

EE445M/EE380L Lab 2 Documentation

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Chapter 1

Data Structure Index

1.1 Data Structures

Here are the data structures with brief descriptions:

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Sema4	5

Chapter 2

File Index

2.1 File List

Here is a list of all documented files with brief descriptions:

inc/ ADC.h	ADC driver for the TM4C123G. Provides interfaces for collecting single samples or a series at a given sampling frequency. Does not allow for sampling of more than one channel at any given time. Timer 2 is reserved for this driver	7
inc/ asmdefs.h	??
inc/ FIFO.h	??
inc/ hw_adc.h	??
inc/ hw_aes.h	??
inc/ hw_can.h	??
inc/ hw_ccm.h	??
inc/ hw_comp.h	??
inc/ hw_des.h	??
inc/ hw_eeprom.h	??
inc/ hw_emac.h	??
inc/ hw_epi.h	??
inc/ hw_ethernet.h	??
inc/ hw_fan.h	??
inc/ hw_flash.h	??
inc/ hw_gpio.h	??
inc/ hw_hibernate.h	??
inc/ hw_i2c.h	??
inc/ hw_i2s.h	??
inc/ hw_ints.h	??
inc/ hw_lcd.h	??
inc/ hw_lpc.h	??
inc/ hw_memmap.h	??
inc/ hw_nvic.h	??
inc/ hw_peci.h	??
inc/ hw_pwm.h	??
inc/ hw_qei.h	??
inc/ hw_shamd5.h	??
inc/ hw_ssi.h	??
inc/ hw_sysctl.h	??
inc/ hw_sysexec.h	??
inc/ hw_timer.h	??

inc/ hw_types.h	??
inc/ hw_uart.h	??
inc/ hw_udma.h	??
inc/ hw_usb.h	??
inc/ hw_watchdog.h	??
inc/ interpreter.h	9
inc/ misc_macros.h	
Some helper macros	9
inc/ OS.h	
Real Time Operating System for Labs 2 and 3 EE445M/EE380L.12	10
inc/ PLL.h	
Runs on LM4F120/TM4C123 A software function to change the bus frequency using the PLL	18
inc/ priorityqueue.h	??
inc/ ST7735.h	
This is a library for the Adafruit 1.8" SPI display	21
inc/ Switch.h	??
inc/ tm4c123gh6pm.h	??
inc/ UART.h	
Runs on LM4F120/TM4C123 Use UART0 to implement bidirectional data transfer to and from a computer running HyperTerminal. This time, interrupts and FIFOs are used	30

Chapter 3

Data Structure Documentation

3.1 `_tcb_s` Struct Reference

Collaboration diagram for `_tcb_s`:



Data Fields

- long * **sp**
- struct `_tcb_s` * **next**
- uint32_t **wake_time**
- unsigned long **id**
- uint8_t **priority**
- uint32_t **period**
- unsigned long **magic**
magic field must contain TCB_MAGIC for TCB to be valid
- void(* **task**)(void)

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

- inc/[OS.h](#)

3.2 `Sema4` Struct Reference

Data Fields

- long **Value**

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

- inc/[OS.h](#)

Chapter 4

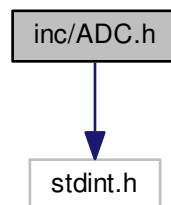
File Documentation

4.1 inc/ADC.h File Reference

ADC driver for the TM4C123G. Provides interfaces for collecting single samples or a series at a given sampling frequency. Does not allow for sampling of more than one channel at any given time. Timer 2 is reserved for this driver.

```
#include <stdint.h>
```

Include dependency graph for ADC.h:



Functions

- int [ADC_Init](#) (uint32_t channelNum)
Configure an ADC channel for continuous sampling. Retrieve measurements from this channel with [ADC_In\(\)](#).
- uint16_t [ADC_In](#) (void)
Returns the most recent sample collected by the channel configured in [ADC_Init\(...\)](#)
- int [ADC_Collect](#) (uint32_t channelNum, uint32_t fs, void(*handler)(unsigned long))
Kick off collection of a sequence of samples to be passed to a user-provided handler. The ADC and Timer will be configured to collect samples at frequency fs.

