Fast nofrills SYNC pin set/clear
00157 /*
00158 #define SETSYNCPIN (CORE_PIN0_PORTSET = CORE_PIN0_BITMASK)
00159 #define CLEARSYNCPIN (CORE_PIN0_PORTCLEAR = CORE_PIN0_BITMASK)
00160 #define TOGGLESYNCPIN (CORE_PIN0_PORTTOGGLE = CORE_PIN0_BITMASK)
00161 */
00162 // Sensor data readout
00163 #define NREADOUT 3694
00164 #define DATASTART 16
00165 #define DATASTOP 3680
00166
00167 // Size of the useful part
00168 #define NPIXELS (DATASTOP-DATASTART)
00169 #define NBYTES (NPIXELS*2)
00170 #define NBYTES32 (NPIXELS*4)
00171
00172 // And first part of that is dark
00173 #define NDARK 13
00174
00175 #ifdef  ALLINONEBOARD
00176 #define NBITS 12
00177 #else
00178 #define NBITS 16
00179 #endif
00180
00181 #define VFS (0.6)
00182 #define VPERBIT (VFS/(1«NBITS))
00183
00184 #define SHUTTERMIN 5
00185
00186 #define SETCNVST (CORE_PIN10_PORTSET = CORE_PIN10_BITMASK)
00187 #define CLEARCNVST (CORE_PIN10_PORTCLEAR = CORE_PIN10_BITMASK)
00188
00189 #define USBSPEED 480.0E6
00190 #define USBTRANSFERSECS ((float)NREADOUT*(16/USBSPEED))
00191
00192 #define COUNTER_MAX_SECS ((float)(65535 * 128) / F_BUS_ACTUAL)
00193
00194 #ifdef DEBUG
00195 int debugprintf(const char* format, ...)
00196 {
00197   char buffer[128] = {0};
00198   int n;
00199   va_list argptr;
00200   va_start(argptr, format);
00201   n = vsprintf (buffer, format, argptr );
00202   va_end(argptr);
00203   if (n > 0) {
00204     Serial.println(buffer);
00205   }
00206   else if (n<0) {
00207     Serial.print("Error: debugprintf vsprintf");
00208     Serial.println(format);
00209   }
00210   return n;
00211 }
00212 #define DEBUGPRINTF(...) debuprintf( __VA_ARGS__ )
00213 #else
00214 #define DEBUGPRINTF(...)
00215 #endif
00216
00217 // ----------------------------------------------------------------------------
00218 // NOTE this is not designed to be thread safe.
00219 // (Consider making it a singleton)
00220
00221 /*********************************************************************
00222  * TCD1304 Device implemented in FlexPWM2, pins 3,4,5,6 and 10
00223  */
00224 typedef enum {
00225   NOTCONFIGURED,
00226   PULSE,
00227   FRAMESET,
00228   TIMER // we only have timer+pulse,  not timer+frameset
00229 } TCD1304_Mode_t;
00230
00231 class TCD1304Device
00232 {
00233 public:
00234
00235   // struct to simplify our namespace for the flexpwm submodules
00236   struct SubModule {
```

```
00237     const char *name;
00238     const uint8_t submod;
00239     const uint8_t mask;
00240     const uint8_t pinA;
00241     const uint8_t muxvalA;
00242     const uint8_t pinB;
00243     const uint8_t muxvalB;
00244     IRQ_NUMBER_t irq;
00245     IMXRT_FLEXPWM_t *flexpwm;
00246     uint16_t period_counts = 0;
00247     uint16_t onA_counts = 0;
00248     uint16_t offA_counts = 0;
00249     uint16_t onB_counts = 0;
00250     uint16_t offB_counts = 0;
00251     uint16_t ctrl2_mask = 0;
00252     uint16_t intena_mask = 0;
00253     uint16_t divider = 1;
00254     uint8_t prescale = 0;
00255     uint8_t filler = 0;
00256     float period_secs = 0;
00257 
00258     bool invertA = false;
00259     bool invertB = false;
00260 
00261     bool newvals = false;
00262 
00263     void (*isr)() = nullptr;
00264     uint16_t inten_mask = 0;
00265 
00266     SubModule(const char *name_,
00267               uint8_t submod_, uint8_t mask_,
00268               uint8_t pinA_, uint8_t muxvalA_,
00269               uint8_t pinB_, uint8_t muxvalB_,
00270               IRQ_NUMBER_t irq_,
00271               IMXRT_FLEXPWM_t *flexpwm_) :
00272       name(name_),
00273       submod(submod_),mask(mask_),
00274       pinA(pinA_), muxvalA(muxvalA_),
00275       pinB(pinB_), muxvalB(muxvalB_),
00276       irq(irq_), flexpwm(flexpwm_) {};
00277   };
00278 
00279   inline static uint64_t sh_cyccnt64_start = 0;
00280   inline static uint64_t sh_cyccnt64_now = 0;
00281   inline static uint64_t sh_cyccnt64_prev = 0;
00282   inline static uint64_t sh_cyccnt64_exposure = 0;
00283 
00284   inline static uint64_t timer_cyccnt64_start = 0;
00285   inline static uint64_t timer_cyccnt64_now = 0;
00286   inline static uint64_t timer_cyccnt64_prev = 0;
00287 
00288   // For the trigger timer
00289   inline static uint64_t trigger_cyccnt64_start = 0;
00290   inline static uint64_t trigger_cyccnt64_now = 0;
00291   inline static uint64_t trigger_cyccnt64_prev = 0;
00292 
00293   // Refrenced by timer and trigger setups and by the header routine
00294   inline static TCD1304_Mode_t mode = NOTCONFIGURED;
00295   inline static bool trigger_mode = false;
00296   inline static bool trigger_attached = false;
00297 
00298   // bookkeeping counters
00299   inline static unsigned int sh_counter    = 0;
00300   inline static unsigned int icg_counter   = 0;
00301   inline static unsigned int cnvst_counter = 0;
00302   inline static unsigned int sh_counts_per_icg = 0;
00303 
00304   // bookkeeping for the charge clearing pulses on SH
00305   inline static unsigned int sh_clearing_counts = SH_CLEARING_DEFAULT;
00306   inline static unsigned int sh_clearing_counter = 0;
00307   inline static unsigned int sh_short_period_counts = 0;
00308 
00309   // read counters and callback
00310   inline static unsigned int read_counter = 0;
00311   inline static unsigned int read_counts  = 0;
00312   inline static uint16_t *read_buffer  = 0;
00313   inline static uint16_t *read_pointer = 0;
00314   inline static void (*read_callback)() = 0;
00315 
00316   // frame counters and frameset callback
00317   inline static unsigned int frame_counter = 0;
```

```
00318   inline static unsigned int frame_counts = 0;
00319   inline static void (*frames_completed_callback)() = 0;
00320
00321   // framesets counters and framsets completed callback
00322   inline static unsigned int frameset_counter = 0;
00323   inline static unsigned int frameset_counts = 0;
00324   inline static void (*framesets_completed_callback)() = 0;
00325
00326   // timer stops at timer_outer_counts, timer_counter is for extended timer
00327   inline static unsigned int timer_inner_counter = 0;
00328   inline static unsigned int timer_inner_counts = 0;
00329   inline static unsigned int timer_outer_counter = 0;
00330   inline static unsigned int timer_outer_counts = 0;
00331   inline static void (*timer_callback)() = 0;
00332
00333   inline static float timer_interframe_min_secs = 0.;
00334   inline static float timer_period_secs = 0;     // inner loop period
00335   inline static float timer_interval_secs = .0;  // the resulting exposure interval
00336
00337   // interrupt (trigger) support
00338   inline static unsigned int trigger_counter = 0;
00339   inline static unsigned int trigger_counts  = 1;
00340   inline static void (*trigger_callback)() = 0;
00341
00342   inline static uint8_t trigger_pin = TRIGGER_PIN;
00343   inline static uint8_t trigger_edge_mode = RISING;
00344   inline static uint8_t trigger_pin_mode = INPUT;
00345
00346   // timing adjustment
00347 #ifdef  ALLINONEBOARD
00348   inline static uint16_t cnvst_extra_delay_counts = 0;   // best signal, steadily decreases with
      increasing delay
00349 #else
00350   inline static uint16_t cnvst_extra_delay_counts = 1;   // this gives the lowest noise, does not improve
      at 2
00351 #endif
00352
00353   // This is for frameset with exposure == frame interval, we skip the first icg for readout
00354   inline static bool skip_one = false;
00355   inline static bool skip_one_reload = false;
00356
00357   // State of the flexpwm interface
00358   inline static bool busytoggled = false;
00359
00360   // Sync pin management
00361   inline static uint8_t sync_pin = SYNC_PIN;
00362   inline static bool synctoggled = false;
00363   inline static bool sync_enabled = true;
00364
00365   // And now.... the submodules
00366   inline static IMXRT_FLEXPWM_t * const flexpwm = &IMXRT_FLEXPWM2;
00367   inline static SubModule clk   = {"clk",CLK_SUBMODULE, CLK_MASK, CLK_PIN,CLK_MUXVAL, 0xFF,0, CLK_IRQ,
      &IMXRT_FLEXPWM2};
00368   inline static SubModule sh    = {"sh", SH_SUBMODULE, SH_MASK,  SH_PIN,SH_MUXVAL, 0xFF,0, SH_IRQ,
      &IMXRT_FLEXPWM2};
00369   inline static SubModule icg   = {"icg", ICG_SUBMODULE, ICG_MASK, ICG_PIN,ICG_MUXVAL, 0xFF,0, ICG_IRQ,
      &IMXRT_FLEXPWM2};
00370   inline static SubModule cnvst = {"cnvst", CNVST_SUBMODULE, CNVST_MASK, 0xFF,0, 0xFF,0, CNVST_IRQ,
      &IMXRT_FLEXPWM2}; // no pin
00371
00372   // this is our interval clock, implemented on PWM4. option for pin3 output.
00373   inline static IMXRT_FLEXPWM_t * const timerflexpwm = &IMXRT_FLEXPWM4;
00374   inline static SubModule timer = {"timer", TIMER_SUBMODULE, TIMER_MASK, 0xFF,0, TIMER_PIN,TIMER_MUXVAL,
      TIMER_IRQ, &IMXRT_FLEXPWM4};
00375
00376   // error bookkeeping
00377   inline static bool error_flag = false;
00378   inline static bool oops_flag = false;
00379
00380
00381   //--------------------------------------------
00382   typedef struct Frame_Header_struct {
00383     uint16_t *buffer;
00384     unsigned int nbuffer;
00385
00386     // from the dummy outputs, first 16 elements
00387     unsigned int avgdummy;
00388     float offset;
00389
00390 #ifdef DEBUG
00391     uint64_t sh_cyccnt64_start = 0;
```

```
00392     uint64_t sh_cyccnt64_now = 0;
00393     uint64_t sh_cyccnt64_prev = 0;
00394     uint64_t sh_cyccnt64_exposure = 0;
00395 
00396     uint64_t timer_cyccnt64_start = 0;
00397     uint64_t timer_cyccnt64_now = 0;
00398     uint64_t timer_cyccnt64_prev = 0;
00399 
00400     uint64_t trigger_cyccnt64_start = 0;
00401     uint64_t trigger_cyccnt64_now = 0;
00402     uint64_t trigger_cyccnt64_prev = 0;
00403 
00404     float frame_difference_secs;
00405  #endif
00406 
00407     float frame_elapsed_secs;
00408     float frame_exposure_secs;
00409 
00410     float timer_elapsed_secs;
00411     float timer_difference_secs;
00412 
00413     float trigger_elapsed_secs;
00414     float trigger_difference_secs;
00415 
00416     unsigned int frame_counter;
00417     unsigned int frameset_counter;
00418     unsigned int trigger_counter;
00419 
00420     TCD1304_Mode_t mode;
00421     bool trigger_mode;
00422 
00423     bool error_flag;
00424     bool oops_flag;
00425 
00426     bool frames_completed ;
00427     bool framesets_completed ;
00428 
00429     bool ready_for_send;
00430   } Frame_Header;
00431 
00432 
00433   //-------------------------------------------
00434   TCD1304Device(unsigned int period=CLK_DEFAULT)
00435   {
00436     stop_with_irqs();
00437 
00438     pinMode(trigger_pin, trigger_pin_mode);
00439 
00440     pinMode(BUSY_PIN, OUTPUT);
00441     digitalWrite(BUSY_PIN, BUSY_PIN_DEFAULT);
00442 
00443     pinMode(SYNC_PIN, OUTPUT);
00444     digitalWrite(SYNC_PIN, SYNC_PIN_DEFAULT);
00445 
00446     pinMode(CNVST_PIN, OUTPUT);
00447     digitalWrite(CNVST_PIN, LOW);
00448 
00449 #ifdef PINPULLS
00450     pinMode(CLK_PIN, INPUT_PULLDOWN);
00451     pinMode(SH_PIN, INPUT_PULLDOWN);
00452     pinMode(ICG_PIN, INPUT_PULLUP);
00453 #endif
00454 
00455   }
00456 
00457   void stop_all()
00458   {
00459     stop_with_irqs();
00460     clear_sync_busy_pins();
00461   }
00462 
00463   static void stop_runs_only()
00464   {
00465     // Stops triggers
00466     stop_triggers();
00467 
00468     // Stop all four submodules
00469     flexpwm_stop();
00470 
00471     // Stop the timer
00472     timer_stop();
```

```
00473   }
00474
00475   static void disable_irqs()
00476   {
00477     // Disable all of the interrupts
00478     NVIC_DISABLE_IRQ(CLK_IRQ);
00479     NVIC_DISABLE_IRQ(ICG_IRQ);
00480     NVIC_DISABLE_IRQ(SH_IRQ);
00481     NVIC_DISABLE_IRQ(CNVST_IRQ);
00482
00483     // Disable the the timer interrupt
00484     NVIC_DISABLE_IRQ(TIMER_IRQ);
00485   }
00486
00487   static void stop_with_irqs()
00488   {
00489     // stop all of the flexpwms
00490     stop_runs_only();
00491
00492     // Disable all of the interrupts
00493     disable_irqs();
00494   }
00495
00496   static void clear_error_flags()
00497   {
00498     oops_flag = false;
00499     error_flag = false;
00500   }
00501
00502   static void clear_mode()
00503   {
00504     mode = NOTCONFIGURED;
00505     trigger_mode = false;
00506   }
00507
00508   static void clear_sync_busy_pins()
00509   {
00510     if (busytoggled) {
00511       busytoggled = false;
00512       digitalToggleFast(BUSY_PIN);
00513     }
00514
00515     // reset sync pin
00516     if (synctoggled) {
00517       digitalToggleFast(SYNC_PIN);
00518       synctoggled = false;
00519     }
00520   }
00521
00522   static void toggle_busypin()
00523   {
00524     busytoggled = !busytoggled;
00525     digitalToggleFast(BUSY_PIN);
00526   }
00527
00528   static void toggle_syncpin()
00529   {
00530     synctoggled = !synctoggled;
00531     digitalToggleFast(SYNC_PIN);
00532   }
00533
00534   static void clear_busypin()
00535   {
00536     if (busytoggled) {
00537       busytoggled = false;
00538       digitalToggleFast(BUSY_PIN);
00539     }
00540   }
00541
00542   static void clear_syncpin()
00543   {
00544     if (synctoggled) {
00545       synctoggled = false;
00546       digitalToggleFast(SYNC_PIN);
00547     }
00548   }
00549
00550   /* ============================================================================
00551      For ring buffering, we'll use this in the read callback to point to the next buffer
00552   */
00553   static void update_read_buffer(uint16_t *buffer)
```

```
00554   {
00555     read_buffer   = buffer;
00556     //read_counts   = nbuffer;
00557 
00558     read_pointer  = read_buffer;
00559     read_counter  = 0;
00560   }
00561 
00562   static void fill_frame_header(Frame_Header *p)
00563   {
00564     unsigned int utmp = 0;
00565     int n;
00566 
00567     p->buffer = read_buffer;
00568     p->nbuffer = read_counts;
00569 
00570     for (n=0; n<DATASTART; n++) {
00571       utmp += read_buffer[n];
00572     }
00573     p->avgdummy = utmp/DATASTART;
00574     p->offset = ((float)utmp * VPERBIT)/DATASTART;
00575 
00576 #ifdef DEBUG
00577     p->sh_cyccnt64_start = sh_cyccnt64_start;
00578     p->sh_cyccnt64_now = sh_cyccnt64_now;
00579     p->sh_cyccnt64_prev = sh_cyccnt64_prev;
00580     p->sh_cyccnt64_exposure = sh_cyccnt64_exposure;
00581 
00582     p->timer_cyccnt64_start = timer_cyccnt64_start;
00583     p->timer_cyccnt64_now = timer_cyccnt64_now;
00584     p->timer_cyccnt64_prev = timer_cyccnt64_prev;
00585 
00586     p->trigger_cyccnt64_start = trigger_cyccnt64_start;
00587     p->trigger_cyccnt64_now = trigger_cyccnt64_now;
00588     p->trigger_cyccnt64_prev = trigger_cyccnt64_prev;
00589 
00590     p->frame_difference_secs = sh_difference_secs();
00591 #endif
00592 
00593     p->frame_counter = frame_counter;
00594     p->frameset_counter = frameset_counter;
00595 
00596     p->trigger_counter = trigger_counter;
00597 
00598     p->frames_completed = (frame_counter+1) == frame_counts ? true : false;
00599     p->framesets_completed = p->frames_completed && ((frameset_counter+1) == frameset_counts) ? true :
      false;
00600 
00601     p->frame_elapsed_secs = sh_elapsed_secs();
00602     p->frame_exposure_secs = sh_exposure_secs();
00603 
00604     p->timer_elapsed_secs = timer_elapsed_secs();
00605     p->timer_difference_secs = timer_difference_secs();
00606 
00607     p->trigger_elapsed_secs = trigger_elapsed_secs();
00608     p->trigger_difference_secs = trigger_difference_secs();
00609 
00610     p->mode = mode;
00611     p->trigger_mode = trigger_mode;
00612 
00613     p->error_flag = error_flag;
00614     p->oops_flag = oops_flag;
00615 
00616     p->ready_for_send = true;
00617   }
00618 
00619   /* ============================================================================
00620      High level API
00621    */
00622 
00623   inline static float read_expected_time = 0.;
00624 
00625   bool read(uint nframes, float exposure, uint16_t *bufferp,
00626             void (*frame_callbackf)(),
00627             void (*frameset_callbackf)(),
00628             void (*completion_callbackf)(),
00629             void (*setup_callbackf)(),
00630             bool start=true)
00631   {
00632     float clk_secs = 0.5E-6;
00633     float sh_secs = 1.0E-6;
```