4.1.1 Detailed Description

ADC driver for the TM4C123G. Provides interfaces for collecting single samples or a series at a given sampling frequency. Does not allow for sampling of more than one channel at any given time. Timer 2 is reserved for this driver.

Author

Riley Wood and Jeageun Jung

4.1.2 Function Documentation

4.1.2.1 `int ADC_Collect (uint32_t channelNum, uint32_t fs, void(*) (unsigned long) handler)`

Kick off collection of a sequence of samples to be passed to a user-provided handler. The ADC and Timer will be configured to collect samples at frequency fs.

Parameters

<i>channelNum</i>	ADC channel to sample
<i>fs</i>	Sampling frequency
<i>handler</i>	Function which will be passed each sample as it is collected.

Returns

int 0 on success, -1 on failure.

4.1.2.2 `uint16_t ADC_In (void)`

Returns the most recent sample collected by the channel configured in `ADC_Init(...)`

If the channel has not finished collecting its first sample, this function returns 0xFFFF.

If you call this rapidly, faster than the ADC samples, this function may repeat values (since it always returns the most recent).

Returns

uint16_t The conversion result

4.1.2.3 `int ADC_Init (uint32_t channelNum)`

Configure an ADC channel for continuous sampling. Retrieve measurements from this channel with [ADC_In\(\)](#).

Parameters

<i>channelNum</i>	The channel to set up
-------------------	-----------------------

Returns

int 0 on success, -1 on failure.

4.2 inc/interpreter.h File Reference

Functions

- void [interpreter_task](#) (void)
OS Task that sends characters to the interpreter.
- void [interpreter_cmd](#) (char *cmd_str)
Pass user input to the interpreter and act on their command.

4.2.1 Detailed Description

List of commands

- adc
 - Prints 2 consecutive ADC samples of channel 0 to the LCD and UART0
- lcd
 - Prints strings on each line of each logical display on the LCD.

4.2.2 Function Documentation

4.2.2.1 void [interpreter_cmd](#) (char * *cmd_str*)

Pass user input to the interpreter and act on their command.

Parameters

<i>cmd_str</i>	String containing the entire user command.
----------------	--

4.3 inc/misc_macros.h File Reference

Some helper macros.

Macros

- #define [lengthof](#)(array) (sizeof(array)/sizeof((array)[0]))
Get the number of elements in an array.
- #define [zeroes](#)(array) memset(array, 0, sizeof(array))
Zeros out an array.

4.3.1 Detailed Description

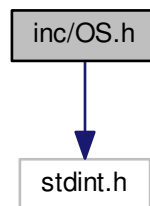
Some helper macros.

4.4 inc/OS.h File Reference

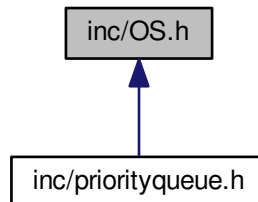
Real Time Operating System for Labs 2 and 3 EE445M/EE380L.12.

```
#include <stdint.h>
```

Include dependency graph for OS.h:



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



Data Structures

- struct [_tcb_s](#)
- struct [Sema4](#)

Macros

- `#define TIME_1MS 80000`
- `#define TIME_2MS (2 * TIME_1MS)`
- `#define TIME_500US (TIME_1MS / 2)`
- `#define TIME_250US (TIME_1MS / 4)`
- `#define TASK_STACK_SIZE 128`
- `#define TCB_MAGIC (0x900d900d)`