```
00634     float sh_offset_secs = 0.6E-6;
00635     float icg_secs = 2.6E-6;
00636     float icg_offset_secs = 0.5E-6;
00637 
00638     if (!setup_pulse(clk_secs, sh_secs, sh_offset_secs, icg_secs, icg_offset_secs,
00639                      bufferp, NREADOUT, frame_callbackf)) {
00640       Serial.println("Error: failed to setup pulse");
00641       return false;
00642     }
00643 
00644     frame_counts = nframes;
00645     frames_completed_callback = frameset_callbackf;
00646     framesets_completed_callback = completion_callbackf;
00647 
00648     if (!setup_timer(exposure,0.,nframes)) {
00649       Serial.println("Error: failed to setup timer");
00650       return false;
00651     }
00652 
00653     if (setup_callbackf) {
00654       setup_callbackf();
00655     }
00656 
00657     if (!start) {
00658       return true;
00659     }
00660 
00661     // start the reads here
00662     timer_start();
00663     if (error_flag) {
00664       return false;
00665     }
00666 
00667     read_expected_time = exposure * nframes;
00668 
00669     return true;
00670   }
00671 
00672   bool read(uint nframes, float exposure, float frame_interval, uint16_t *bufferp,
00673             void (*frame_callbackf)(),
00674             void (*frameset_callbackf)(),
00675             void (*completion_callbackf)(),
00676             void (*setup_callbackf)(),
00677             bool start=true)
00678   {
00679 
00680     float clk_secs = 0.5E-6;
00681     float sh_secs = 1.0E-6;
00682     float sh_offset_secs = 0.6E-6;
00683     float icg_secs = 2.6E-6;
00684     float icg_offset_secs = 0.5E-6;
00685 
00686     if (!setup_frameset(clk_secs, sh_secs, sh_offset_secs, icg_secs, icg_offset_secs,
00687                         exposure, frame_interval, nframes,
00688                         bufferp, NREADOUT, frame_callbackf)) {
00689 
00690       Serial.println("Error: failed to setup frameset");
00691       return false;
00692     }
00693 
00694     frames_completed_callback = frameset_callbackf;
00695     framesets_completed_callback = completion_callbackf;
00696 
00697 
00698     if (setup_callbackf) {
00699       setup_callbackf();
00700     }
00701 
00702     if (!start) {
00703       return true;
00704     }
00705 
00706     // start the reads here
00707     frameset_start();
00708     if (error_flag) {
00709       return false;
00710     }
00711 
00712     read_expected_time = frame_interval * nframes;
00713 
00714     return true;
```

```
00715   }
00716
00717   bool start_read()
00718   {
00719     if (mode == TIMER) {
00720       timer_start();
00721       return !error_flag;
00722     }
00723     else if (mode == FRAMESET) {
00724       frameset_start();
00725       return !error_flag;
00726     }
00727
00728     Serial.println("Error: start_read, not configured");
00729     return false;
00730   }
00731
00732   bool wait_read(float timeout=0., float timestep=0.01, bool verbose=false)
00733   {
00734     if (!timeout) timeout = read_expected_time - timer_elapsed_secs() + 0.010;
00735     if (timeout < 0.1) timeout = 0.1;
00736
00737     if (mode == TIMER) {
00738       return timer_wait(timeout,timestep, verbose);
00739     }
00740     else if (mode == FRAMESET) {
00741       return flexpwm_wait(timeout,timestep, verbose);
00742     }
00743
00744     Serial.println("Error: wait_read not configured");
00745     return false;
00746   }
00747
00748   // ------------------------------------------------------------------------------
00749   bool triggered_read(uint ntriggers, uint nframes, float exposure, uint16_t *bufferp,
00750                       void (*frame_callbackf)(),
00751                       void (*frameset_callbackf)(),
00752                       void (*completion_callbackf)(),
00753                       void (*setup_callbackf)(),
00754                       bool start=true)
00755   {
00756     if (!read(nframes, exposure, bufferp,frame_callbackf, frameset_callbackf, completion_callbackf,
      nullptr, false)) {
00757       Serial.println("Error: triggerd_read setup read");
00758       return false;
00759     }
00760
00761     if (!setup_triggers(ntriggers)) {
00762       Serial.println("Error: triggerd_read setup triggers");
00763       return false;
00764     }
00765
00766     if (setup_callbackf) setup_callbackf();
00767
00768     if (start) {
00769       return start_triggers();
00770     }
00771
00772     return true;
00773   }
00774
00775   bool triggered_read(uint ntriggers, uint nframes, float exposure, float interval, uint16_t *bufferp,
00776                       void (*frame_callbackf)(),
00777                       void (*frameset_callbackf)(),
00778                       void (*completion_callbackf)(),
00779                       void (*setup_callbackf)(),
00780                       bool start=true)
00781   {
00782     if (!read(nframes, exposure, interval, bufferp,
00783               frame_callbackf, frameset_callbackf, completion_callbackf, nullptr, false)) {
00784       Serial.println("Error: triggerd_read setup read");
00785       return false;
00786     }
00787
00788     if (!setup_triggers(ntriggers)) {
00789       Serial.println("Error: triggerd_read setup trigger");
00790       return false;
00791     }
00792
00793     if (setup_callbackf) setup_callbackf();
00794
```

```
00795     if (start) {
00796       return start_triggers();
00797     }
00798
00799     return true;
00800   }
00801
00802   bool wait_triggered_read(float timeout=1., float timestep=0.01, bool verbose=false)
00803   {
00804     if (wait_triggers(timeout,timestep,verbose)) {
00805       return wait_read(timeout,timestep,verbose);
00806     }
00807
00808     return false;
00809   }
00810
00811
00812   /* ============================================================================
00813      64 bit elapsed time clock based on cpu cycles
00814      note that this is in the tcd1304 namespace
00815   */
00816   static uint64_t cycles64()
00817   {
00818     static uint32_t oldCycles = ARM_DWT_CYCCNT;
00819     static uint32_t highDWORD = 0;
00820     uint32_t newCycles = ARM_DWT_CYCCNT;
00821     if (newCycles < oldCycles)
00822     {
00823         ++highDWORD;
00824     }
00825     oldCycles = newCycles;
00826     return (((uint64_t)highDWORD « 32) | newCycles);
00827   }
00828
00829   /* ------------------------------------------------------
00830      Elapsed time from first frame (sh) to most recent (cf actual timer interval)
00831   */
00832   static double sh_elapsed_secs()
00833   {
00834     return (double)(sh_cyccnt64_now - sh_cyccnt64_start)/F_CPU;
00835   }
00836
00837   static double sh_difference_secs()
00838   {
00839     return (double)(sh_cyccnt64_now - sh_cyccnt64_prev)/F_CPU;
00840   }
00841
00842   static double sh_exposure_secs()
00843   {
00844     return (double)sh_cyccnt64_exposure/F_CPU;
00845   }
00846   /* ------------------------------------------------------
00847      Elapsed time from timer start to most recent timer interrupt
00848   */
00849   static double timer_elapsed_secs()
00850   {
00851     return (double)(timer_cyccnt64_now - timer_cyccnt64_start)/F_CPU;
00852   }
00853
00854   static double timer_difference_secs()
00855   {
00856     return (double)(timer_cyccnt64_now - timer_cyccnt64_prev)/F_CPU;
00857   }
00858
00859   /* ------------------------------------------------------
00860      Elapsed time from timer start to most recent timer interrupt
00861   */
00862   static double trigger_elapsed_secs()
00863   {
00864     return (double)(trigger_cyccnt64_now - trigger_cyccnt64_start)/F_CPU;
00865   }
00866
00867   static double trigger_difference_secs()
00868   {
00869     return (double)(trigger_cyccnt64_now - trigger_cyccnt64_prev)/F_CPU;
00870   }
00871
00872   /* ============================================================
00873      Print error message
00874   */
00875   static void print_errormsg(const char *name, const char *errmsg)
```

```
00876   {
00877     Serial.print("Error: ");
00878     Serial.print(name);
00879     Serial.print(" ");
00880     Serial.println(errmsg);
00881   }
00882
00883   static void print_errormsg(SubModule *p, const char *errmsg)
00884   {
00885     print_errormsg(p->name,errmsg);
00886   }
00887
00888   static void print_counters()
00889   {
00890     Serial.print(" sh "); Serial.print(sh_counter);
00891     Serial.print(" icg "); Serial.print(icg_counter);
00892     Serial.print(" cnvst "); Serial.print(cnvst_counter);
00893     Serial.print(" read "); Serial.print(read_counter);
00894     Serial.print(" "); Serial.print(read_counts);
00895     Serial.print(" frame "); Serial.print(frame_counter);
00896     Serial.print(" "); Serial.print(frame_counts);
00897     Serial.print(" frameset "); Serial.print(frameset_counter);
00898     Serial.print(" "); Serial.print(frameset_counts);
00899     if (mode==TIMER) {
00900       Serial.print(" timer "); Serial.print(timer_inner_counter);
00901       Serial.print(" "); Serial.print(timer_inner_counts);
00902       Serial.print(" outer "); Serial.print(timer_outer_counter);
00903       Serial.print(" "); Serial.print(timer_outer_counts);
00904     }
00905     if (trigger_mode) {
00906       Serial.print(" triggers "); Serial.print(trigger_counter);
00907       Serial.print(" "); Serial.print(trigger_counts);
00908     }
00909     Serial.println("");
00910   }
00911
00912
00913   /* ============================================================================
00914      Print, check, setup submodule configuration, load into hardware
00915   */
00916   void print_submodule(SubModule *p)
00917   {
00918     char cbuffer[128] = {0};
00919
00920     float frequency = p->period_counts ? F_BUS_ACTUAL/(p->divider*p->period_counts) : 0;
00921     float period_secs = (float) (p->period_counts*p->divider)/F_BUS_ACTUAL;
00922
00923     float A_on_secs = (float)(p->onA_counts*p->divider)/F_BUS_ACTUAL;
00924     float A_off_secs = (float)(p->offA_counts*p->divider)/F_BUS_ACTUAL;
00925     float A_duration_secs = (float)((p->offA_counts-p->onA_counts)*p->divider)/F_BUS_ACTUAL;
00926
00927     float B_on_secs = (float)(p->onB_counts*p->divider)/F_BUS_ACTUAL;
00928     float B_off_secs = (float)(p->offB_counts*p->divider)/F_BUS_ACTUAL;
00929     float B_duration_secs = (float)((p->offB_counts-p->onB_counts)*p->divider)/F_BUS_ACTUAL;
00930
00931     snprintf( cbuffer, sizeof(cbuffer),
00932               "FLEXPWM: %s submod %d mask 0x%x pinA %d muxA %d pinB %d muxB %d irq %d flexpwm %p",
00933               p->name, p->submod, p->mask, p->pinA, p->muxvalA, p->pinB, p->muxvalB, p->irq, p->flexpwm);
00934     Serial.println(cbuffer);
00935
00936     snprintf( cbuffer, sizeof(cbuffer),
00937           "flexpwm: %s period %u presc %d div %d => %.6g secs %.6g Hz ctrl2_mask x%02x",
00938           p->name, p->period_counts, p->prescale, p->divider, period_secs, frequency, p->ctrl2_mask);
00939     Serial.println(cbuffer);
00940
00941     snprintf( cbuffer, sizeof(cbuffer),
00942           "flexpwm: %s A pin %d mux 0x%x on %u off %u %s => %.6g to %.6g, %.6g secs",
00943           p->name, p->pinA, p->muxvalA, p->onA_counts, p->offA_counts,
00944           p->invertA?"inverting":"noninverting",
00945           A_on_secs, A_off_secs, A_duration_secs);
00946     Serial.println(cbuffer);
00947
00948     snprintf( cbuffer, sizeof(cbuffer),
00949           "flexpwm: %s B pin %d mux 0x%x on %u off %u %s => %.6g to %.6g, %.6g secs",
00950           p->name, p->pinB, p->muxvalB, p->onB_counts, p->offB_counts,
00951           p->invertB?"inverting":"noninverting",
00952           B_on_secs, B_off_secs, B_duration_secs);
00953     Serial.println(cbuffer);
00954   }
00955
00956   // ----------------------------------------------------
```

```
00957   bool check_submodule(SubModule *p)
00958   {
00959     bool retv = true;
00960     if (p->divider<1) {
00961       print_errormsg(p->name, "divider < 1");
00962       retv = false;
00963     }
00964     if (p->divider>128) {
00965       print_errormsg(p->name, "divider > 128");
00966       retv = false;
00967     }
00968
00969     if (p->onA_counts || p->offA_counts) {
00970       if (p->onA_counts>=p->offA_counts) {
00971         print_errormsg(p->name, "onA > offA");
00972         retv = false;
00973       }
00974       if (p->offA_counts>p->period_counts) {
00975         print_errormsg(p->name, "offA >= period");
00976         retv = false;
00977       }
00978     }
00979
00980     if (p->onB_counts || p->offB_counts) {
00981       if (p->onB_counts>=p->offB_counts) {
00982         print_errormsg(p->name, "onB > offB");
00983         retv = false;
00984       }
00985       if (p->offB_counts>p->period_counts) {
00986         print_errormsg(p->name, "offB >= period");
00987         retv = false;
00988       }
00989     }
00990
00991     return retv;
00992   }
00993
00994   // -----------------------------------------------------
00995   bool print_and_check_submodule(SubModule *p)
00996   {
00997     print_submodule(p);
00998     return check_submodule(p);
00999   }
01000
01001   // -----------------------------------------------------
01002   void load_submodule(SubModule *p)
01003   {
01004     IMXRT_FLEXPWM_t *q = p->flexpwm;
01005     unsigned int submod = p->submod;
01006     uint16_t mask = p->mask;
01007
01008     Serial.print("loading sub_module ");
01009     Serial.println(p->name);
01010
01011     // stop this channel - harmless if it was done globally already
01012     q->MCTRL |= FLEXPWM_MCTRL_CLDOK(mask);
01013     q->MCTRL &= ~FLEXPWM_MCTRL_RUN(mask);
01014
01015     q->SM[submod].CTRL = FLEXPWM_SMCTRL_FULL | FLEXPWM_SMCTRL_PRSC(p->prescale);
01016
01017     q->SM[submod].INIT = 0;
01018     q->SM[submod].VAL0 = 0;
01019     q->SM[submod].VAL1 = p->period_counts - 1;
01020     q->SM[submod].VAL2 = p->onA_counts;
01021     q->SM[submod].VAL3 = (p->offA_counts > 0) ? p->offA_counts: 0;
01022     q->SM[submod].VAL4 = p->onB_counts;
01023     q->SM[submod].VAL5 = (p->offB_counts > 0) ? p->offB_counts : 0;
01024
01025     // Convenience, save the clock period in seconds
01026     p->period_secs = (float) p->period_counts * ((float)(1<<p->prescale)/ F_BUS_ACTUAL);
01027
01028     // Do we have a Pin for the A channel?
01029     if (p->pinA != 0xFF && p->offA_counts) {
01030
01031       q->OUTEN |= FLEXPWM_OUTEN_PWMA_EN(mask);
01032
01033       *(portConfigRegister(p->pinA)) =  p->muxvalA;
01034
01035       if (p->invertA) {
01036         q->SM[submod].OCTRL |= 1<<10;  // Is inverted
01037       }
```

```
01038       else {
01039         q->SM[submod].OCTRL &= ~(1<<10);  // Is not inverted
01040       }
01041     }
01042     else {
01043       q->OUTEN &= ~FLEXPWM_OUTEN_PWMA_EN(mask);
01044     }
01045
01046     // Do we have a Pin for the B channel?
01047     if (p->pinB != 0xFF && p->offB_counts) {
01048
01049       q->OUTEN |= FLEXPWM_OUTEN_PWMB_EN(mask);
01050
01051       *(portConfigRegister(p->pinB)) = p->muxvalB;
01052
01053       if (p->invertB) {
01054         q->SM[submod].OCTRL |= 1<<9;  // Is inverted
01055       }
01056       else {
01057         q->SM[submod].OCTRL &= ~(1<<9);  // Is not inverted
01058       }
01059     }
01060     else {
01061       q->OUTEN &= ~FLEXPWM_OUTEN_PWMB_EN(mask);
01062     }
01063
01064     // Setup shared clocks and forced starts
01065     q->SM[submod].CTRL2 = p->ctrl2_mask;
01066
01067     p->newvals = false;
01068   }
01069
01070   // ------------------------------------------------------------------------
01071   bool setup_submodule( SubModule *p, uint8_t prescale, uint16_t period_counts,
01072                         uint16_t onA_counts, uint16_t offA_counts, bool invertA,
01073                         uint16_t onB_counts, uint16_t offB_counts, bool invertB,
01074                         uint16_t ctrl2_mask)
01075   {
01076     if (p) {
01077       p->divider = (1<<p->prescale);
01078       p->period_counts = period_counts;
01079
01080       p->onA_counts = onA_counts;
01081       p->offA_counts = offA_counts;
01082       p->invertA = invertA;
01083
01084       p->onB_counts = onB_counts;
01085       p->offB_counts = offB_counts;
01086       p->invertB = invertB;
01087
01088       p->ctrl2_mask = ctrl2_mask;
01089
01090       if (print_and_check_submodule(p)) {
01091         load_submodule(p);
01092         return true;
01093       }
01094     }
01095     return false;
01096   }
01097
01098   /* ========================================================================
01099      Attach ISR and enable
01100      see above, CMPF_MASKA_ON, CMPF_MASKA_OFF, etc
01101   */
01102   void attach_isr( SubModule *p, uint16_t cmpf_mask, void (*isrf)())
01103   {
01104     IMXRT_FLEXPWM_t *q = p->flexpwm;
01105     unsigned int submod = p->submod;
01106     uint16_t status;
01107
01108     // bookkeeping to support renabling
01109     p->inten_mask = cmpf_mask;
01110     p->isr = isrf;
01111
01112     // disable the irq for this submodule
01113     NVIC_DISABLE_IRQ(p->irq);
01114
01115     // clear all of this module's interrupt status bits
01116     status = q->SM[submod].STS;
01117     q->SM[submod].STS = status;
01118
```

```
01119     // enable the specified bits only
01120     q->SM[submod].INTEN = cmpf_mask;
01121     p->intena_mask = cmpf_mask;
01122
01123     // register the isr to this irq
01124     attachInterruptVector(p->irq, isrf);
01125
01126     // and now, enable interrupts on this irq
01127     NVIC_ENABLE_IRQ(p->irq);
01128   }
01129
01130
01131   /* ============================================================
01132      Setup callbacks for frames (a single frameset) completed.
01133   */
01134   void clear_frames_completed_callback()
01135   {
01136     frames_completed_callback = 0;
01137   }
01138
01139   void load_frames_completed_callback(void (*callback)(), unsigned int nframes=0)
01140   {
01141     // allow for rearm callback. same nframes
01142     if (nframes) {
01143       frame_counts = nframes;
01144     }
01145     frames_completed_callback = callback;
01146   }
01147
01148   /* ============================================================
01149      Setup callbacks for frameset completed.
01150   */
01151   void clear_framesets_completed_callback()
01152   {
01153     framesets_completed_callback = 0;
01154   }
01155
01156   void load_framesets_completed_callback(void (*callback)(), unsigned int nsets=0)
01157   {
01158     // allow for rearm callback. same nframes
01159     if (nsets) {
01160       frameset_counts = nsets;
01161     }
01162     framesets_completed_callback = callback;
01163   }
01164
01165   /* ============================================================================
01166      FlexPWM stop and wait
01167   */
01168
01169   inline static bool flexpwm_running = false;
01170
01171   static void flexpwm_start()
01172   {
01173     oops_flag = false;
01174     error_flag = false;
01175     flexpwm_running = true;
01176     flexpwm->MCTRL |= 0xF;   // set load ok for all four submodules
01177     flexpwm->MCTRL |= ((CLK_MASK|SH_MASK|ICG_MASK) « 8); // set run clk, sh, icg
01178   }
01179
01180   static void flexpwm_stop()
01181   {
01182     flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(0xF);
01183     flexpwm->MCTRL = 0; // stop everything
01184     flexpwm_running = false;
01185   }
01186
01187   bool flexpwm_wait(float timeout_=1., float timestep_=0.01, bool verbose=false)
01188   {
01189     uint32_t timeout = (uint) (timeout_ * 1000);
01190     uint32_t increment = (uint) (timestep_ * 1000);
01191     uint32_t elapsed = 0;
01192
01193     if (verbose) {
01194       Serial.print("flexpwm_wait "); Serial.print(timeout);
01195       Serial.print(" "); Serial.println(increment);
01196     }
01197
01198     while(flexpwm_running && !error_flag && elapsed < timeout) {
01199       delay(increment);
```

```
01200       elapsed += increment;
01201     }
01202     if (error_flag) {
01203       Serial.println("Error: flexpwm_wait error_flag is set.");
01204       return false;
01205     }
01206     if (elapsed >= timeout) {
01207       Serial.print("Error: flexpwm_wait timeout" );
01208       Serial.print(" elapsed "); Serial.print(elapsed);
01209       Serial.print(" timeout "); Serial.print(timeout);
01210       Serial.println(" millisecs");
01211       return false;
01212     }
01213     if (flexpwm_running) {
01214       Serial.print("Error: flexpwm_wait oops!  Return with frameset still running");
01215       Serial.print(" elapsed "); Serial.print(elapsed);
01216       Serial.print(" timeout "); Serial.print(timeout);
01217       Serial.println(" millisecs");
01218       return false;
01219     }
01220
01221     if (verbose) {
01222       Serial.print("Success: flexpwm_wait");
01223       Serial.print(" running "); Serial.print(flexpwm_running);
01224       Serial.print(" error "); Serial.print(error_flag);
01225       Serial.print(" elapsed "); Serial.print(elapsed);
01226       Serial.print(" timeout "); Serial.print(timeout);
01227       Serial.println(" millisecs");
01228     }
01229
01230     return true;
01231   }
01232
01236
01237   inline static bool pulse_armed = false;
01238
01239
01240   static void pulse_sh_isr()
01241   {
01242     uint16_t status;
01243
01244     bool do_sync_toggle_here = false;
01245
01246     // this is a trailing edge interrupt := exposure timer
01247     uint64_t cyccnt64_now = cycles64();
01248
01249     // clear the interrupt
01250     status = flexpwm->SM[SH_SUBMODULE].STS;
01251     flexpwm->SM[SH_SUBMODULE].STS = status;
01252
01253 #if 1
01254     // ====================================
01255     // no clearing pulses
01256     if (!sh_clearing_counts) {
01257       // no more sh interrupts
01258       flexpwm->SM[SH_SUBMODULE].INTEN = 0;
01259
01260       // never on again until next start
01261       flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01262       flexpwm->SM[SH_SUBMODULE].VAL2 = 0xFFFF;
01263       flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01264
01265       do_sync_toggle_here = true;
01266     }
01267
01268     // first pulse
01269     else if (!sh_clearing_counter) {
01270       /* shorten the period, this will happen
01271      after completing the present period. */
01272       flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01273       flexpwm->SM[SH_SUBMODULE].VAL1 = sh_short_period_counts;
01274       flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01275
01276       // this is the end of the previous exposure
01277       do_sync_toggle_here = true;
01278
01279       // need to count
01280       sh_clearing_counter++;
01281     }
01282
01283     // last pulse?
```

```
01284     else if (++sh_clearing_counter == sh_clearing_counts) {
01285       // no more sh interrupts
01286       flexpwm->SM[SH_SUBMODULE].INTEN = 0;
01287 
01288       // never on again until next start
01289       flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01290       flexpwm->SM[SH_SUBMODULE].VAL2 = 0xFFFF;
01291       flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01292 
01293       sh_clearing_counter = 0;
01294 
01295       // this is the start of the next exposure
01296       do_sync_toggle_here = true;
01297     }
01298 
01299     // for elapsed time and exposure
01300     sh_cyccnt64_prev = sh_cyccnt64_now;
01301     sh_cyccnt64_now  = cyccnt64_now;
01302 
01303     // sync is toggled on start and end of exposure
01304     if (sync_enabled && do_sync_toggle_here) {
01305       digitalToggleFast(SYNC_PIN);
01306       synctoggled = !synctoggled;
01307     }
01308 
01309     // ====================================
01310 #else
01311     sh_clearing_counter++;
01312 
01313     // Either no clearing pulses, or clearing is done
01314     if (sh_clearing_counter >= sh_clearing_counts) {
01315       // no more sh interrupts
01316       flexpwm->SM[SH_SUBMODULE].INTEN = 0;
01317 
01318       // never on again until next start
01319       flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01320       flexpwm->SM[SH_SUBMODULE].VAL2 = 0xFFFF;
01321       flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01322 
01323       sh_clearing_counter = 0;
01324     }
01325 
01326     // First clearing pulse
01327     else if (sh_clearing_counter == 1) {
01328       /* shorten the period, this will happen
01329      after completing the present period. */
01330       flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01331       flexpwm->SM[SH_SUBMODULE].VAL1 = sh_short_period_counts;
01332       flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01333     }
01334 
01335     // for elapsed time and exposure
01336     sh_cyccnt64_prev = sh_cyccnt64_now;
01337     sh_cyccnt64_now  = cyccnt64_now;
01338 
01339     // sync toggles on trailing edge of SH
01340     if (sync_enabled) {
01341       digitalToggleFast(SYNC_PIN);
01342       synctoggled = !synctoggled;
01343     }
01344 #endif
01345 
01346     // bookkeeping
01347     sh_counter++;
01348 
01349     // diagnostics
01350     if (!(status&CMPF_MASKA_OFF)) {
01351       oops_flag = true;
01352       Serial.println("OOPS! pulse sh without off bit set");
01353     }
01354   }
01355 
01356   static void pulse_icg_isr()
01357   {
01358     uint16_t status;
01359 
01360     status = flexpwm->SM[ICG_SUBMODULE].STS;
01361     flexpwm->SM[ICG_SUBMODULE].STS = status;
01362 
01363     //Serial.print("icg_isr "); print_counters();
01364 
```

```
01365     // ------------------------------------------
01366     // Start the cnvst clock
01367     flexpwm->MCTRL |= FLEXPWM_MCTRL_RUN(CNVST_MASK);
01368     // ------------------------------------------
01369
01370     // no more icg interrupts
01371     flexpwm->SM[ICG_SUBMODULE].INTEN = 0;
01372
01373     // never on again
01374     flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(ICG_MASK);
01375     flexpwm->SM[ICG_SUBMODULE].VAL2 = 0xFFFF;
01376     flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(ICG_MASK);
01377
01378     flexpwm->SM[CLK_SUBMODULE].CTRL2 = FLEXPWM_SMCTRL2_FORCE;  // force out while ldok, initializes the
      counters
01379
01380     // here is our exposure, diff to most recent previous sh gate
01381     sh_cyccnt64_exposure = sh_cyccnt64_now - sh_cyccnt64_prev;
01382
01383     // bookkeeping
01384     icg_counter++;
01385
01386     // diagnostics
01387     if (!(status&CMPF_MASKA_OFF)) {
01388       oops_flag = true;
01389       Serial.println("OOPS! pulse icg without off bit set");
01390     }
01391   }
01392
01393   static void pulse_cnvst_isr()
01394   {
01395     uint16_t status;
01396
01397     status = flexpwm->SM[CNVST_SUBMODULE].STS;
01398     flexpwm->SM[CNVST_SUBMODULE].STS = status;
01399
01400     if ((status&CMPF_MASKA_OFF)) {
01401
01402       if (read_counter < read_counts) {
01403
01404 #ifdef ALLINONEBOARD
01405         adc->adc0->startReadFast(ANALOGPIN);
01406         while ( adc->adc0->isConverting() );
01407         *read_pointer = adc->adc0->readSingle();
01408 #else
01409         // Assert the convert pin
01410         SETCNVST;
01411         delayNanoseconds( 670 );  // 710 nanoseconds minus spi setup time
01412         CLEARCNVST;               // need 30 nanoseconds after this
01413
01414         *read_pointer = SPI.transfer16(0xFFFF);
01415         *read_pointer ^= (0x1<<15);
01416 #endif
01417
01418         // bookkeeping for the read
01419         read_pointer++;
01420         read_counter++;
01421
01422         // The read is done
01423         if (read_counter == read_counts) {
01424
01425           // no more cnvst interrupts
01426           flexpwm->SM[CNVST_SUBMODULE].INTEN = 0;
01427
01428           // Stop everything on this flexpwm
01429           // ** Indicate stop only after callback **
01430           flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(0xF);  // clear ldok for all submodules
01431           flexpwm->MCTRL = 0;                          // clear run for all submodules
01432
01433           // ----------------------------------------
01434           // User supplied function, per read complete
01435           // Recommend that the user ignore frame 0
01436           if (read_callback) {
01437             read_callback();
01438           }
01439
01440           // ** Now we can indicate stopped **
01441           flexpwm_running = false;
01442
01443           // ==========================================
01444           // Frame bookkeeping, re-arm etc
```

```
01445           frame_counter++;
01446
01447           // More frames?
01448           if (frame_counter < frame_counts) {
01449             pulse_arm();
01450           }
01451
01452           // Nope, we're done with this frameset
01453           else if (frame_counter == frame_counts) {
01454
01455         if (frames_completed_callback) {
01456           frames_completed_callback();
01457         }
01458
01459             // frameset completed, update frameset counter
01460             frameset_counter++;
01461
01462             // More framesets?
01463             if (frameset_counter < frameset_counts) {
01464               pulse_init_frames();  // init the icg counter too.
01465             }
01466
01467             // Nope, we're done with all of the framesets
01468             else if (frameset_counter == frameset_counts) {
01469
01470               if (framesets_completed_callback) {
01471                 framesets_completed_callback();
01472               }
01473
01474               // reset sync pin
01475               if (synctoggled) {
01476                 digitalToggleFast(SYNC_PIN);
01477                 synctoggled = false;
01478               }
01479
01480               // and get ready for the next frame set
01481               pulse_init_frameset();
01482             }
01483
01484             // oops, shouldn't get here
01485             else {
01486               oops_flag = true;
01487               Serial.println("Oops!  cnvst interrupt after frameset_counts complete");
01488             }
01489
01490           }
01491
01492           // oops, shouldn't get here
01493           else {
01494             oops_flag = true;
01495             Serial.println("Oops!  cnvst interrupt after frame_counts complete");
01496           }
01497
01498         }
01499
01500       }
01501
01502       // oops, shouldn't get here
01503       else {
01504         oops_flag = true;
01505         Serial.println("OOPS! pulse cnvst interrupt after read_counts complete");
01506       }
01507
01508     }
01509
01510     // oops, shouldn't get here
01511     else {
01512       oops_flag = true;
01513       Serial.print("OOPS! pulse cnvst without off bit set ");
01514       Serial.println(status,HEX);
01515     }
01516
01517     // diagnostics
01518     cnvst_counter++;
01519
01520   }
01521
01522   static void pulse_start()
01523   {
01524     if (pulse_armed) {
01525       sh_clearing_counter = 0;
```

```
01526       flexpwm_start();
01527     }
01528     else {
01529       stop_runs_only();
01530       Serial.println("Error: pulse_start() - but not armed");
01531       error_flag = true;
01532     }
01533   }
01534
01535   static void pulse_arm()
01536   {
01537     uint16_t status;
01538
01539     if (!busytoggled) {
01540       busytoggled = true;
01541       digitalToggleFast(BUSY_PIN);
01542     }
01543
01544     read_pointer = read_buffer;
01545     read_counter = 0;
01546
01547     sh_clearing_counter = 0;
01548
01549     // Restore the SH submodule counter and interrupt enable
01550     status = flexpwm->SM[SH_SUBMODULE].STS;
01551     flexpwm->SM[SH_SUBMODULE].STS = status;
01552
01553     flexpwm->SM[SH_SUBMODULE].INTEN = CMPF_MASKA_OFF;
01554
01555     flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(SH_MASK);
01556     flexpwm->SM[SH_SUBMODULE].VAL1 = sh.period_counts - 1;
01557     flexpwm->SM[SH_SUBMODULE].VAL2 = sh.onA_counts;
01558     flexpwm->SM[SH_SUBMODULE].VAL3 = sh.offA_counts;
01559     flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(SH_MASK);
01560
01561     // Restore the ICG submodule counter and interrupt enable
01562     status = flexpwm->SM[ICG_SUBMODULE].STS;
01563     flexpwm->SM[ICG_SUBMODULE].STS = status;
01564
01565     flexpwm->SM[ICG_SUBMODULE].INTEN = CMPF_MASKA_OFF;
01566
01567     flexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(ICG_MASK);
01568     flexpwm->SM[ICG_SUBMODULE].VAL2 = icg.onA_counts;
01569     flexpwm->SM[ICG_SUBMODULE].VAL3 = icg.offA_counts;
01570     flexpwm->MCTRL |= FLEXPWM_MCTRL_LDOK(ICG_MASK);
01571
01572     // Restore the CNVST submodule interrupt enable
01573     status = flexpwm->SM[CNVST_SUBMODULE].STS;
01574     flexpwm->SM[CNVST_SUBMODULE].STS = status;
01575
01576     flexpwm->SM[CNVST_SUBMODULE].INTEN = CMPF_MASKA_OFF;
01577
01578 #ifdef DEBUG
01579     Serial.println("pulse armed");
01580 #endif
01581     pulse_armed = true;
01582   }
01583
01584   static void pulse_init_frames()
01585   {
01586     sh_cyccnt64_start   = 0;
01587     sh_cyccnt64_prev    = 0;
01588     sh_cyccnt64_now     = 0;
01589
01590     sh_counter    = 0;
01591     icg_counter   = 0;
01592     cnvst_counter = 0;
01593
01594     sh_clearing_counter = 0;
01595
01596     frame_counter = 0;
01597
01598     pulse_arm();
01599
01600 #ifdef DEBUG
01601     Serial.println("pulse init frames");
01602 #endif
01603   }
01604
01605   static void pulse_init_frameset()
01606   {
```

```
01607     pulse_init_frames();
01608
01609     frameset_counter = 0;
01610
01611     pulse_arm();
01612   }
01613
01614   bool setup_pulse(float clk_secs, float sh_secs, float sh_offset_secs, float icg_secs, float
      icg_offset_secs,
01615                    uint16_t *buffer, unsigned int nbuffer, void (*callbackf)())
01616   {
01617     char cbuffer[128] = {0};
01618     unsigned int cnvst_delay = 1;
01619
01620     // stop everything and disconnect irqs
01621     stop_with_irqs();
01622
01623     // clear the error flags
01624     clear_error_flags();
01625
01626     // clear run and trigger mode
01627     clear_mode();
01628
01629     // clear sync and busy pins
01630     clear_sync_busy_pins();
01631
01632
01633     sprintf(cbuffer,
01634             "tcd1304 setup pulse with clk %.5gs sh %.5gs offset %.5gs icg offset %.5gs",
01635         clk_secs, sh_secs, sh_offset_secs, icg_offset_secs);
01636     Serial.println(cbuffer);
01637
01638     // clear elapsed times
01639     sh_cyccnt64_start   = 0;
01640     sh_cyccnt64_prev    = 0;
01641     sh_cyccnt64_now     = 0;
01642
01643     timer_cyccnt64_start   = 0;
01644     timer_cyccnt64_prev    = 0;
01645     timer_cyccnt64_now     = 0;
01646
01647     trigger_cyccnt64_start   = 0;
01648     trigger_cyccnt64_prev    = 0;
01649     trigger_cyccnt64_now     = 0;
01650
01651     // clear bookkeeping counters
01652     sh_counter    = 0;
01653     icg_counter   = 0;
01654     cnvst_counter = 0;
01655
01656     sh_clearing_counter = 0;
01657
01658     // default to 1 frame and 1 frameset
01659     frame_counter = 0;
01660     frame_counts = 1;
01661
01662     frameset_counter = 0;
01663     frameset_counts = 1;
01664
01665     // ------------------------------------------------------------------
01666     // Setup the master clock
01667
01668     if (clk_secs < 0.25E-6 || clk_secs > 1.25E-6) {
01669       sprintf(cbuffer,
01670               "Error: setup_flexpwm_single_sequence with clk interval %.6g secs out of range 1E-6 to
      5.E-6",
01671               clk_secs);
01672       Serial.println(cbuffer);
01673       return false;
01674     }
01675
01676     clk.prescale = 0;
01677     clk.divider   = (1<<clk.prescale);
01678
01679     clk.period_counts = ceil(clk_secs*F_BUS_ACTUAL/clk.divider);
01680
01681     clk.onA_counts    = 0;
01682     clk.offA_counts   = (clk.period_counts/2);
01683     clk.invertA       = false;
01684
01685     clk.onB_counts    = 0;
```