Typedefs

- typedef struct `_tcb_s tcb_t`
- typedef struct `Sema4 Sema4Type`

Functions

- void `OS_Init` (void)
- void `OS_InitSemaphore` (`Sema4Type` *semaPt, long value)
- void `OS_Wait` (`Sema4Type` *semaPt)
- void `OS_Signal` (`Sema4Type` *semaPt)
- void `OS_bWait` (`Sema4Type` *semaPt)
- void `OS_bSignal` (`Sema4Type` *semaPt)
- int `OS_AddThread` (void(*task)(void), unsigned long stackSize, unsigned long priority)
- unsigned long `OS_Id` (void)
- int `OS_AddPeriodicThread` (void(*task)(void), unsigned long period, unsigned long priority)
- int `OS_AddSW1Task` (void(*task)(void), unsigned long priority)
- int `OS_AddSW2Task` (void(*task)(void), unsigned long priority)
- void `OS_Sleep` (unsigned long sleepTime)
- void `OS_Kill` (void)
- void `OS_Suspend` (void)
- void `OS_Fifo_Init` (unsigned long size)
- int `OS_Fifo_Put` (unsigned long data)
- unsigned long `OS_Fifo_Get` (void)
- long `OS_Fifo_Size` (void)
- void `OS_MailBox_Init` (void)
- void `OS_MailBox_Send` (unsigned long data)
- unsigned long `OS_MailBox_Recv` (void)
- unsigned long long `OS_Time` (void)
- unsigned long long `OS_TimeDifference` (unsigned long long start, unsigned long long stop)
- void `OS_ClearMsTime` (void)
- unsigned long `OS_MsTime` (void)
- void `OS_Launch` (unsigned long theTimeSlice)
- long `StartCritical` (void)
- void `EndCritical` (long sr)
- void `DisableInterrupts` (void)
- void `EnableInterrupts` (void)

4.4.1 Detailed Description

Real Time Operating System for Labs 2 and 3 EE445M/EE380L.12.

RTOS kernel capable of round-robin scheduling, up to 2 low-jitter periodic tasks.

Reserves WTIMER1A and B for periodic task scheduling. Reserves SysTick timer for round-robin scheduling. Reserves WTIMER0 as a 64-bit time source.

Interface by Jonathan W. Valvano 2/20/17, valvano@mail.utexas.edu Implementation by Riley Wood and Jeageun Jung

Author

Riley Wood and Jeageun Jung

4.4.2 Function Documentation

4.4.2.1 `int OS_AddPeriodicThread (void(*) (void) task, unsigned long period, unsigned long priority)`

Add a background periodic task. Typically this function receives the highest priority You are free to select the time resolution for this function It is assumed that the user task will run to completion and return This task can not spin, block, loop, sleep, or kill This task can call OS_Signal OS_bSignal OS_AddThread This task does not have a Thread ID In lab 2, this command will be called 0 or 1 times In lab 2, the priority field can be ignored In lab 3, this command will be called 0 1 or 2 times In lab 3, there will be up to four background threads, and this priority field determines the relative priority of these four threads

Parameters

<i>pointer</i>	to a void/void background function
<i>period</i>	given in system time units (12.5ns)
<i>priority</i>	0 is the highest, 5 is the lowest

Returns

1 if successful, 0 if this thread can not be added

4.4.2.2 `int OS_AddSW1Task (void(*) (void) task, unsigned long priority)`

add a background task to run whenever the SW1 (PF4) button is pushed

Parameters

<i>pointer</i>	to a void/void background function
<i>priority</i>	0 is the highest, 5 is the lowest

Returns

1 if successful, 0 if this thread can not be added It is assumed that the user task will run to completion and return This task can not spin, block, loop, sleep, or kill This task can call OS_Signal OS_bSignal OS_AddThread This task does not have a Thread ID In labs 2 and 3, this command will be called 0 or 1 times In lab 2, the priority field can be ignored In lab 3, there will be up to four background threads, and this priority field determines the relative priority of these four threads