```
01686     clk.offB_counts   = 0;
01687     clk.invertB       = false;
01688
01689     clk.inten_mask    = 0;
01690
01691     clk.ctrl2_mask    = PWM_CTRL2_CLOCK_MASTER;
01692
01693     // ------------------------------------------------------------------
01694     // Setup the CNVST clock, 4 times the clock period,
01695     cnvst.prescale = clk.prescale;
01696     cnvst.divider = (1«cnvst.prescale);
01697
01698     cnvst.period_counts = 4*clk.period_counts;
01699
01700     cnvst.onA_counts    = (cnvst_delay + cnvst_extra_delay_counts)*clk.period_counts;    // allow extra
      delay for testing
01701     cnvst.offA_counts   = cnvst.onA_counts + ceil(CNVST_PULSE_SECS*F_BUS_ACTUAL/cnvst.divider);
01702     cnvst.invertA       = false;
01703
01704     cnvst.onB_counts    = 0;
01705     cnvst.offB_counts   = 0;
01706     cnvst.invertB       = false;
01707
01708     //cnvst.ctrl2_mask    = PWM_CTRL2_CLOCK_SYNC;
01709     cnvst.ctrl2_mask    = PWM_CTRL2_CLOCK_MASTER; // needs to be master, because run bit is disabled when
      running from clk's clock.
01710
01711     // ------------------------------------------------------------------
01712     // setup the sh, sh_offset-icg_offset is the icg-sh timing, runs once, isr has to set on,off to 0xffff
01713     sh.prescale = clk.prescale;
01714     sh.divider = (1«sh.prescale);
01715
01716     sh.period_counts  = 0x8000;
01717     sh.onA_counts     = ceil(sh_offset_secs*F_BUS_ACTUAL/sh.divider);
01718     sh.offA_counts    = sh.onA_counts + ceil(sh_secs*F_BUS_ACTUAL/sh.divider);
01719     sh.invertA        = false;
01720
01721     sh.onB_counts     = 0;
01722     sh.offB_counts    = 0;
01723     sh.invertB        = false;
01724
01725     sh.ctrl2_mask     = PWM_CTRL2_CLOCK_SLAVE;
01726     //sh.ctrl2_mask     = FLEXPWM_SMCTRL2_CLK_SEL(0x2);
01727
01728     // ------------------------------------------------------------------
01729     // setup icg,  icg interrupt has to stop sh and icg by moving val2  to > val1
01730     icg.prescale = clk.prescale;
01731     icg.divider = (1«icg.prescale);
01732
01733     icg.period_counts = 0x8000;
01734     icg.onA_counts = ceil(icg_offset_secs*F_BUS_ACTUAL/icg.divider);
01735     icg.offA_counts = icg.onA_counts + ceil(icg_secs*F_BUS_ACTUAL/icg.divider);
01736     icg.invertA       = true;
01737
01738     icg.onB_counts    = 0;
01739     icg.offB_counts   = 0;
01740     icg.invertB       = false;
01741
01742     icg.ctrl2_mask     = PWM_CTRL2_CLOCK_SLAVE;
01743     //icg.ctrl2_mask    = FLEXPWM_SMCTRL2_CLK_SEL(0x2);
01744
01745     // if we are going to run some clearing cycles on the shift gate
01746     if (sh_clearing_counts) {
01747       // make sure it comes after the icg isr and before the first cnvst isr
01748       sh.period_counts = icg.offA_counts + clk.period_counts;
01749     }
01750
01751     // if we go to short clearing cycles, this is the period
01752     sh_short_period_counts = 2*(sh.offA_counts - sh.onA_counts) + 1;
01753     if (sh_short_period_counts <= sh.offA_counts) {
01754       sh_short_period_counts = sh.offA_counts + 1;
01755     }
01756
01757     // ------------------------------------------------------------------
01758     Serial.println("");
01759     if (!print_and_check_submodule(&clk)) {
01760       return false;
01761     }
01762
01763     Serial.println("");
01764     if (!print_and_check_submodule(&icg)) {
```

```
01765       return false;
01766     }
01767
01768     Serial.println("");
01769     if (!print_and_check_submodule(&sh)) {
01770       return false;
01771     }
01772
01773     Serial.println("");
01774     if (!print_and_check_submodule(&cnvst)) {
01775       return false;
01776     }
01777
01778     Serial.println("");
01779     Serial.print("flexpwm: clearing_pulses ");
01780     Serial.println(sh_clearing_counts);
01781
01782     // ------------------------------------------------------------------
01783     load_submodule(&clk);
01784     load_submodule(&icg);
01785     load_submodule(&sh);
01786     load_submodule(&cnvst);
01787
01788     // ------------------------------------------------
01789     // Setup the readout buffer
01790     read_buffer   = buffer;
01791     read_counts   = nbuffer;
01792
01793     read_pointer  = read_buffer;
01794     read_counter  = 0;
01795
01796     read_callback = callbackf;
01797
01798     // ------------------------------------------------
01799     attach_isr( &sh, CMPF_MASKA_OFF, pulse_sh_isr);
01800     attach_isr( &icg, CMPF_MASKA_OFF, pulse_icg_isr);
01801     attach_isr( &cnvst, CMPF_MASKA_OFF, pulse_cnvst_isr);
01802
01803     // ------------------------------------------------
01804     // stuff that other routines need to know
01805     mode = PULSE;
01806     pulse_armed  = true;
01807     trigger_mode = false;
01808
01809     // timer needs this
01810     timer_interframe_min_secs  = (icg.offA_counts/F_BUS_ACTUAL)*icg.divider;    // offset before read
      starts
01811     timer_interframe_min_secs += ((float)cnvst.period_counts/F_BUS_ACTUAL)*cnvst.divider * read_counts;
      // read time
01812     timer_interframe_min_secs += USBTRANSFERSECS;
01813
01814     // round up to 1 msec
01815     timer_interframe_min_secs = ceil((timer_interframe_min_secs+1.E-3)/1.E-3)*1.E-3;
01816
01817     Serial.print("TCD1304 setup_pulse success, min frame interval ");
01818     Serial.print(timer_interframe_min_secs,6);
01819     Serial.println(" secs");
01820
01821     return true;
01822   }
01823
01825   // Frameset, short exposure times
01827
01828   inline static bool frameset_armed = false;
01829
01830   static void frameset_sh_isr()
01831   {
01832     uint16_t status;
01833     unsigned int remainder;
01834
01835     // this is a trailing edge interrupt := exposure timer
01836     uint64_t cyccnt64_now = cycles64();
01837
01838     // clear the interrupt
01839     status = flexpwm->SM[SH_SUBMODULE].STS;
01840     flexpwm->SM[SH_SUBMODULE].STS = status;
01841
01842     // this is where we are relative to the icg pulse
01843     remainder = sh_counter % sh_counts_per_icg;
01844
01845     // one test for both pulses beginning and ending the sampling interval
```

```
01846     if (remainder <= 1) {
01847       if (sync_enabled) {
01848         digitalToggleFast(SYNC_PIN);
01849         synctoggled = !synctoggled;
01850       }
01851       sh_cyccnt64_prev = sh_cyccnt64_now;
01852       sh_cyccnt64_now  = cyccnt64_now;
01853       sh_cyccnt64_exposure = cyccnt64_now - sh_cyccnt64_prev;
01854     }
01855
01856     // bookkeeping
01857     sh_counter++;
01858
01859     // diagnostics
01860     if (!(status&CMPF_MASKA_OFF)) {
01861       oops_flag = true;
01862       Serial.println("OOPS! pulse sh without off bit set");
01863     }
01864   }
01865
01866   static void frameset_icg_isr()
01867   {
01868     uint16_t status;
01869
01870     status = flexpwm->SM[ICG_SUBMODULE].STS;
01871     flexpwm->SM[ICG_SUBMODULE].STS = status;
01872
01873     //Serial.print("icg_isr "); print_counters();
01874
01875     // ------------------------------------------
01876     // Start the cnvst clock
01877     flexpwm->MCTRL |= FLEXPWM_MCTRL_RUN(CNVST_MASK);
01878     // ------------------------------------------
01879
01880     // bookkeeping
01881     icg_counter++;
01882
01883     // diagnostics
01884     if (!(status&CMPF_MASKA_OFF)) {
01885       oops_flag = true;
01886       Serial.println("OOPS! pulse icg without off bit set");
01887     }
01888   }
01889
01890   static void frameset_cnvst_isr()
01891   {
01892     uint16_t status;
01893
01894     status = flexpwm->SM[CNVST_SUBMODULE].STS;
01895     flexpwm->SM[CNVST_SUBMODULE].STS = status;
01896
01897     if ((status&CMPF_MASKA_OFF)) {
01898
01899       if (read_counter < read_counts) {
01900
01901 #ifdef ALLINONEBOARD
01902         adc->adc0->startReadFast(ANALOGPIN);
01903         while ( adc->adc0->isConverting() );
01904         *read_pointer = adc->adc0->readSingle();
01905 #else
01906         // Assert the convert pin
01907         SETCNVST;
01908         delayNanoseconds( 670 );  // 710 nanoseconds minus spi setup time
01909         CLEARCNVST;               // need 30 nanoseconds after this
01910
01911         *read_pointer = SPI.transfer16(0xFFFF);
01912         *read_pointer ^= (0x1<<15);
01913 #endif
01914
01915         // bookkeeping for the read
01916         read_pointer++;
01917         read_counter++;
01918
01919         // The read is done
01920         if (read_counter == read_counts) {
01921
01922           // stop cnvst
01923           flexpwm->MCTRL &= ~FLEXPWM_MCTRL_RUN(CNVST_MASK);
01924
01925           // ----------------------------------------
01926           // User supplied function, per read complete
```

```
01927           // Recommend that the user ignore frame 0
01928           if (read_callback) {
01929             read_callback();
01930           }
01931
01932           // ========================================
01933           // Frame bookkeeping
01934           frame_counter++;
01935
01936           // More frames?
01937           if (frame_counter < frame_counts) {
01938             frameset_arm();
01939           }
01940
01941           // Are we done with this frameset?
01942           else if (frame_counter == frame_counts) {
01943
01944             // stop everything on this flexpwm
01945             flexpwm_stop();
01946
01947         if (frames_completed_callback) {
01948           frames_completed_callback();
01949         }
01950
01951             // frameset completed, update frameset counter
01952             frameset_counter++;
01953
01954             // More framesets?
01955             if (frameset_counter < frameset_counts) {
01956               frameset_init_frames();  // init the icg counter too.
01957             }
01958
01959             // Nope, we're done with all of the framesets
01960             else if (frameset_counter == frameset_counts) {
01961
01962               if (framesets_completed_callback) {
01963                 framesets_completed_callback();
01964               }
01965
01966               // reset sync pin
01967               if (synctoggled) {
01968                 digitalToggleFast(SYNC_PIN);
01969                 synctoggled = false;
01970               }
01971
01972               // and get ready for the next frame set
01973               frameset_init_frameset();
01974
01975             }
01976
01977             // oops, shouldn't get here
01978             else {
01979               oops_flag = true;
01980               Serial.println("Oops!  cnvst interrupt after frameset_counts complete");
01981             }
01982
01983           }
01984
01985           // oops, shouldn't get here
01986           else if (frame_counter > frame_counts) {
01987             oops_flag = true;
01988             Serial.println("Oops!  cnvst interrupt after frame_counts complete.");
01989           }
01990         }
01991       }
01992
01993       // oops, shouldn't get here
01994       else {
01995         oops_flag = true;
01996         Serial.println("OOPS! pulse cnvst interrupt after read_counts complete");
01997       }
01998
01999     }
02000
02001     // oops, shouldn't get here
02002     else {
02003       oops_flag = true;
02004       Serial.print("OOPS! pulse cnvst without off bit set ");
02005       Serial.println(status,HEX);
02006     }
02007
```

```
02008     // diagnostics
02009     cnvst_counter++;
02010
02011   }
02012
02013
02014   static void frameset_start()
02015   {
02016     if (flexpwm_running) {
02017       error_flag = true;
02018       Serial.println("Error: framset already running");
02019       return;
02020     }
02021
02022     if (!frameset_armed) {
02023       error_flag = true;
02024       Serial.println("Error: framset not armed");
02025       return;
02026     }
02027
02028     timer_cyccnt64_start = cycles64();
02029     timer_cyccnt64_prev  = timer_cyccnt64_start;
02030     timer_cyccnt64_now   = timer_cyccnt64_start;
02031
02032     // start the clk, sh, icg
02033     flexpwm_start();
02034   }
02035
02036
02037   // -----------------------------------------------
02038   static void frameset_arm()
02039   {
02040     if (!busytoggled) {
02041       busytoggled = true;
02042       digitalToggleFast(BUSY_PIN);
02043     }
02044
02045     read_pointer = read_buffer;
02046     read_counter = 0;
02047
02048     frameset_armed = true;
02049   }
02050
02051   static void frameset_init_frames()
02052   {
02053     sh_cyccnt64_start   = 0;
02054     sh_cyccnt64_prev    = 0;
02055     sh_cyccnt64_now     = 0;
02056
02057     sh_counter    = 0;
02058     icg_counter   = 0;
02059     cnvst_counter = 0;
02060
02061     frame_counter = 0;
02062
02063     sh_clearing_counter = 0;
02064
02065     frameset_arm();
02066
02067   }
02068
02069   static void frameset_init_frameset()
02070   {
02071     frameset_init_frames();
02072
02073     frameset_counter = 0;
02074
02075     frameset_arm();
02076   }
02077
02078   bool setup_frameset(float clk_secs, float sh_secs, float sh_offset_secs, float icg_secs, float
      icg_offset_secs,
02079                       float exposure_secs, float frame_interval_secs, unsigned int nframes,
02080                       uint16_t *buffer, unsigned int nbuffer, void (*callbackf)())
02081   {
02082     //char cbuffer[128] = {0};
02083     unsigned int cnvst_delay = 1;
02084
02085     unsigned int prescale = 0;
02086     unsigned int divider = 1;
02087
```

```
02088     float clock_period_secs;
02089
02090     unsigned int clock_period_counts;
02091     unsigned int exposure_period_counts;
02092     unsigned int frame_period_counts;
02093
02094
02095     // ------------------------------------------------------------------
02096     // stop everything and disable irqs
02097     stop_with_irqs();
02098
02099     // clear sync and busy pins
02100     clear_sync_busy_pins();
02101
02102     // clear the error flags
02103     clear_error_flags();
02104
02105     // clear run mode and trigger mode
02106     clear_mode();
02107
02108     // ------------------------------------------------------------------
02109     // announce ourselves
02110     Serial.print("#tcd1304 setup frameset, clk "); Serial.print(clk_secs,8);
02111     Serial.print(" sh "); Serial.print(sh_secs,8);
02112     Serial.print(" offset "); Serial.print(sh_offset_secs,8);
02113     Serial.print(" icg "); Serial.print(icg_secs,8);
02114     Serial.print(" offset "); Serial.print(icg_offset_secs,8);
02115     Serial.print(" exposure "); Serial.print(exposure_secs,6);
02116     Serial.print(" interval "); Serial.print(frame_interval_secs,6);
02117     Serial.print(" frames "); Serial.println(nframes);
02118
02119     // ------------------------------------------------------------------
02120     // clear elapsed times
02121     sh_cyccnt64_start   = 0;
02122     sh_cyccnt64_prev    = 0;
02123     sh_cyccnt64_now     = 0;
02124
02125     timer_cyccnt64_start   = 0;
02126     timer_cyccnt64_prev    = 0;
02127     timer_cyccnt64_now     = 0;
02128
02129     trigger_cyccnt64_start   = 0;
02130     trigger_cyccnt64_prev    = 0;
02131     trigger_cyccnt64_now     = 0;
02132
02133     // clear bookkeeping counters
02134     sh_counter    = 0;
02135     icg_counter   = 0;
02136     cnvst_counter = 0;
02137
02138     sh_clearing_counter = 0;
02139
02140     // default to 1 frame and 1 frameset
02141     frame_counter = 0;
02142     //frame_counts = nframes ? nframes : 10;
02143     frame_counts = nframes ? nframes+1 : 10;
02144
02145     frameset_counter = 0;
02146     frameset_counts = 1;
02147
02148     // ------------------------------------------------------------------
02149     // Some basic checks
02150     if (exposure_secs*2 > frame_interval_secs) {
02151       Serial.println("Error: requested exposure > requested frame interval/2");
02152       error_flag = true;
02153       return false;
02154     }
02155
02156     if (clk_secs > exposure_secs) {
02157       Serial.println("Error: requested clk > requested exposure");
02158       error_flag = true;
02159       return false;
02160     }
02161
02162     if (clk_secs < 0.25E-6) {
02163       Serial.println("Error: requested clk < 0.25E-6 (4MHz)");
02164       error_flag = true;
02165       return false;
02166     }
02167
02168     if (clk_secs > 1.25E-6) {
```

```
02169       Serial.println("Error: requested clk > 1.25E-6 (800kHZ)");
02170       error_flag = true;
02171       return false;
02172     }
02173
02174     // -----------------------------------------------------------------
02175     // need to find divider for the frame interval
02176     while (frame_interval_secs * (F_BUS_ACTUAL/divider) > 65533) {  // reserve two time slots, 0xFFFF - 2
02177       if (prescale >= 7) {
02178         Serial.println("Error: requested frame interval is too large");
02179         error_flag = true;
02180         return false;
02181       }
02182       prescale++;
02183       divider = (1<<prescale);
02184     }
02185     Serial.print("#Exposure prescale "); Serial.print(prescale);
02186     Serial.print(" divider "); Serial.println(divider);
02187
02188     clock_period_counts = ceil(clk_secs*F_BUS_ACTUAL);
02189     clock_period_counts = ceil(clock_period_counts/divider) * divider;
02190     clock_period_secs   = (float)clock_period_counts/F_BUS_ACTUAL;
02191     Serial.print("#Clock period counts "); Serial.print(clock_period_counts);
02192     Serial.print(" secs "); Serial.println(clock_period_secs,8);
02193
02194     if ((clock_period_counts < 4)|| (clock_period_secs > (1./TCD1304_MINCLKHZ))|| (clock_period_secs <
      (1./TCD1304_MAXCLKHZ))) {
02195       Serial.println("Error: not able to support this combination of clock and exposure times.");
02196       error_flag = true;
02197       return false;
02198     }
02199     Serial.print("#Clock period counts "); Serial.println(clock_period_counts);
02200
02201     exposure_period_counts = ceil(exposure_secs*F_BUS_ACTUAL);
02202     exposure_period_counts = (exposure_period_counts/clock_period_counts) * clock_period_counts; //
      already a multple of divider
02203     Serial.print("#Exposure period counts "); Serial.println(exposure_period_counts);
02204
02205     frame_period_counts = ceil(frame_interval_secs*F_BUS_ACTUAL);
02206     frame_period_counts = (frame_period_counts/exposure_period_counts) * exposure_period_counts; //
      already a multple of divider
02207     Serial.print("#Frame period counts "); Serial.println(frame_period_counts);
02208
02209
02210     sh_counts_per_icg = frame_period_counts/exposure_period_counts;
02211     Serial.print("#Exposure to frame ratio ");
      Serial.println((float)frame_period_counts/exposure_period_counts);
02212
02213     // -----------------------------------------------------------------
02214     // Setup the master clock, always with divider = 1
02215     clk.prescale      = 0;
02216     clk.divider       = 1;
02217
02218     clk.period_counts = clock_period_counts;
02219
02220     clk.onA_counts    = 0;
02221     clk.offA_counts   = (clk.period_counts/2);
02222     clk.invertA       = false;
02223
02224     clk.onB_counts    = 0;
02225     clk.offB_counts   = 0;
02226     clk.invertB       = false;
02227
02228     clk.inten_mask    = 0;
02229
02230     clk.ctrl2_mask    = PWM_CTRL2_CLOCK_MASTER;
02231
02232     // -----------------------------------------------------------------
02233     // Setup the CNVST clock, 4 times the clock period, on the same clock divider
02234     cnvst.prescale      = clk.prescale;
02235     cnvst.divider       = clk.divider;
02236
02237     cnvst.period_counts = 4*clk.period_counts;
02238
02239     cnvst.onA_counts    = (cnvst_delay + cnvst_extra_delay_counts)*clk.period_counts;    // allow extra
      delay for testing
02240     cnvst.offA_counts   = cnvst.onA_counts + ceil(CNVST_PULSE_SECS*F_BUS_ACTUAL/cnvst.divider);
02241     cnvst.invertA       = false;
02242
02243     cnvst.onB_counts    = 0;
02244     cnvst.offB_counts   = 0;
```