4.4.2.3 `int OS_AddSW2Task (void(*) (void) task, unsigned long priority)`

add a background task to run whenever the SW2 (PF0) button is pushed

Parameters

<i>pointer</i>	to a void/void background function
<i>priority</i>	0 is highest, 5 is lowest

Returns

1 if successful, 0 if this thread can not be added It is assumed user task will run to completion and return This task can not spin block loop sleep or kill This task can call issue OS_Signal, it can call OS_AddThread This task does not have a Thread ID In lab 2, this function can be ignored In lab 3, this command will be called will be called 0 or 1 times In lab 3, there will be up to four background threads, and this priority field determines the relative priority of these four threads

4.4.2.4 int OS_AddThread (void(*) (void) *task*, unsigned long *stackSize*, unsigned long *priority*)

add a foreground thread to the scheduler stack size must be divisible by 8 (aligned to double word boundary) In Lab 2, you can ignore both the stackSize and priority fields In Lab 3, you can ignore the stackSize fields

Parameters

<i>task</i>	Task function
<i>stackSize</i>	Size of the stack in bytes. Should be divisible by 8
<i>priority</i>	Priority of the task. 0 is highest, 5 is lowest.

Returns

1 if successful, 0 if this thread can not be added

4.4.2.5 void OS_bSignal (Sema4Type * *semaPt*)

Lab2 spinlock, set to 1 Lab3 wakeup blocked thread if appropriate

Parameters

<i>semaPt</i>	pointer to a binary semaphore
---------------	-------------------------------

4.4.2.6 void OS_bWait (Sema4Type * *semaPt*)

Lab2 spinlock, set to 0 Lab3 block if less than zero

Parameters

<i>semaPt</i>	pointer to a binary semaphore
---------------	-------------------------------

4.4.2.7 void OS_ClearMsTime (void)

Sets the system time to zero (from Lab 1). You are free to change how this works.

Returns

none

4.4.2.8 unsigned long OS_Fifo_Get (void)

Remove one data sample from the Fifo. Called in foreground, will spin/block if empty

Returns

data

4.4.2.9 void OS_Fifo_Init (unsigned long *size*)

Initialize the Fifo to be empty. In Lab 2, you can ignore the size field. In Lab 3, you should implement the user-defined fifo size. In Lab 3, you can put whatever restrictions you want on size e.g., 4 to 64 elements e.g., must be a power of 2,4,8,16,32,64,128

Parameters

<i>size</i>	Size of the fifo
-------------	------------------

Returns

none

4.4.2.10 int OS_Fifo_Put (unsigned long *data*)

Enter one data sample into the Fifo. Called from the background, so no waiting. Since this is called by interrupt handlers this function can not disable or enable interrupts.

Parameters

<i>data</i>	Data to put in the FIFO
-------------	-------------------------

Returns

true if data is properly saved, false if data not saved, because it was full

4.4.2.11 long OS_Fifo_Size (void)

Check the status of the Fifo.

Returns

returns the number of elements in the Fifo. Greater than zero if a call to OS_Fifo_Get will return right away, zero or less than zero if the Fifo is empty, zero or less than zero if a call to OS_Fifo_Get will spin or block

4.4.2.12 unsigned long OS_Id (void)

returns the thread ID for the currently running thread

Returns

Thread ID, number greater than zero

4.4.2.13 void OS_Init (void)

initialize operating system, disable interrupts until OS_Launch initialize OS controlled I/O: serial, ADC, systick, LaunchPad I/O and timers

4.4.2.14 void OS_InitSemaphore (Sema4Type * semaPt, long value)

initialize semaphore

Parameters

<i>semaPt</i>	pointer to a semaphore
---------------	------------------------

4.4.2.15 void OS_Kill (void)

kill the currently running thread, release its TCB and stack

4.4.2.16 void OS_Launch (unsigned long theTimeSlice)

Start the scheduler, enable interrupts. In Lab 2, you can ignore the theTimeSlice field. In Lab 3, you should implement the user-defined TimeSlice field. It is ok to limit the range of theTimeSlice to match the 24-bit SysTick.

Parameters

<i>theTimeSlice</i>	number of 12.5ns clock cycles for each time slice
---------------------	---

Returns

none (does not return)

4.4.2.17 void OS_MailBox_Init (void)

Initialize communication channel

Returns

none

4.4.2.18 unsigned long OS_MailBox_Recv (void)

Remove mail from the MailBox. This function will be called from a foreground thread. It will spin/block if the MailBox is empty.

Returns

data received

4.4.2.19 void OS_MailBox_Send (unsigned long *data*)

Enter mail into the MailBox. This function will be called from a foreground thread. It will spin/block if the MailBox contains data not yet received

Parameters

<i>data</i>	to be sent
-------------	------------

Returns

none

4.4.2.20 unsigned long OS_MsTime (void)

Reads the current time in msec (from Lab 1). You are free to select the time resolution for this function. It is ok to make the resolution to match the first call to OS_AddPeriodicThread.

Returns

time in ms units

4.4.2.21 void OS_Signal (Sema4Type * *semaPt*)

increment semaphore Lab2 spinlock Lab3 wakeup blocked thread if appropriate

Parameters

<i>semaPt</i>	pointer to a counting semaphore
---------------	---------------------------------

4.4.2.22 void OS_Sleep (unsigned long *sleepTime*)

Place this thread into a dormant state. You are free to select the time resolution for this function. OS_Sleep(0) implements cooperative multitasking.

Parameters

<i>sleepTime</i>	number of msec to sleep
------------------	-------------------------

4.4.2.23 void OS_Suspend (void)

suspend execution of currently running thread. scheduler will choose another thread to execute. Can be used to implement cooperative multitasking. Same function as OS_Sleep(0).

4.4.2.24 unsigned long long OS_Time (void)

Return the system time in system time units (12.5ns)

Returns

time in 12.5ns units, 0 to 4294967295

4.4.2.25 unsigned long long OS_TimeDifference (unsigned long long start, unsigned long long stop)

Calculates difference between two times. The time resolution should be less than or equal to 1us, and the precision at least 12 bits. It is ok to change the resolution and precision of this function as long as this function and OS_Time have the same resolution and precision.

Parameters

<i>start</i>	Start time measured with OS_Time
<i>stop</i>	Stop time measured with OS_Time

Returns

time difference in 12.5ns units

4.4.2.26 void OS_Wait (Sema4Type * semaPt)

decrement semaphore Lab2 spinlock Lab3 block if less than zero

Parameters

<i>semaPt</i>	pointer to a counting semaphore
---------------	---------------------------------

4.5 inc/PLL.h File Reference

Runs on LM4F120/TM4C123 A software function to change the bus frequency using the PLL.

Macros

- `#define Bus80MHz 4`
- `#define Bus80_000MHz 4`
- `#define Bus66_667MHz 5`
- `#define Bus50_000MHz 7`
- `#define Bus50MHz 7`
- `#define Bus44_444MHz 8`
- `#define Bus40_000MHz 9`
- `#define Bus40MHz 9`
- `#define Bus36_364MHz 10`
- `#define Bus33_333MHz 11`
- `#define Bus30_769MHz 12`
- `#define Bus28_571MHz 13`
- `#define Bus26_667MHz 14`
- `#define Bus25_000MHz 15`
- `#define Bus25MHz 15`
- `#define Bus23_529MHz 16`
- `#define Bus22_222MHz 17`
- `#define Bus21_053MHz 18`
- `#define Bus20_000MHz 19`
- `#define Bus20MHz 19`
- `#define Bus19_048MHz 20`
- `#define Bus18_182MHz 21`
- `#define Bus17_391MHz 22`
- `#define Bus16_667MHz 23`
- `#define Bus16_000MHz 24`
- `#define Bus16MHz 24`
- `#define Bus15_385MHz 25`
- `#define Bus14_815MHz 26`
- `#define Bus14_286MHz 27`
- `#define Bus13_793MHz 28`
- `#define Bus13_333MHz 29`
- `#define Bus12_903MHz 30`
- `#define Bus12_500MHz 31`
- `#define Bus12_121MHz 32`
- `#define Bus11_765MHz 33`
- `#define Bus11_429MHz 34`
- `#define Bus11_111MHz 35`
- `#define Bus10_811MHz 36`
- `#define Bus10_526MHz 37`
- `#define Bus10_256MHz 38`
- `#define Bus10_000MHz 39`
- `#define Bus10MHz 39`
- `#define Bus9_756MHz 40`
- `#define Bus9_524MHz 41`
- `#define Bus9_302MHz 42`
- `#define Bus9_091MHz 43`
- `#define Bus8_889MHz 44`