```
02245     cnvst.invertB       = false;
02246
02247     //cnvst.ctrl2_mask    = PWM_CTRL2_CLOCK_SYNC;
02248     cnvst.ctrl2_mask    = PWM_CTRL2_CLOCK_MASTER; // needs to be master, because run bit is disabled when
      running from clk's clock.
02249
02250     // -----------------------------------------------------------------
02251     // setup the sh, sh_offset-icg_offset is the icg-sh timing, runs once, isr has to set on,off to 0xffff
02252     sh.prescale       = prescale;
02253     sh.divider        = divider;
02254
02255     sh.period_counts  = exposure_period_counts/divider;
02256
02257     sh.onA_counts     = ceil(sh_offset_secs*F_BUS_ACTUAL/sh.divider);
02258     sh.offA_counts    = sh.onA_counts + ceil(sh_secs*F_BUS_ACTUAL/sh.divider);
02259     sh.invertA        = false;
02260
02261     sh.onB_counts     = 0;
02262     sh.offB_counts    = 0;
02263     sh.invertB        = false;
02264
02265     sh.ctrl2_mask     = PWM_CTRL2_CLOCK_SLAVE;
02266     //sh.ctrl2_mask     = FLEXPWM_SMCTRL2_CLK_SEL(0x2);
02267
02268     // -----------------------------------------------------------------
02269     // setup icg,  icg interrupt has to stop sh and icg by moving val2  to > val1
02270     icg.prescale      = prescale;
02271     icg.divider       = divider;
02272
02273     icg.period_counts = frame_period_counts/divider;
02274
02275     // icg happens on the second sh pulse
02276     icg.onA_counts    = sh.period_counts + ceil(icg_offset_secs*F_BUS_ACTUAL/icg.divider);
02277     icg.offA_counts   = icg.onA_counts + ceil(icg_secs*F_BUS_ACTUAL/icg.divider);
02278     icg.invertA       = true;
02279
02280     icg.onB_counts    = 0;
02281     icg.offB_counts   = 0;
02282     icg.invertB       = false;
02283
02284     icg.ctrl2_mask     = PWM_CTRL2_CLOCK_SLAVE;
02285     //icg.ctrl2_mask    = FLEXPWM_SMCTRL2_CLK_SEL(0x2);
02286
02287     // -----------------------------------------------------------------
02288     Serial.println("");
02289     if (!print_and_check_submodule(&clk)) {
02290       error_flag = true;
02291       return false;
02292     }
02293
02294     Serial.println("");
02295     if (!print_and_check_submodule(&icg)) {
02296       error_flag = true;
02297       return false;
02298     }
02299
02300     Serial.println("");
02301     if (!print_and_check_submodule(&sh)) {
02302       error_flag = true;
02303       return false;
02304     }
02305
02306     Serial.println("");
02307     if (!print_and_check_submodule(&cnvst)) {
02308       error_flag = true;
02309       return false;
02310     }
02311
02312     // -----------------------------------------------------------------
02313     load_submodule(&clk);
02314     load_submodule(&icg);
02315     load_submodule(&sh);
02316     load_submodule(&cnvst);
02317
02318     // -----------------------------------------
02319     // Setup the readout buffer
02320     read_buffer   = buffer;
02321     read_counts   = nbuffer;
02322
02323     read_pointer  = read_buffer;
02324     read_counter  = 0;
```

```
02325
02326     read_callback = callbackf;
02327
02328     // ------------------------------------------
02329     attach_isr( &sh, CMPF_MASKA_OFF, frameset_sh_isr);
02330     attach_isr( &icg, CMPF_MASKA_OFF, frameset_icg_isr);
02331     attach_isr( &cnvst, CMPF_MASKA_OFF, frameset_cnvst_isr);
02332
02333     // ------------------------------------------
02334     // stuff that other routines need to know
02335     mode            = FRAMESET;
02336     trigger_mode    = false;
02337
02338     frameset_armed  = true;
02339
02340     return true;
02341   }
02342
02343   // ============================================================================
02344   //#define DEBUG_TCD1304_TIMER
02345
02346   inline static bool timer_first_time_flag = true;
02347   inline static bool timer_running = false;
02348
02349   static void timer_isr()
02350   {
02351     volatile uint16_t status;
02352
02353     uint64_t cyccnt64_now = cycles64();
02354
02355     status = timerflexpwm->SM[TIMER_SUBMODULE].STS;
02356     timerflexpwm->SM[TIMER_SUBMODULE].STS = status;
02357
02358     // spurious first invocation
02359     if (!status) {
02360       if (timer_inner_counter) {
02361         error_flag = true;
02362         timer_stop();
02363         Serial.println("Error: OOPS! pulse timer with null status, stopping ");
02364       }
02365       return;
02366     }
02367
02368     timer_inner_counter++;
02369
02370     // competed the inner counter, call the callback
02371     if (timer_first_time_flag || timer_inner_counter == timer_inner_counts) {
02372
02373       timer_cyccnt64_prev = timer_cyccnt64_now;
02374       timer_cyccnt64_now  = cyccnt64_now;
02375
02376       if (timer_callback) {
02377         timer_callback();
02378       }
02379
02380       // Reset the inner counter
02381       timer_inner_counter = 0;
02382
02383       // clear the first time flag
02384       timer_first_time_flag = false;
02385
02386       // Update and check the outer counter, are we done?
02387       timer_outer_counter++;
02388       if (timer_outer_counter == timer_outer_counts) {
02389         // stop the timer only, we might be interrupt driven
02390         timer_stop();
02391       }
02392     }
02393
02394     // diagnostics
02395     if (!(status&timer.intena_mask)) {
02396       timer_stop();
02397       error_flag = true;
02398       Serial.print("Error: OOPS! pulse timer without the right bit, status ");
02399       Serial.println(status,HEX);
02400       print_counters();
02401     }
02402   }
02403
02404   static void timer_start()
02405   {
```

```
02406     if (timer_running) {
02407       error_flag = true;
02408       Serial.println("Error: timer_start() already running");
02409       return;
02410     }
02411 
02412     timer_cyccnt64_start = cycles64();
02413     timer_cyccnt64_prev  = timer_cyccnt64_start;
02414     timer_cyccnt64_now   = timer_cyccnt64_start;
02415 
02416     if (pulse_armed  && frame_counts && timer_inner_counts && timer_outer_counts) {
02417 
02418       oops_flag = false;
02419       error_flag = false;
02420 
02421       timer_running = true;  // do it before the start, in case isr changes it
02422 
02423       frame_counter = 0;
02424       timer_inner_counter = 0;
02425       timer_outer_counter = 0;
02426       timer_first_time_flag = true;
02427 
02428       timerflexpwm->SM[TIMER_SUBMODULE].STS = 0xFF;     // clear all interrupt bits
02429 
02430       timerflexpwm->MCTRL |= TIMER_MASK;        // set load ok for timer submodule
02431       timerflexpwm->MCTRL |= (TIMER_MASK « 8); // set run for timer submodule
02432     }
02433     else {
02434 
02435       error_flag = true;
02436 
02437       Serial.print("Error: timer_start() - but not setup ");
02438       Serial.print(" pulse armed " ); Serial.print(pulse_armed);
02439       Serial.print(" frame_counts "); Serial.print(frame_counts);
02440       Serial.print(" timer_inner_counts "); Serial.print(timer_inner_counts);
02441       Serial.print(" timer_outer_counts "); Serial.println(timer_inner_counts);
02442 
02443       timer_stop();
02444     }
02445   }
02446 
02447   static void timer_stop()
02448   {
02449     timerflexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(TIMER_MASK);
02450     timerflexpwm->MCTRL = 0;
02451     timer_running = false;
02452   }
02453 
02454   static void timer_stop_with_irq()
02455   {
02456     timerflexpwm->MCTRL |= FLEXPWM_MCTRL_CLDOK(TIMER_MASK);
02457     timerflexpwm->MCTRL = 0;
02458     timer_running = false;
02459     NVIC_DISABLE_IRQ(TIMER_IRQ);
02460   }
02461 
02462   bool timer_wait(float timeout_=1., float timestep_=0.01, bool verbose=false)
02463   {
02464     uint32_t timeout = (uint) (timeout_ * 1000);
02465     uint32_t increment = (uint) (timestep_ * 1000);
02466     uint32_t elapsed = 0;
02467 
02468     if (verbose) {
02469       Serial.print("timer_wait "); Serial.print(timeout);
02470       Serial.print(" "); Serial.println(increment);
02471     }
02472 
02473     while(timer_running && !error_flag && elapsed < timeout) {
02474       delay(increment);
02475       elapsed += increment;
02476     }
02477     if (error_flag) {
02478       Serial.println("Error: timer_wait error_flag is set.");
02479       return false;
02480     }
02481     if (elapsed >= timeout) {
02482       Serial.print("Error: timer_wait timeout" );
02483       Serial.print(" elapsed "); Serial.print(elapsed);
02484       Serial.print(" timeout "); Serial.print(timeout);
02485       Serial.println(" millisecs");
02486       return false;
```

```
02487     }
02488     if (timer_running) {
02489       Serial.print("Error: timer_wait oops!  Return with timer still running");
02490       Serial.print(" elapsed "); Serial.print(elapsed);
02491       Serial.print(" timeout "); Serial.print(timeout);
02492       Serial.println(" millisecs");
02493       return false;
02494     }
02495 
02496     if (verbose) {
02497       Serial.print("Success: timer_wait");
02498       Serial.print(" running "); Serial.print(timer_running);
02499       Serial.print(" error "); Serial.print(error_flag);
02500       Serial.print(" elapsed "); Serial.print(elapsed);
02501       Serial.print(" timeout "); Serial.print(timeout);
02502       Serial.println(" millisecs");
02503     }
02504 
02505     return true;
02506   }
02507 
02508   bool setup_timer(float exposure_secs, float exposure_offset_secs, unsigned int ncounts=0)
02509   {
02510     unsigned int u32;
02511     uint16_t cmpf_mask;
02512     char cbuffer[128] = {0};
02513 
02514     // stop everything
02515     stop_runs_only();    // this clears run bits but leaves interrupts attached
02516 
02517     // we cannot touch the run mode, only clear the trigger mode
02518     trigger_mode = false;
02519 
02520     // clear error and oops flags
02521     clear_error_flags();
02522 
02523     // reset elapsed time counters
02524     timer_cyccnt64_start   = 0;
02525     timer_cyccnt64_prev    = 0;
02526     timer_cyccnt64_now     = 0;
02527 
02528     // Check, timer is for single pulse flexpwm only
02529     if ((mode!=PULSE) && (mode!=TIMER)) {
02530       Serial.println("Error: setup_timer, need to call setup_pulse() first");
02531       return false;
02532     }
02533 
02534     // Check, minimum exposure is the readout and transfer time
02535     if (exposure_secs < timer_interframe_min_secs) {
02536       sprintf(cbuffer,
02537               "Error: setup_timer exposure %.6gs is too short for this pulse configuration, need at least
      %.6g",
02538               exposure_secs,timer_interframe_min_secs);
02539       Serial.println(cbuffer);
02540       return false;
02541     }
02542 
02543     // Check, maximum offset is length of one exposure
02544     if (exposure_offset_secs > exposure_secs) {
02545       sprintf(cbuffer,
02546               "Error: setup_timer exposure offset %.6gs is too long, need offset less than exposure",
02547               exposure_offset_secs);
02548       Serial.println(cbuffer);
02549       return false;
02550     }
02551 
02552     /* ======================================================
02553        Setup timer callback, counts and period
02554     */
02555     timer_callback     = pulse_start;
02556     timer_outer_counts = ncounts ? ncounts+1 : frame_counts;
02557     frame_counts = timer_outer_counts;
02558 
02559     // Exposure within one iteration of the counter
02560     if (exposure_secs <= COUNTER_MAX_SECS) {
02561       timer_period_secs   = exposure_secs;
02562       timer_interval_secs = exposure_secs;
02563       timer_inner_counts  = 1;
02564     }
02565 
02566     // Exposure requires multuple iterations, set period greater than transfer and offset
```

```
02567     else {
02568       if (USBTRANSFERSECS > 0.024 || exposure_offset_secs > 0.025) {
02569         timer_period_secs = 0.050;
02570       }
02571       else if (USBTRANSFERSECS > 0.009 || exposure_offset_secs > 0.010) {
02572         timer_period_secs = 0.025;
02573       }
02574       else {
02575         timer_period_secs = 0.010;
02576       }
02577       timer_inner_counts  = 0;
02578     }
02579 
02580     /* ========================================================
02581        From here we setup the control structure and hardware
02582     */
02583     timer.prescale = 0;
02584     timer.divider = 1;
02585     u32 = (timer_period_secs*F_BUS_ACTUAL)/timer.divider;
02586     while (u32 > 65535 && timer.prescale < 7) {
02587       timer.prescale++;
02588       timer.divider = (1<<timer.prescale);
02589       u32 = (timer_period_secs*F_BUS_ACTUAL)/timer.divider;
02590     }
02591 
02592     if (u32 > 65535) {
02593       Serial.println("Error: unable to find prescale divider for exposure time");
02594       return false;
02595     }
02596 
02597     timer.period_counts = u32;
02598 
02599     timer_period_secs = (float) timer.period_counts * timer.divider / F_BUS_ACTUAL;
02600 
02601     // round to nearest multiple of timer_period_secs
02602     if (!timer_inner_counts) {
02603       timer_inner_counts = floor((exposure_secs+timer_period_secs/2)/timer_period_secs);
02604     }
02605 
02606     timer_interval_secs = timer_period_secs * timer_inner_counts;
02607 
02608     Serial.print("timer: timer inner period secs "); Serial.print(timer_period_secs,6);
02609     Serial.print(" counts ") ; Serial.print(timer_inner_counts);
02610     Serial.print(" actual interval ") ; Serial.println(timer_interval_secs,6);
02611 
02612     timer.onA_counts    = 0;
02613     timer.offA_counts   = 0;
02614     timer.invertA       = false;
02615 
02616     timer.onB_counts    = 0;
02617     timer.offB_counts   = ceil((exposure_offset_secs*F_BUS_ACTUAL)/timer.divider);
02618     cmpf_mask           = CMPF_MASKB_OFF;
02619     if (!timer.offB_counts) {
02620       timer.offB_counts = 1;
02621       cmpf_mask         = CMPF_MASKB_ON;
02622     }
02623     timer.invertB       = false;
02624 
02625     timer.inten_mask    = 0;
02626 
02627     timer.ctrl2_mask    = PWM_CTRL2_CLOCK_MASTER;
02628 
02629     Serial.println("");
02630     if (!print_and_check_submodule(&timer)) {
02631       return false;
02632     }
02633 
02634     // ================================================
02635     // timer mode is enabled
02636     mode = TIMER;  // we only have timer+pulse, we do not have timer+frameset
02637 
02638     // setup the hardware
02639     load_submodule(&timer);
02640 
02641     // and, attach to the timer irq
02642     attach_isr( &timer, cmpf_mask, timer_isr);
02643 
02644     return true;
02645   }
02646 
02647   /* ============================================================
```

```
02648       Setup triggers
02649   */
02650   //#define DEBUG_TRIGGERS
02651
02652   inline static bool trigger_busy = false;
02653
02654   static void trigger_isr()
02655   {
02656     uint64_t cyccnt_now = cycles64();
02657
02658 #ifdef DEBUG_TRIGGERS
02659     Serial.print("interrupt "); Serial.println(trigger_counter);
02660     Serial.print(" t="); Serial.println( (float)(cyccnt_now-interrup_cyccnt64_start)/F_CPU, 6);
02661 #endif
02662
02663     if (trigger_busy) {
02664       oops_flag = true;
02665       Serial.println("Oops! trigger interrupt while busy");
02666       return;
02667     }
02668     trigger_busy = true;
02669
02670     // need to do this before sending data to the host
02671     trigger_cyccnt64_prev = trigger_cyccnt64_now;
02672     trigger_cyccnt64_now  = cyccnt_now;
02673
02674     // the callback should have the right counter
02675     trigger_counter++;
02676
02677     // this might result in a data send
02678     if (trigger_callback) {
02679       trigger_callback();
02680     }
02681
02682     // are we stopping?
02683     if (trigger_counter >= trigger_counts) {
02684       detachInterrupt(digitalPinToInterrupt(trigger_pin));
02685       trigger_attached = false;
02686
02687 #ifdef DEBUG_TRIGGERS
02688       Serial.println("interrupt stop");
02689 #endif
02690     }
02691
02692     trigger_busy = false;
02693   }
02694
02695   static void stop_triggers()
02696   {
02697     if (trigger_attached) {
02698       detachInterrupt(digitalPinToInterrupt(trigger_pin));
02699       trigger_attached = false;
02700     }
02701   }
02702
02703   bool start_triggers( )
02704   {
02705     oops_flag = false;
02706     error_flag = false;
02707
02708     if (!trigger_mode) {
02709       Serial.println("start triggers but not trigger mode");
02710       return false;
02711     }
02712     if (trigger_attached) {
02713       Serial.println("start triggers but trigger already attached");
02714       return false;
02715     }
02716
02717     Serial.printf("start_triggers %d\n",trigger_pin);
02718
02719     trigger_counter = 0;
02720
02721     trigger_cyccnt64_start = cycles64();
02722     trigger_cyccnt64_now = trigger_cyccnt64_start;
02723     trigger_cyccnt64_prev = trigger_cyccnt64_start;
02724
02725     // attach the trigger interrupt
02726     trigger_attached = true;
02727     attachInterrupt(digitalPinToInterrupt(trigger_pin), trigger_isr, trigger_edge_mode);
02728
```

```
02729     return true;
02730   }
02731
02732   bool wait_triggers(float timeout_=1., float timestep_=0.01, bool verbose=false)
02733   {
02734     uint32_t timeout = (uint) (timeout_ * 1000);
02735     uint32_t increment = (uint) (timestep_ * 1000);
02736     uint32_t elapsed = 0;
02737
02738     if (verbose) {
02739       Serial.printf("trigger_wait %d %d\n", timeout, increment);
02740     }
02741
02742     while(trigger_attached && !error_flag && elapsed < timeout) {
02743       delay(increment);
02744       elapsed += increment;
02745     }
02746     if (error_flag) {
02747       Serial.println("Error: trigger_wait error_flag is set.");
02748       return false;
02749     }
02750     if (elapsed >= timeout) {
02751       Serial.printf("Error: wait_interrupt timedout %d / %d msecs\n",elapsed,timeout );
02752       return false;
02753     }
02754     if (timer_running) {
02755       Serial.printf("Error: timer_wait oops! still running %d / %d msecs\n",elapsed,timeout);
02756       return false;
02757     }
02758
02759     if (verbose) {
02760       Serial.printf("Success: timer_wait running %x error %x %d/%d msecs\n",
02761                     trigger_attached, error_flag, elapsed, timeout);
02762     }
02763
02764     return true;
02765   }
02766
02767
02768   bool setup_triggers(unsigned int ncounts=0)
02769   {
02770     stop_runs_only();     // clear the run bits
02771
02772     // we cannot clear the operating mode, only the trigger mode.
02773     trigger_mode = false;
02774     error_flag = false;
02775     oops_flag = false;
02776
02777     if (mode==NOTCONFIGURED) {
02778       Serial.println("Error: setup_interrupt, but flexpwm is not configured, call setup_flexpwm() first");
02779       error_flag = true;
02780       return false;
02781     }
02782
02783     else if (mode==PULSE) {
02784
02785       trigger_callback = pulse_start;
02786       trigger_counts   = ncounts ? ncounts : frame_counts;
02787
02788       if(!trigger_counts) {
02789         Serial.println("Error: setup_interrupt pulse, but no frame_counts");
02790         error_flag = true;
02791         return false;
02792       }
02793
02794       frame_counts       = trigger_counts;
02795       trigger_mode = true;
02796     }
02797
02798     else if (mode==TIMER) {
02799       trigger_callback = timer_start;
02800       trigger_counts   = ncounts ? ncounts : 1;
02801       trigger_mode = true;
02802     }
02803
02804     else if (mode==FRAMESET) {
02805
02806       trigger_callback = frameset_start;
02807       trigger_counts   = ncounts ? ncounts : frameset_counts;
02808
02809       if(!trigger_counts) {
```