- #define **Bus8_696MHz** 45
- #define **Bus8_511MHz** 46
- #define **Bus8_333MHz** 47
- #define **Bus8_163MHz** 48
- #define **Bus8_000MHz** 49
- #define **Bus8MHz** 49
- #define **Bus7_843MHz** 50
- #define **Bus7_692MHz** 51
- #define **Bus7_547MHz** 52
- #define **Bus7_407MHz** 53
- #define **Bus7_273MHz** 54
- #define **Bus7_143MHz** 55
- #define **Bus7_018MHz** 56
- #define **Bus6_897MHz** 57
- #define **Bus6_780MHz** 58
- #define **Bus6_667MHz** 59
- #define **Bus6_557MHz** 60
- #define **Bus6_452MHz** 61
- #define **Bus6_349MHz** 62
- #define **Bus6_250MHz** 63
- #define **Bus6_154MHz** 64
- #define **Bus6_061MHz** 65
- #define **Bus5_970MHz** 66
- #define **Bus5_882MHz** 67
- #define **Bus5_797MHz** 68
- #define **Bus5_714MHz** 69
- #define **Bus5_634MHz** 70
- #define **Bus5_556MHz** 71
- #define **Bus5_479MHz** 72
- #define **Bus5_405MHz** 73
- #define **Bus5_333MHz** 74
- #define **Bus5_263MHz** 75
- #define **Bus5_195MHz** 76
- #define **Bus5_128MHz** 77
- #define **Bus5_063MHz** 78
- #define **Bus5_000MHz** 79
- #define **Bus4_938MHz** 80
- #define **Bus4_878MHz** 81
- #define **Bus4_819MHz** 82
- #define **Bus4_762MHz** 83
- #define **Bus4_706MHz** 84
- #define **Bus4_651MHz** 85
- #define **Bus4_598MHz** 86
- #define **Bus4_545MHz** 87
- #define **Bus4_494MHz** 88
- #define **Bus4_444MHz** 89
- #define **Bus4_396MHz** 90
- #define **Bus4_348MHz** 91
- #define **Bus4_301MHz** 92
- #define **Bus4_255MHz** 93
- #define **Bus4_211MHz** 94
- #define **Bus4_167MHz** 95
- #define **Bus4_124MHz** 96
- #define **Bus4_082MHz** 97
- #define **Bus4_040MHz** 98

- `#define Bus4_000MHz 99`
- `#define Bus4MHz 99`
- `#define Bus3_960MHz 100`
- `#define Bus3_922MHz 101`
- `#define Bus3_883MHz 102`
- `#define Bus3_846MHz 103`
- `#define Bus3_810MHz 104`
- `#define Bus3_774MHz 105`
- `#define Bus3_738MHz 106`
- `#define Bus3_704MHz 107`
- `#define Bus3_670MHz 108`
- `#define Bus3_636MHz 109`
- `#define Bus3_604MHz 110`
- `#define Bus3_571MHz 111`
- `#define Bus3_540MHz 112`
- `#define Bus3_509MHz 113`
- `#define Bus3_478MHz 114`
- `#define Bus3_448MHz 115`
- `#define Bus3_419MHz 116`
- `#define Bus3_390MHz 117`
- `#define Bus3_361MHz 118`
- `#define Bus3_333MHz 119`
- `#define Bus3_306MHz 120`
- `#define Bus3_279MHz 121`
- `#define Bus3_252MHz 122`
- `#define Bus3_226MHz 123`
- `#define Bus3_200MHz 124`
- `#define Bus3_175MHz 125`
- `#define Bus3_150MHz 126`
- `#define Bus3_125MHz 127`

Functions

- void [PLL_Init](#) (uint32_t freq)
configure the system to get its clock from the PLL

4.5.1 Detailed Description

Runs on LM4F120/TM4C123 A software function to change the bus frequency using the PLL.

Author

Daniel Valvano

4.5.2 Function Documentation

4.5.2.1 void PLL_Init (uint32_t freq)

configure the system to get its clock from the PLL

Parameters

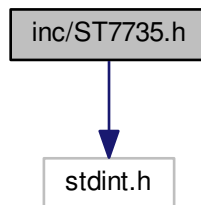
<i>freq</i>	Macro defined in PLL.h to choose frequency
-------------	--

4.6 inc/ST7735.h File Reference

This is a library for the Adafruit 1.8" SPI display.

```
#include <stdint.h>
```

Include dependency graph for ST7735.h:



Macros

- `#define ST7735_TFTWIDTH 128`
- `#define ST7735_TFTHEIGHT 160`
- `#define ST7735_BLACK 0x0000`
- `#define ST7735_BLUE 0xF800`
- `#define ST7735_RED 0x001F`
- `#define ST7735_GREEN 0x07E0`
- `#define ST7735_CYAN 0xFFE0`
- `#define ST7735_MAGENTA 0xF81F`
- `#define ST7735_YELLOW 0x07FF`
- `#define ST7735_WHITE 0xFFFF`

Enumerations

- enum `initRFlags` { `none`, `INITR_GREENTAB`, `INITR_REDTAB`, `INITR_BLACKTAB` }
some flags for [ST7735_InitR\(\)](#)