```
02810         Serial.println("Error: setup_interrupt frameset, but no frameset_counts");
02811         error_flag = true;
02812         return false;
02813       }
02814
02815       frameset_counts    = trigger_counts;
02816       trigger_mode = true;
02817     }
02818
02819     else {
02820       Serial.println("Error: setup_interrupt, but mode not recognized");
02821       error_flag = true;
02822     }
02823
02824     return trigger_mode;
02825   }
02826
02827
02831     /*
02832     IMXRT_FLEXPWM_t *q = p->flexpwm;
02833     unsigned int submod = p->submod;
02834     uint16_t mask = p->mask;
02835     */
02836
02837   void set_clock_master(uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)
02838   {
02839     q->SM[submod].CTRL2 &= 0xFFF0;
02840     q->SM[submod].CTRL2 |= PWM_CTRL2_CLOCK_MASTER;
02841   }
02842
02843   void set_clock_master(SubModule *p)
02844   {
02845     set_clock_master(p->submod, p->flexpwm);
02846   }
02847
02848   // ------------------------------------------------------------
02849   void set_clock_slave(uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm)
02850   {
02851     q->SM[submod].CTRL2 &= 0xFFF0;
02852     q->SM[submod].CTRL2 |= PWM_CTRL2_CLOCK_SLAVE;
02853   }
02854
02855   void set_clock_slave(SubModule *p)
02856   {
02857     set_clock_slave(p->submod, p->flexpwm);
02858   }
02859
02860   // ------------------------------------------------------------
02861   void set_clock_sync(uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm){
02862     q->SM[submod].CTRL2 &= 0xFFF0;
02863     q->SM[submod].CTRL2 |= PWM_CTRL2_CLOCK_SYNC;
02864   }
02865
02866   void set_clock_sync(SubModule *p)
02867   {
02868     set_clock_sync(p->submod, p->flexpwm);
02869   }
02870
02871   // ------------------------------------------------------------
02872   void clear_ldok(uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm) {
02873     q->MCTRL |= FLEXPWM_MCTRL_CLDOK(mask);
02874   }
02875
02876   void set_ldok(uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm) {
02877     q->MCTRL |= FLEXPWM_MCTRL_LDOK(mask);
02878   }
02879
02880   // ------------------------------------------------------------
02881   void clear_run(uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm) {
02882     q->MCTRL &= FLEXPWM_MCTRL_RUN(~mask);
02883   }
02884   void set_run(uint8_t mask, IMXRT_FLEXPWM_t *q=flexpwm) {
02885     q->MCTRL |= FLEXPWM_MCTRL_RUN(mask);
02886   }
02887
02888   // ------------------------------------------------------------
02889   void force(uint8_t submod, IMXRT_FLEXPWM_t *q=flexpwm) {
02890     if(submod<4) {
02891       q->SM[submod].CTRL2 = FLEXPWM_SMCTRL2_FORCE;
02892     }
02893   }
```

```
02894
02895   // ------------------------------------------------------------
02896   void set_prescale(uint8_t submod, uint8_t prescale=0, IMXRT_FLEXPWM_t *q=flexpwm) {
02897     if (submod<4) {
02898       q->SM[submod].CTRL = FLEXPWM_SMCTRL_FULL | FLEXPWM_SMCTRL_PRSC(prescale);
02899     }
02900   }
02901
02902   void set_init(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02903     if (submod<4) {
02904       q->SM[submod].INIT = value;
02905     }
02906   }
02907
02908   void set_val0(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02909     if (submod<4) {
02910       q->SM[submod].VAL0 = value;
02911     }
02912   }
02913
02914   void set_val1(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02915     if (submod<4) {
02916       q->SM[submod].VAL1 = value;
02917     }
02918   }
02919
02920   void set_val2(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02921     if (submod<4) {
02922       q->SM[submod].VAL2 = value;
02923     }
02924   }
02925
02926   void set_val3(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02927     if (submod<4) {
02928       q->SM[submod].VAL3 = value;
02929     }
02930   }
02931
02932   void set_val4(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02933     if (submod<4) {
02934       q->SM[submod].VAL4 = value;
02935     }
02936   }
02937
02938   void set_val5(uint8_t submod,uint16_t value, IMXRT_FLEXPWM_t *q=flexpwm) {
02939     if (submod<4) {
02940       q->SM[submod].VAL5 = value;
02941     }
02942   }
02943   // ------------------------------------------------------------
02944   uint16_t set_outen( uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm) {
02945     q->OUTEN = mask16;
02946     return q->OUTEN;
02947   }
02948
02949   uint16_t set_outen_on( uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm) {
02950     q->OUTEN |= mask16;
02951     return q->OUTEN;
02952   }
02953
02954   uint16_t set_outen_off( uint16_t mask16, IMXRT_FLEXPWM_t *q=flexpwm) {
02955     q->OUTEN &= ~mask16;
02956     return q->OUTEN;
02957   }
02958
02959   uint16_t set_outenA_on( uint8_t mask8, IMXRT_FLEXPWM_t *q=flexpwm) {
02960     q->OUTEN |= FLEXPWM_OUTEN_PWMA_EN(mask8);
02961     return q->OUTEN;
02962   }
02963
02964
02965
02966   // ============================================================
02967
02968   void printbits16_(uint16_t u16, int bits)
02969   {
02970     while(bits> 0) {
02971       bits--;
02972       Serial.print((u16»bits)&1);
02973     }
02974   }
```

```
02975
02976   void register_dump(IMXRT_FLEXPWM_t * const  q=flexpwm, uint8_t mask=0xFF)
02977   {
02978     uint16_t u16;
02979
02980     Serial.print("flexpwm ");
02981     Serial.println((unsigned int)q, HEX);
02982
02983     u16 = q->MCTRL;
02984     Serial.print("MCTRL "); printbits16_(u16,16); // Serial.print(u16,BIN);
02985     Serial.print(" IPOL "); printbits16_((u16»12),4); // Serial.print((u16»12)&0XF,BIN);
02986     Serial.print(" RUN "); printbits16_((u16»8),4); // Serial.print((u16»8)&0XF,BIN);
02987     Serial.print(" LDOK "); printbits16_(u16,4); // Serial.print(u16&0XF,BIN);
02988     Serial.println("");
02989
02990     u16 = q->MCTRL2;
02991     Serial.print("MCTRL2 MONPLL "); Serial.print(u16&0XF,BIN);
02992     Serial.println("");
02993
02994     u16 = q->OUTEN;
02995     Serial.print("OUTEN "); printbits16_(u16,16); // Serial.print(u16,BIN);
02996     Serial.print(" PWMA "); printbits16_((u16»8),4); // Serial.print((u16>8)&0xF,BIN);
02997     Serial.print(" PWMB "); printbits16_((u16»4),4); // Serial.print((u16>4)&0xF,BIN);
02998     Serial.print(" PWMX "); printbits16_(u16,4); // Serial.print(u16&0xF,BIN);
02999     Serial.println("");
03000
03001     for (uint8_t submodule = 0; submodule<4; submodule++) {
03002
03003       if (mask & (1«submodule)) {
03004
03005         Serial.println("#-------------------------------------");
03006         Serial.print("Submodule "); Serial.print(submodule);
03007         Serial.println("");
03008
03009         u16 = q->SM[submodule].CNT;
03010         Serial.print("CNT "); Serial.println(u16);
03011
03012         u16 = q->SM[submodule].INIT;
03013         Serial.print("INIT "); Serial.println(u16);
03014
03015         u16 = q->SM[submodule].CTRL2;
03016         Serial.print("CTRL2 "); printbits16_(u16,16); // Serial.print(u16,BIN);
03017         Serial.print(" DBGEN "); Serial.print((u16»15));
03018         Serial.print(" WAITEN "); Serial.print(((u16»14)&1));
03019         Serial.print(" INDEP "); Serial.print(((u16»13)&1));
03020         Serial.print(" PWM23_INIT "); Serial.print(((u16»12)&1));
03021         Serial.print(" PWM45_INIT "); Serial.print(((u16»11)&1));
03022         Serial.print(" PWMX_INIT "); Serial.print(((u16»10)&1));
03023         Serial.print(" INIT_SEL "); Serial.print(((u16»8)&3));
03024         Serial.print(" FRCEN "); Serial.print(((u16»7)&1));
03025         Serial.print(" FORCE "); Serial.print(((u16»6)&1));
03026         Serial.print(" FORCE_SEL "); Serial.print(((u16»3)&7));
03027         Serial.print(" RELOAD_SEL "); Serial.print(((u16»2)&1));
03028         Serial.print(" CLK_SEL "); Serial.print((u16&3));
03029         Serial.println("");
03030
03031         u16 = q->SM[submodule].CTRL;
03032         Serial.print("CTRL "); printbits16_(u16,16); // Serial.print(u16,BIN);
03033         Serial.print(" LDFQ "); Serial.print(((u16»12)&0xF));
03034         Serial.print(" HALF "); Serial.print(((u16»11)&1));
03035         Serial.print(" FULL "); Serial.print(((u16»10)&1));
03036         Serial.print(" DT "); Serial.print(((u16»9)&0x1));Serial.print(((u16»8)&0x1));
03037         Serial.print(" COMPMODE "); Serial.print(((u16»10)&1));
03038         Serial.print(" PRSC "); Serial.print(((u16»4)&0x7));
03039         Serial.print(" SPLIT "); Serial.print(((u16»3)&1));
03040         Serial.print(" LDMOD "); Serial.print(((u16»2)&1));
03041         Serial.print(" DBLX "); Serial.print(((u16»1)&1));
03042         Serial.print(" DBLEN "); Serial.print((u16&1));
03043         Serial.println("");
03044
03045         u16 = q->SM[submodule].OCTRL;
03046         Serial.print("OCTRL "); printbits16_(u16,16); // Serial.print(u16,BIN);
03047         Serial.print(" PWMA_IN "); Serial.print(((u16»15)&1));
03048         Serial.print(" PWMB_IN "); Serial.print(((u16»14)&1));
03049         Serial.print(" PWMX_IN "); Serial.print(((u16»13)&1));
03050         Serial.print(" POLA "); Serial.print((u16»10)&1);
03051         Serial.print(" POLB "); Serial.print((u16»9)&1);
03052         Serial.print(" POLX "); Serial.print((u16»8)&1);
03053         Serial.print(" PWMA_FS "); Serial.print((u16»4)&3);
03054         Serial.print(" PWMB_FS "); Serial.print((u16»2)&3);
03055         Serial.print(" PWMX_FS "); Serial.print(u16&3);
```

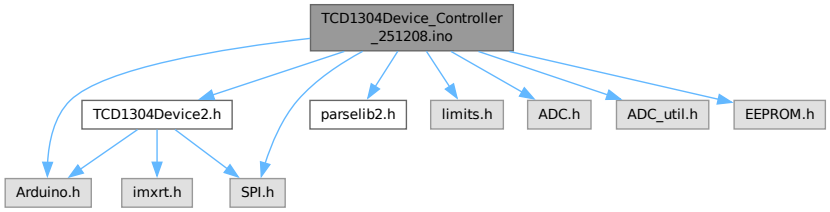
```
03056         Serial.println("");
03057
03058         u16 = q->SM[submodule].VAL0;
03059         Serial.print("VAL0 "); Serial.print(u16);
03060
03061         u16 = q->SM[submodule].VAL1;
03062         Serial.print(" VAL1 "); Serial.print(u16);
03063
03064         u16 = q->SM[submodule].VAL2;
03065         Serial.print(" VAL2 "); Serial.print(u16);
03066
03067         u16 = q->SM[submodule].VAL3;
03068         Serial.print(" VAL3 "); Serial.print(u16);
03069
03070         u16 = q->SM[submodule].VAL4;
03071         Serial.print(" VAL4 "); Serial.print(u16);
03072
03073         u16 = q->SM[submodule].VAL5;
03074         Serial.print(" VAL5 "); Serial.print(u16);
03075         Serial.println("");
03076
03077         u16 = q->SM[submodule].STS;
03078         Serial.print("STS "); printbits16_(u16,16); // Serial.print(u16,BIN);
03079         Serial.print(" RUF "); Serial.print(((u16»14)&0x1));
03080         Serial.print(" REF "); Serial.print(((u16»13)&0x1));
03081         Serial.print(" RF "); Serial.print(((u16»12)&0x1));
03082         Serial.print(" CFA1 "); Serial.print(((u16»11)&0x1));
03083         Serial.print(" CFA0 "); Serial.print(((u16»10)&0x1));
03084         Serial.print(" CFB1 "); Serial.print(((u16»9)&0x1));
03085         Serial.print(" CFB0 "); Serial.print(((u16»8)&0x1));
03086         Serial.print(" CFX1 "); Serial.print(((u16»7)&0x1));
03087         Serial.print(" CFX0 "); Serial.print(((u16»6)&0x1));
03088         Serial.print(" CMPF "); printbits16_(u16,6); // Serial.print(u16&0x3F,BIN);
03089         Serial.println("");
03090
03091         u16 = q->SM[submodule].INTEN;
03092         Serial.print("INTEN "); printbits16_(u16,16); // Serial.print(u16,BIN);
03093         Serial.print(" REIE "); Serial.print(((u16»13)&0x1));
03094         Serial.print(" RIE "); Serial.print(((u16»12)&0x1));
03095         Serial.print(" CA1IE "); Serial.print(((u16»11)&0x1));
03096         Serial.print(" CA0IE "); Serial.print(((u16»10)&0x1));
03097         Serial.print(" CB1IE "); Serial.print(((u16»9)&0x1));
03098         Serial.print(" CB0IE "); Serial.print(((u16»8)&0x1));
03099         Serial.print(" CX1IE "); Serial.print(((u16»7)&0x1));
03100         Serial.print(" CX0IE "); Serial.print(((u16»6)&0x1));
03101         Serial.print(" CMPIE "); printbits16_(u16,6); // Serial.print(u16&0x3F,BIN);
03102         Serial.println("");
03103       }
03104     }
03105   }
03106
03107   // ----------------------------------------
03108   static void setup_digital_pins()
03109   {
03110     pinMode(TRIGGER_PIN, INPUT);
03111
03112     pinMode(BUSY_PIN, OUTPUT);
03113     digitalWriteFast(BUSY_PIN, BUSY_PIN_DEFAULT);
03114
03115     pinMode(SYNC_PIN, OUTPUT);
03116     digitalWriteFast(SYNC_PIN, SYNC_PIN_DEFAULT);
03117
03118     // Clock
03119     pinMode(CLK_PIN,  OUTPUT);
03120     digitalWriteFast(CLK_PIN, LOW);
03121
03122     pinMode(CLK_MONITOR_PIN, INPUT);
03123
03124     // SH gate
03125     pinMode(SH_PIN, OUTPUT);
03126     digitalWriteFast(SH_PIN, LOW);
03127
03128     // Integratinon Clear Gate
03129     pinMode(ICG_PIN, OUTPUT);
03130     digitalWriteFast(ICG_PIN, HIGH);
03131
03132     // CNVST to ADC
03133     pinMode(CNVST_PIN, OUTPUT);
03134     digitalWriteFast(CNVST_PIN, LOW);
03135
03136     // clear the mode
```

```
03137     clear_mode();
03138   }
03139
03140   static void close()
03141   {
03142     // stop both flexpwms, disable interrrupts and reset clear and busy pins
03143     stop_with_irqs();
03144
03145     // Reactivation as digital i/o pins
03146     setup_digital_pins();
03147
03148   }
03149
03150
03151
03152 };
03153
03154 #endif
```

5.7 TCD1304Device_Controller_251208.ino File Reference

```
#include "Arduino.h"
#include "TCD1304Device2.h"
#include "parselib2.h"
#include <SPI.h>
#include <limits.h>
#include <ADC.h>
#include <ADC_util.h>
#include <EEPROM.h>
```

Include dependency graph for TCD1304Device_Controller_251208.ino:



Classes

- struct usb_string_descriptor_struct_manufacturer
- struct usb_string_descriptor_struct_product
- struct usb_string_descriptor_struct_serial_number

Macros

- #define DRMCNELSONLAB
- #define CONTROLLER_OCPIN 23
- #define CONTROLLER_CSPIN 10
- #define CONTROLLER_CSPIN2 9

- #define CYCLES_PER_USEC (F_CPU / 1000000)
- #define thisMANUFACTURER_NAME {'D','R','M','C','N','E','L','S','O','N','L','A','B' }
- #define thisMANUFACTURER_NAME_LEN 13
- #define thisPRODUCT_NAME {'T','C','D','1','3','0','4','S','P','I'}
- #define thisPRODUCT_NAME_LEN 10
- #define thisPRODUCT_SERIAL_NUMBER { 'S','N','0','0','0','0','0','0','0','0','0','1' }
- #define thisPRODUCT_SERIAL_NUMBER_LEN 12
- #define RCVLEN 256
- #define SNDLEN 256
- #define IMR_INDEX 5
- #define ISR_INDEX 6
- #define NADC_CHANNELS 4
- #define ADC_RESOLUTION (3.3/4096.)
- #define EEPROM_SIZE 1080
- #define EEPROM_ID_ADDR 0
- #define EEPROM_ID_LEN 64
- #define EEPROM_COEFF_ADDR 64
- #define EEPROM_NCOEFFS 4
- #define EEPROM_COEFF_LEN (EEPROM_NCOEFFS ∗ sizeof(float))
- #define EEPROM_UNITS_ADDR (EEPROM_COEFF_ADDR + EEPROM_COEFF_LEN)
- #define EEPROM_NUNITS 8
- #define EEPROM_UNITS_LEN EEPROM_NUNITS
- #define NBUFFERS 32
- #define BINARY 0
- #define ASCII 1

Functions

- SPISettings spi_settings (30000000, MSBFIRST, SPI_MODE0)
- float tempmonGetTemp (void)
- void blink ()
- void pulsePin (unsigned int pin, unsigned int usecs)
- void ocpinRead ()
- void ocpinISR ()
- void ocpinAttach ()
- void ocpinDetach ()
- void resumePinInterrupts (uint8_t pin)
- void disablePinInterrupts (uint8_t pin)
- uint64_t cycles64 ()
- int fastAnalogRead (uint8_t pin)
- void sendADCs (unsigned int averages)
- void sendChipTemperature (unsigned int averages)
- void eeread (unsigned int address, int nbytes, char ∗p)
- void eewrite (unsigned int address, int nbytes, char ∗p)
- void eereadUntil (unsigned int address, int nbytes, char ∗p)
- void eewriteUntil (unsigned int address, int nbytes, char ∗p)
- void eeErase (unsigned int address, int nbytes)
- void eraseIdentifier ()
- void readIdentifier (char ∗p)
- void storeIdentifier (char ∗p)

- void printIdentifier ()
- void eraseUnits ()
- void readUnits (char *p)
- void storeUnits (char *p)
- void printUnits ()
- void eraseCoefficients ()
- void readCoefficients (float *vals)
- void storeCoefficients (float *vals)
- void printCoefficients ()
- void clock_isr ()
- void clock_stop ()
- void clock_start ()
- bool clock_setup (float secs, unsigned int ncounts=0)
- uint8_t calculateCRC (uint16_t *bufferp)
- uint32_t sumData (uint16_t *bufferp)
- void sendBuffer_Formatted (uint16_t *bp)
- void sendBuffer_Binary (uint16_t *bp)
- void sendDataCRC (uint16_t *bp)
- void sendDataSum (uint16_t *bp)
- void sendData (uint16_t *bp)
- void sendDataReady ()
- void sendTestData (uint16_t *bp)
- void send_header ()
- bool send_frame (TCD1304Device ::Frame_Header *p)
- void send_frames ()
- void frame_callback ()
- bool strPin (char *pc, uint8_t *pin, char **next)
- void printTriggerSetup ()
- bool strTrigger (char *pc, char **next)
- bool strSubModule (char *s, char **next=0)
- void help (const char *key)
- void setup ()
- void loop ()

Variables

- ADC * adc = new ADC( )
- TCD1304Device tcd1304device = TCD1304Device( )
- usb_string_descriptor_struct_manufacturer usb_string_manufacturer_name
- usb_string_descriptor_struct_product usb_string_product_name
- usb_string_descriptor_struct_serial_number usb_string_serial_number
- char rcvbuffer [RCVLEN]
- uint16_t nrcvbuf = 0
- char sndbuffer [SNDLEN]
- const char versionstr [ ] = "TCD1304Device vers 0.4 " __DATE__
- const char authorstr [ ] = "Patents Pending and (c) 2020, 2023, 2025 by Mitchell C. Nelson, Ph.D. "
- const char srcfilestr [ ] = __FILE__
- const char sensorstr [ ] = "TCD1304"
- const int syncPin = SYNC_PIN
- const int busyPin = BUSY_PIN

- const int triggerPin = TRIGGER_PIN
- const int fMPin = CLK_PIN
- const int ICGPin = ICG_PIN
- const int SHPin = SH_PIN
- const int CNVSTPin = CNVST_PIN
- const int SDIPin = 11
- const int SDOPin = 12
- const int CLKPin = 13
- const int analogPin = A0
- bool ocpinstate = false
- bool ocpinattached = false
- elapsedMicros elapsed_usecs
- elapsedMicros diagnostic_usecs
- bool diagnostics = false
- uint16_t adc_data [NADC_CHANNELS] = { 0 }
- unsigned int adc_averages = 0
- unsigned int chipTemp_averages = 0
- IntervalTimer clock_timer
- void(∗ clock_callback)() = nullptr
- unsigned int clock_counts = 0
- unsigned int clock_counter = 0
- float clock_usecs = 0
- bool clock_mode = false
- unsigned char crctable [256]
- TCD1304Device::Frame_Header frame_header_ring [NBUFFERS] = {0}
- TCD1304Device::Frame_Header ∗ framep = &frame_header_ring[0]
- uint16_t buffer_ring [NBUFFERS][NREADOUT] = { 0 }
- uint16_t ∗ bufferp = buffer_ring[0]
- unsigned int frame_index = 0
- unsigned int buffer_index = 0
- unsigned int frame_send_index = 0
- unsigned int dataformat = BINARY
- unsigned int counter = 0
- bool data_async = true
- bool crc_enable = false
- bool sum_enable = false

5.7.1 Macro Definition Documentation

5.7.1.1 ADC_RESOLUTION

```
#define ADC_RESOLUTION (3.3/4096.)
```

5.7.1.2 ASCII

```
#define ASCII 1
```

5.7.1.3 BINARY

```
#define BINARY 0
```

5.7.1.4 CONTROLLER_CSPIN

```
#define CONTROLLER_CSPIN 10
```

5.7.1.5 CONTROLLER_CSPIN2

```
#define CONTROLLER_CSPIN2 9
```

5.7.1.6 CONTROLLER_OCPIN

```
#define CONTROLLER_OCPIN 23
```

5.7.1.7 CYCLES_PER_USEC

```
#define CYCLES_PER_USEC (F_CPU / 1000000)
```

5.7.1.8 DRMCNELSONLAB

```
#define DRMCNELSONLAB
```

5.7.1.9 EEPROM_COEFF_ADDR

```
#define EEPROM_COEFF_ADDR 64
```

5.7.1.10 EEPROM_COEFF_LEN

```
#define EEPROM_COEFF_LEN (EEPROM_NCOEFFS * sizeof(float))
```

5.7.1.11 EEPROM_ID_ADDR

```
#define EEPROM_ID_ADDR 0
```

5.7.1.12 EEPROM_ID_LEN

```
#define EEPROM_ID_LEN 64
```

5.7.1.13 EEPROM_NCOEFFS

```
#define EEPROM_NCOEFFS 4
```

5.7.1.14 EEPROM_NUNITS

```
#define EEPROM_NUNITS 8
```

5.7.1.15 EEPROM_SIZE

```
#define EEPROM_SIZE 1080
```

5.7.1.16 EEPROM_UNITS_ADDR

```
#define EEPROM_UNITS_ADDR (EEPROM_COEFF_ADDR + EEPROM_COEFF_LEN)
```

5.7.1.17 EEPROM_UNITS_LEN

```
#define EEPROM_UNITS_LEN EEPROM_NUNITS
```

5.7.1.18 IMR_INDEX

```
#define IMR_INDEX 5
```

5.7.1.19 ISR_INDEX

```
#define ISR_INDEX 6
```

5.7.1.20 NADC_CHANNELS

```
#define NADC_CHANNELS 4
```

5.7.1.21 NBUFFERS

```
#define NBUFFERS 32
```

5.7.1.22 RCVLEN

```
#define RCVLEN 256
```

5.7.1.23 SNDLEN

```
#define SNDLEN 256
```

5.7.1.24 thisMANUFACTURER_NAME

```
#define thisMANUFACTURER_NAME {'D','R','M','C','N','E','L','S','O','N','L','A','B' }
```

5.7.1.25 thisMANUFACTURER_NAME_LEN

```
#define thisMANUFACTURER_NAME_LEN 13
```

5.7.1.26 thisPRODUCT_NAME

```
#define thisPRODUCT_NAME {'T','C','D','1','3','0','4','S','P','I'}
```

5.7.1.27 thisPRODUCT_NAME_LEN

```
#define thisPRODUCT_NAME_LEN 10
```

5.7.1.28 thisPRODUCT_SERIAL_NUMBER

```
#define thisPRODUCT_SERIAL_NUMBER { 'S','N','0','0','0','0','0','0','0','0','0','1' }
```

5.7.1.29 thisPRODUCT_SERIAL_NUMBER_LEN

```
#define thisPRODUCT_SERIAL_NUMBER_LEN 12
```

5.7.2 Function Documentation

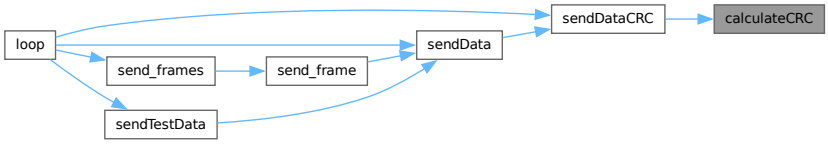
5.7.2.1 blink()

```
void blink ()
```

5.7.2.2 calculateCRC()

```
uint8_t calculateCRC (
            uint16_t * bufferp)  [inline]
```

Here is the caller graph for this function:



5.7.2.3 clock_isr()

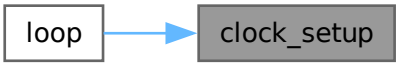
```
void clock_isr ()
```

Here is the caller graph for this function:

5.7.2.4 clock_setup()

```
bool clock_setup (
            float secs,
            unsigned int ncounts = 0)
```

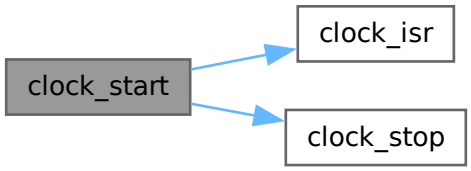
Here is the caller graph for this function:



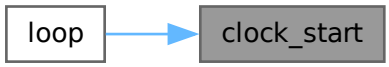
5.7.2.5 clock_start()

```
void clock_start ()
```

Here is the call graph for this function:



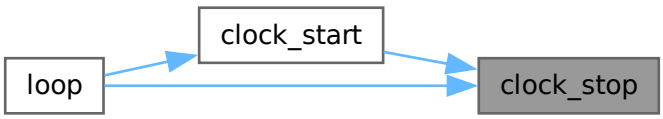
Here is the caller graph for this function:



5.7.2.6 clock_stop()

```
void clock_stop ()
```

Here is the caller graph for this function:



5.7.2.7 cycles64()

```
uint64_t cycles64 ()
```

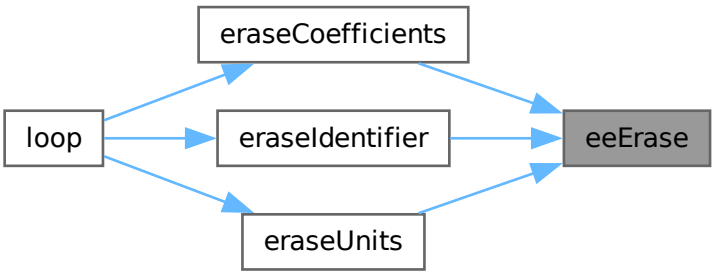
5.7.2.8 disablePinInterrupts()

```
void disablePinInterrupts (
            uint8_t pin)
```

5.7.2.9 eeErase()

```
void eeErase (
            unsigned int address,
            int nbytes)
```

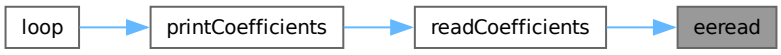
Here is the caller graph for this function:



5.7.2.10 eeread()

```
void eeread (
            unsigned int address,
            int nbytes,
            char * p)
```

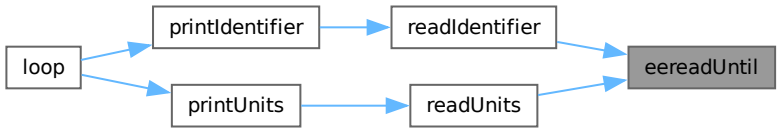
Here is the caller graph for this function:



5.7.2.11 eereadUntil()

```
void eereadUntil (
            unsigned int address,
            int nbytes,
            char * p)
```

Here is the caller graph for this function:



5.7.2.12 eewrite()

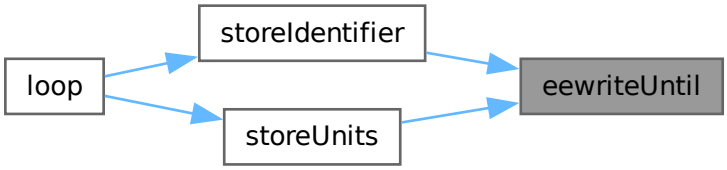
```
void eewrite (
            unsigned int address,
            int nbytes,
            char * p)
```

Here is the caller graph for this function:

5.7.2.13 eewriteUntil()

```
void eewriteUntil (
            unsigned int address,
            int nbytes,
            char * p)
```

Here is the caller graph for this function:



5.7.2.14 eraseCoefficients()

```
void eraseCoefficients ()
```

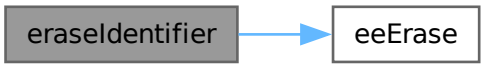
Here is the call graph for this function:

Here is the caller graph for this function:

5.7.2.15 eraseIdentifier()

```
void eraseIdentifier ()
```

Here is the call graph for this function:



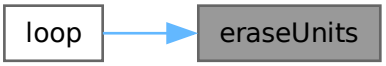
Here is the caller graph for this function:

5.7.2.16 eraseUnits()

```
void eraseUnits ()
```

Here is the call graph for this function:

Here is the caller graph for this function:



5.7.2.17 fastAnalogRead()

```
int fastAnalogRead (
            uint8_t pin)  [inline]
```

Here is the caller graph for this function:

5.7.2.18 frame_callback()

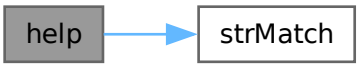
```
void frame_callback ()
```

Here is the caller graph for this function:

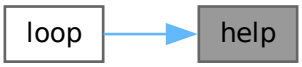
5.7.2.19 help()

```
void help (
            const char * key)
```

Here is the call graph for this function:



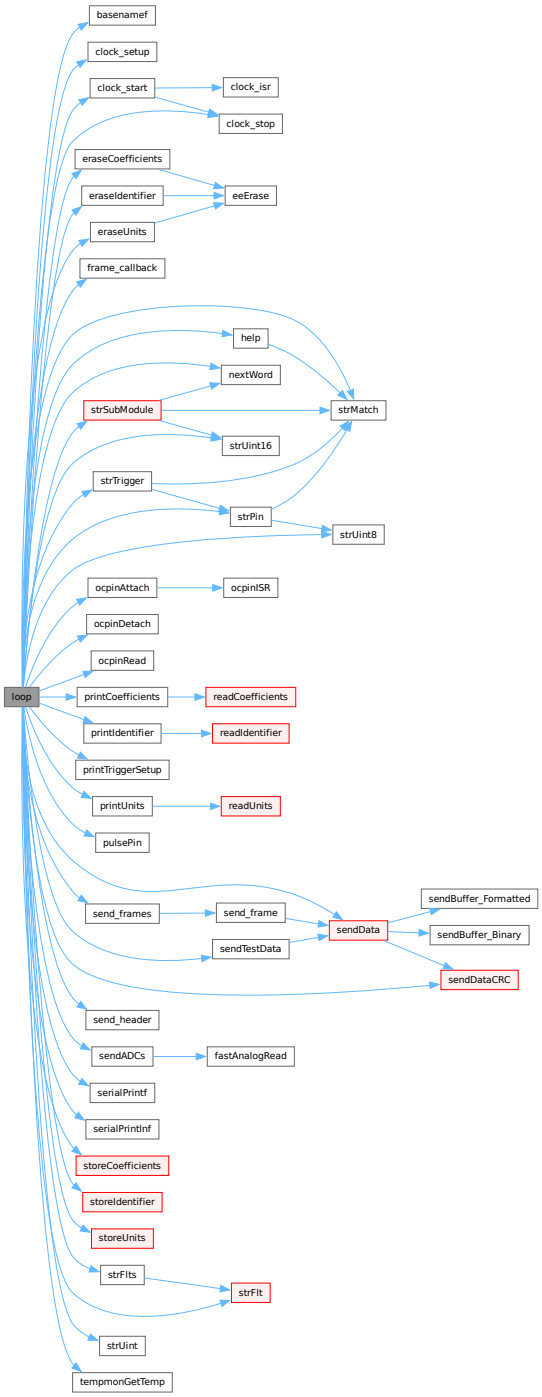
Here is the caller graph for this function:



5.7.2.20 loop()

```
void loop ()
```

Here is the call graph for this function:

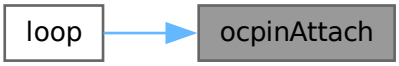


5.7.2.21 ocpinAttach()

```
void ocpinAttach ()
```

Here is the call graph for this function:

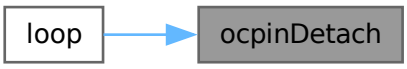
Here is the caller graph for this function:



5.7.2.22 ocpinDetach()

```
void ocpinDetach ()
```

Here is the caller graph for this function:



5.7.2.23 ocpinISR()

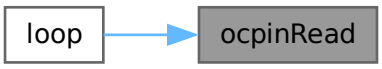
```
void ocpinISR ()
```

Here is the caller graph for this function:

5.7.2.24 ocpinRead()

```
void ocpinRead ()
```

Here is the caller graph for this function:



5.7.2.25 printCoefficients()

```
void printCoefficients ()
```

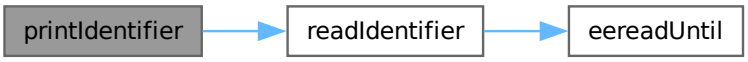
Here is the call graph for this function:

Here is the caller graph for this function:

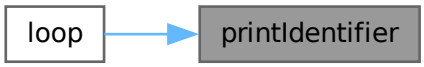
5.7.2.26 printIdentifier()

```
void printIdentifier ()
```

Here is the call graph for this function:



Here is the caller graph for this function:



5.7.2.27 printTriggerSetup()

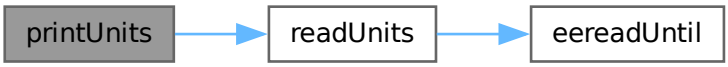
```
void printTriggerSetup ()
```

Here is the caller graph for this function:

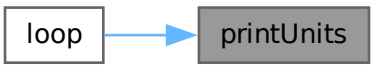
5.7.2.28 printUnits()

```
void printUnits ()
```

Here is the call graph for this function:



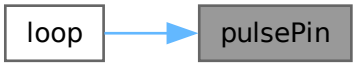
Here is the caller graph for this function:



5.7.2.29 pulsePin()

```
void pulsePin (
            unsigned int pin,
            unsigned int usecs)
```

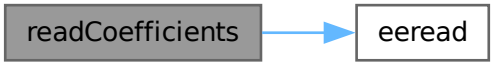
Here is the caller graph for this function:



5.7.2.30 readCoefficients()

```
void readCoefficients (
            float * vals)
```

Here is the call graph for this function:



Here is the caller graph for this function:

5.7.2.31 readIdentifier()

```
void readIdentifier (
            char * p)
```

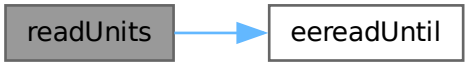
Here is the call graph for this function:

Here is the caller graph for this function:

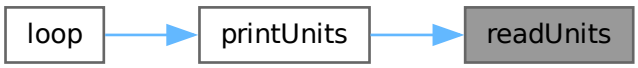
5.7.2.32 readUnits()

```
void readUnits (
            char * p)
```

Here is the call graph for this function:



Here is the caller graph for this function:



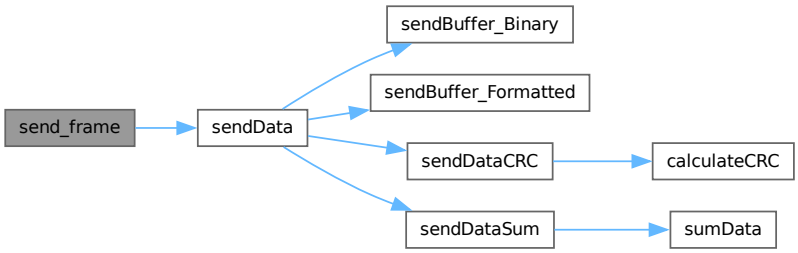
5.7.2.33 resumePinInterrupts()

```
void resumePinInterrupts (
            uint8_t pin)
```

5.7.2.34 send_frame()

```
bool send_frame (
            TCD1304Device ::Frame_Header * p)
```

Here is the call graph for this function:

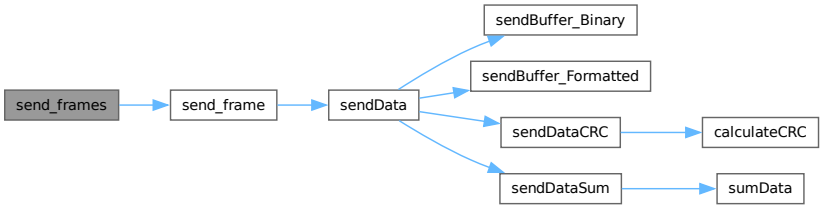


Here is the caller graph for this function:

5.7.2.35 send_frames()

```
void send_frames ()
```

Here is the call graph for this function:



Here is the caller graph for this function:

5.7.2.36 send_header()

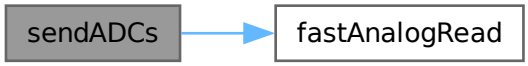
```
void send_header ()
```

Here is the caller graph for this function:

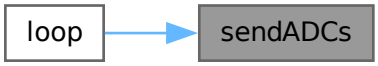
5.7.2.37 sendADCs()

```
void sendADCs (
            unsigned int averages)
```

Here is the call graph for this function:



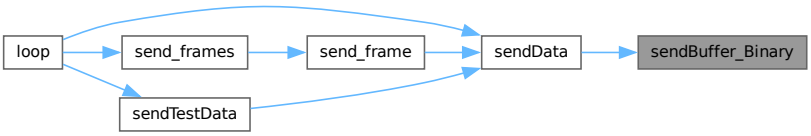
Here is the caller graph for this function:



5.7.2.38 sendBuffer_Binary()

```
void sendBuffer_Binary (
            uint16_t * bp)
```

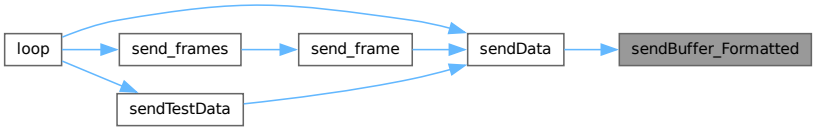
Here is the caller graph for this function:



5.7.2.39 sendBuffer_Formatted()

```
void sendBuffer_Formatted (
            uint16_t * bp)
```

Here is the caller graph for this function:



5.7.2.40 sendChipTemperature()

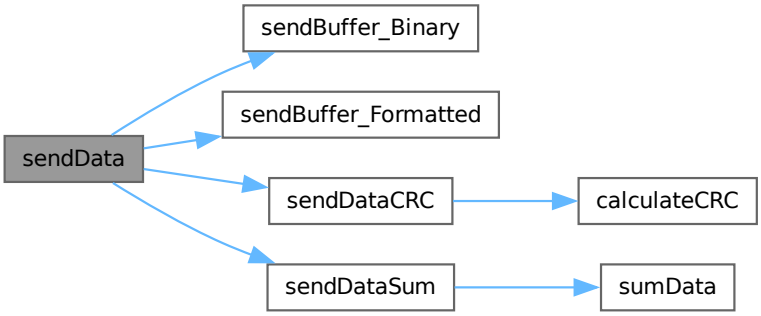
```
void sendChipTemperature (
            unsigned int averages)
```

Here is the call graph for this function:

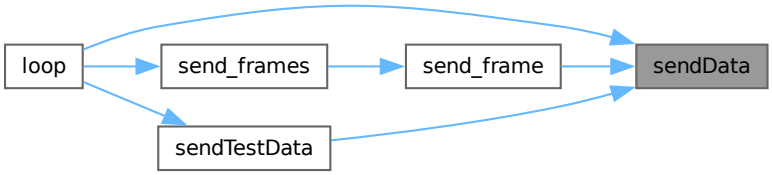
5.7.2.41 sendData()

```
void sendData (
            uint16_t * bp)
```

Here is the call graph for this function:



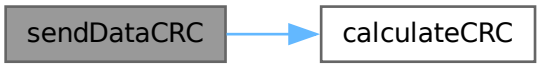
Here is the caller graph for this function:



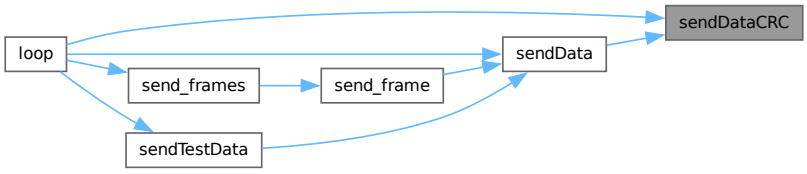
5.7.2.42 sendDataCRC()

```
void sendDataCRC (
            uint16_t * bp)  [inline]
```

Here is the call graph for this function:



Here is the caller graph for this function:



5.7.2.43 sendDataReady()

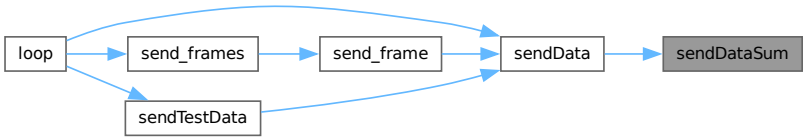
```
void sendDataReady ()
```

5.7.2.44 sendDataSum()

```
void sendDataSum (
            uint16_t * bp)  [inline]
```

Here is the call graph for this function:

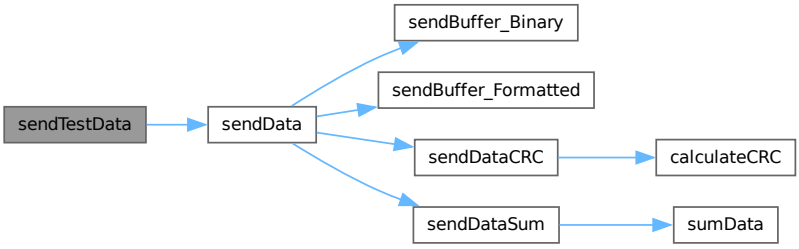
Here is the caller graph for this function:



5.7.2.45 sendTestData()

```
void sendTestData (
            uint16_t * bp)
```

Here is the call graph for this function:

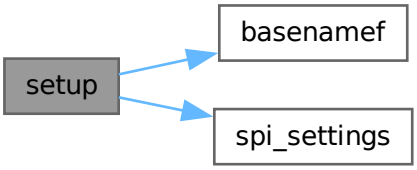


Here is the caller graph for this function:

5.7.2.46 setup()

```
void setup ()
```

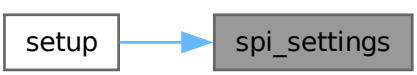
Here is the call graph for this function:



5.7.2.47 spi_settings()

```
SPISettings spi_settings (
            30000000 ,
            MSBFIRST ,
            SPI_MODE0 )
```

Here is the caller graph for this function:



5.7.2.48 storeCoefficients()

```
void storeCoefficients (
            float * vals)
```

Here is the call graph for this function:

Here is the caller graph for this function:

5.7.2.49 storeIdentifier()

```
void storeIdentifier (
            char * p)
```

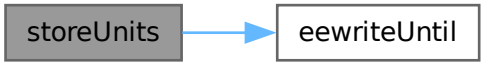
Here is the call graph for this function:

Here is the caller graph for this function:

5.7.2.50 storeUnits()

```
void storeUnits (
            char * p)
```

Here is the call graph for this function:



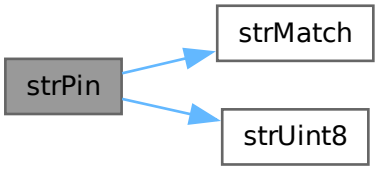
Here is the caller graph for this function:

5.7.2.51 strPin()

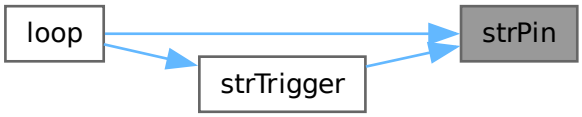
```
bool strPin (
            char * pc,
```

```
            uint8_t * pin,
            char ** next)
```

Here is the call graph for this function:



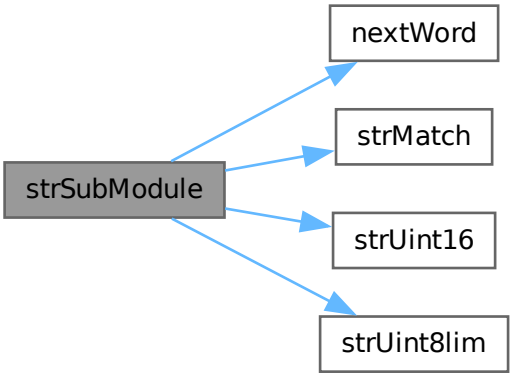
Here is the caller graph for this function:



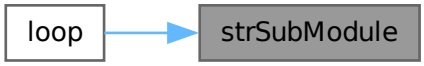
5.7.2.52 strSubModule()

```
bool strSubModule (
            char * s,
            char ** next = 0)
```

Here is the call graph for this function:



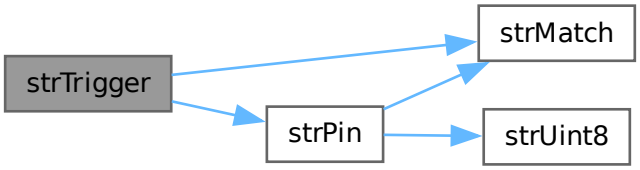
Here is the caller graph for this function:



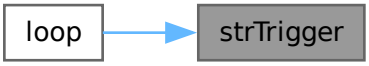
5.7.2.53 strTrigger()

```
bool strTrigger (
            char * pc,
            char ** next)
```

Here is the call graph for this function:



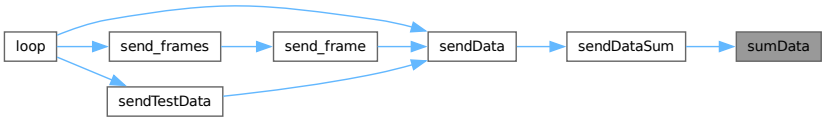
Here is the caller graph for this function:



5.7.2.54 sumData()

```
uint32_t sumData (
            uint16_t * bufferp)  [inline]
```

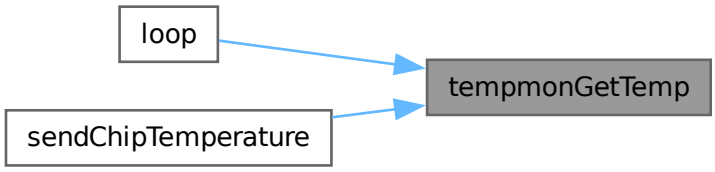
Here is the caller graph for this function:



5.7.2.55 tempmonGetTemp()

```
float tempmonGetTemp (
            void )  [extern]
```

Here is the caller graph for this function:



5.7.3 Variable Documentation

5.7.3.1 adc

```
ADC* adc = new ADC( )
```

5.7.3.2 adc_averages

```
unsigned int adc_averages = 0
```

5.7.3.3 adc_data

```
uint16_t adc_data[NADC_CHANNELS] = { 0 }
```

5.7.3.4 analogPin

```
const int analogPin = A0
```

5.7.3.5 authorstr

```
const char authorstr[] = "Patents Pending and (c) 2020, 2023, 2025 by Mitchell C. Nelson, Ph.D. "
```

5.7.3.6 buffer_index

```
unsigned int buffer_index = 0
```

5.7.3.7 buffer_ring

```
uint16_t buffer_ring[NBUFFERS][NREADOUT] = { 0 }
```

5.7.3.8 bufferp

```
uint16_t* bufferp = buffer_ring[0]
```

5.7.3.9 busyPin

```
const int busyPin = BUSY_PIN
```

5.7.3.10 chipTemp_averages

```
unsigned int chipTemp_averages = 0
```

5.7.3.11 CLKPin

```
const int CLKPin = 13
```

5.7.3.12 clock_callback

```
void(* clock_callback) () () = nullptr
```

5.7.3.13 clock_counter

```
unsigned int clock_counter = 0
```

5.7.3.14 clock_counts

```
unsigned int clock_counts = 0
```

5.7.3.15 clock_mode

```
bool clock_mode = false
```

5.7.3.16 clock_timer

```
IntervalTimer clock_timer
```

5.7.3.17 clock_usecs

```
float clock_usecs = 0
```

5.7.3.18 CNVSTPin

```
const int CNVSTPin = CNVST_PIN
```

5.7.3.19 counter

```
unsigned int counter = 0
```

5.7.3.20 crc_enable

```
bool crc_enable = false
```

5.7.3.21 crctable

```
unsigned char crctable[256]
```

Initial value:

```
= {
  0x00,0x31,0x62,0x53,0xc4,0xf5,0xa6,0x97,0xb9,0x88,0xdb,0xea,0x7d,0x4c,0x1f,0x2e,
  0x43,0x72,0x21,0x10,0x87,0xb6,0xe5,0xd4,0xfa,0xcb,0x98,0xa9,0x3e,0x0f,0x5c,0x6d,
  0x86,0xb7,0xe4,0xd5,0x42,0x73,0x20,0x11,0x3f,0x0e,0x5d,0x6c,0xfb,0xca,0x99,0xa8,
  0xc5,0xf4,0xa7,0x96,0x01,0x30,0x63,0x52,0x7c,0x4d,0x1e,0x2f,0xb8,0x89,0xda,0xeb,
  0x3d,0x0c,0x5f,0x6e,0xf9,0xc8,0x9b,0xaa,0x84,0xb5,0xe6,0xd7,0x40,0x71,0x22,0x13,
  0x7e,0x4f,0x1c,0x2d,0xba,0x8b,0xd8,0xe9,0xc7,0xf6,0xa5,0x94,0x03,0x32,0x61,0x50,
  0xbb,0x8a,0xd9,0xe8,0x7f,0x4e,0x1d,0x2c,0x02,0x33,0x60,0x51,0xc6,0xf7,0xa4,0x95,
  0xf8,0xc9,0x9a,0xab,0x3c,0x0d,0x5e,0x6f,0x41,0x70,0x23,0x12,0x85,0xb4,0xe7,0xd6,
  0x7a,0x4b,0x18,0x29,0xbe,0x8f,0xdc,0xed,0xc3,0xf2,0xa1,0x90,0x07,0x36,0x65,0x54,
  0x39,0x08,0x5b,0x6a,0xfd,0xcc,0x9f,0xae,0x80,0xb1,0xe2,0xd3,0x44,0x75,0x26,0x17,
  0xfc,0xcd,0x9e,0xaf,0x38,0x09,0x5a,0x6b,0x45,0x74,0x27,0x16,0x81,0xb0,0xe3,0xd2,
  0xbf,0x8e,0xdd,0xec,0x7b,0x4a,0x19,0x28,0x06,0x37,0x64,0x55,0xc2,0xf3,0xa0,0x91,
  0x47,0x76,0x25,0x14,0x83,0xb2,0xe1,0xd0,0xfe,0xcf,0x9c,0xad,0x3a,0x0b,0x58,0x69,
  0x04,0x35,0x66,0x57,0xc0,0xf1,0xa2,0x93,0xbd,0x8c,0xdf,0xee,0x79,0x48,0x1b,0x2a,
  0xc1,0xf0,0xa3,0x92,0x05,0x34,0x67,0x56,0x78,0x49,0x1a,0x2b,0xbc,0x8d,0xde,0xef,
  0x82,0xb3,0xe0,0xd1,0x46,0x77,0x24,0x15,0x3b,0x0a,0x59,0x68,0xff,0xce,0x9d,0xac
}
```

5.7.3.22 data_async

```
bool data_async = true
```

5.7.3.23 dataformat

```
unsigned int dataformat = BINARY
```

5.7.3.24 diagnostic_usecs

```
elapsedMicros diagnostic_usecs
```

5.7.3.25 diagnostics

```
bool diagnostics = false
```

5.7.3.26 elapsed_usecs

```
elapsedMicros elapsed_usecs
```

5.7.3.27 fMPin

```
const int fMPin = CLK_PIN
```

5.7.3.28 frame_header_ring

```
TCD1304Device::Frame_Header frame_header_ring[NBUFFERS] = {0}
```

5.7.3.29 frame_index

```
unsigned int frame_index = 0
```

5.7.3.30 frame_send_index

```
unsigned int frame_send_index = 0
```

5.7.3.31 framep

```
TCD1304Device::Frame_Header* framep = &frame_header_ring[0]
```

5.7.3.32 ICGPin

```
const int ICGPin = ICG_PIN
```

5.7.3.33 nrcvbuf

```
uint16_t nrcvbuf = 0
```

5.7.3.34 ocpinattached

```
bool ocpinattached = false
```

5.7.3.35 ocpinstate

```
bool ocpinstate = false
```

5.7.3.36 rcvbuffer

```
char rcvbuffer[RCVLEN]
```

5.7.3.37 SDIPin

```
const int SDIPin = 11
```

5.7.3.38 SDOPin

```
const int SDOPin = 12
```

5.7.3.39 sensorstr

```
const char sensorstr[] = "TCD1304"
```

5.7.3.40 SHPin

```
const int SHPin = SH_PIN
```

5.7.3.41 sndbuffer

```
char sndbuffer[SNDLEN]
```

5.7.3.42 srcfilestr

```
const char srcfilestr[] = __FILE__
```

5.7.3.43 sum_enable

```
bool sum_enable = false
```

5.7.3.44 syncPin

```
const int syncPin = SYNC_PIN
```

5.7.3.45 tcd1304device

```
TCD1304Device tcd1304device = TCD1304Device( )
```

5.7.3.46 triggerPin

```
const int triggerPin = TRIGGER_PIN
```

5.7.3.47 usb_string_manufacturer_name

```
usb_string_descriptor_struct_manufacturer usb_string_manufacturer_name
```

Initial value:

```
= {
    2 + thisMANUFACTURER_NAME_LEN * 2,
    3,
    thisMANUFACTURER_NAME
  }
```

5.7.3.48 usb_string_product_name

```
usb_string_descriptor_struct_product usb_string_product_name
```

Initial value:

```
= {
    2 + thisPRODUCT_NAME_LEN * 2,
    3,
    thisPRODUCT_NAME
  }
```

5.7.3.49 usb_string_serial_number

```
usb_string_descriptor_struct_serial_number usb_string_serial_number
```

Initial value:

```
=
    {
      2 + thisPRODUCT_SERIAL_NUMBER_LEN * 2,
      3,
      thisPRODUCT_SERIAL_NUMBER
    }
```

5.7.3.50 versionstr

```
const char versionstr[] = "TCD1304Device vers 0.4 " __DATE__
```

Index