Functions

- void [ST7735_InitB](#) (void)
Initialization for ST7735B screens.
- void [ST7735_InitR](#) (enum [initRFlags](#) option)
Initialization for ST7735R screens (green or red tabs).
- void [ST7735_DrawPixel](#) (int16_t x, int16_t y, uint16_t color)
Color the pixel at the given coordinates with the given color. Requires 13 bytes of transmission.
- void [ST7735_DrawFastVLine](#) (int16_t x, int16_t y, int16_t h, uint16_t color)
*Draw a vertical line at the given coordinates with the given height and color. A vertical line is parallel to the longer side of the rectangular display Requires (11 + 2*h) bytes of transmission (assuming image fully on screen)*
- void [ST7735_DrawFastHLine](#) (int16_t x, int16_t y, int16_t w, uint16_t color)
*Draw a horizontal line at the given coordinates with the given width and color. A horizontal line is parallel to the shorter side of the rectangular display Requires (11 + 2*w) bytes of transmission (assuming image fully on screen)*
- void [ST7735_FillScreen](#) (uint16_t color)
Fill the screen with the given color. Requires 40,971 bytes of transmission.
- void [ST7735_FillRect](#) (int16_t x, int16_t y, int16_t w, int16_t h, uint16_t color)
*Draw a filled rectangle at the given coordinates with the given width, height, and color. Requires (11 + 2*w*h) bytes of transmission (assuming image fully on screen)*
- uint16_t [ST7735_Color565](#) (uint8_t r, uint8_t g, uint8_t b)
Pass 8-bit (each) R,G,B and get back 16-bit packed color.
- uint16_t [ST7735_SwapColor](#) (uint16_t x)
Swaps the red and blue values of the given 16-bit packed color; green is unchanged.
- void [ST7735_DrawBitmap](#) (int16_t x, int16_t y, const uint16_t *image, int16_t w, int16_t h)
*Displays a 16-bit color BMP image. A bitmap file that is created by a PC image processing program has a header and may be padded with dummy columns so the data have four byte alignment. This function assumes that all of that has been stripped out, and the array image[] has one 16-bit halfword for each pixel to be displayed on the screen (encoded in reverse order, which is standard for bitmap files). An array can be created in this format from a 24-bit-per-pixel .bmp file using the associated converter program. (x,y) is the screen location of the lower left corner of BMP image Requires (11 + 2*w*h) bytes of transmission (assuming image fully on screen) Must be less than or equal to 128 pixels wide by 160 pixels high.*
- void [ST7735_DrawCharS](#) (int16_t x, int16_t y, char c, int16_t textColor, int16_t bgColor, uint8_t size)
*Simple character draw function. This is the same function from Adafruit_GFX.c but adapted for this processor. However, each call to [ST7735_DrawPixel\(\)](#) calls [setAddrWindow\(\)](#), which needs to send many extra data and commands. If the background color is the same as the text color, no background will be printed, and text can be drawn right over existing images without covering them with a box. Requires (11 + 2*size*size)*6*8 (image fully on screen; textcolor != bgColor)*
- void [ST7735_DrawChar](#) (int16_t x, int16_t y, char c, int16_t textColor, int16_t bgColor, uint8_t size)
*Advanced character draw function. This is similar to the function from Adafruit_GFX.c but adapted for this processor. However, this function only uses one call to [setAddrWindow\(\)](#), which allows it to run at least twice as fast. Requires (11 + size*size*6*8) bytes of transmission (assuming image fully on screen)*
- uint32_t [ST7735_DrawString](#) (uint16_t x, uint16_t y, char *pt, int16_t textColor, int16_t bgColor)
*String draw function. 16 rows (0 to 15) and 21 characters (0 to 20) Requires (11 + size*size*6*8) bytes of transmission for each character If bgColor is same as textColor, no background will be filled in for chars.*
- void [ST7735_SetCursor](#) (uint32_t newX, uint32_t newY)
Move the cursor to the desired X- and Y-position. The next character will be printed here. X=0 is the leftmost column. Y=0 is the top row.
- void [ST7735_OutUDec](#) (uint32_t n)
Output a 32-bit number in unsigned decimal format Position determined by [ST7735_SetCursor](#) command Color set by [ST7735_SetTextColor](#).
- void [ST7735_SetRotation](#) (uint8_t m)
Change the image rotation. Requires 2 bytes of transmission.
- void [ST7735_InvertDisplay](#) (int i)
Send the command to invert all of the colors. Requires 1 byte of transmission.
- void [ST7735_PlotClear](#) (int32_t ymin, int32_t ymax)

- Clear the graphics buffer, set X coordinate to 0 This routine clears the display.*

 - void [ST7735_PlotPoint](#) (int32_t y)

Used in the voltage versus time plot, plot one point at y It does output to display.
 - void [ST7735_PlotLine](#) (int32_t y)

Used in the voltage versus time plot, plot line to new point It does output to display.
 - void [ST7735_PlotPoints](#) (int32_t y1, int32_t y2)

Used in the voltage versus time plot, plot two points at y1, y2 It does output to display.
 - void [ST7735_PlotBar](#) (int32_t y)

Used in the voltage versus time bar, plot one bar at y It does not output to display until RIT128x96x4ShowPlot called.
 - void [ST7735_PlotdBfs](#) (int32_t y)

Used in the amplitude versus frequency plot, plot bar point at y 0 to 0.625V scaled on a log plot from min to max It does output to display.
 - void [ST7735_PlotNext](#) (void)

Used in all the plots to step the X coordinate one pixel X steps from 0 to 127, then back to 0 again It does not output to display.
 - void [ST7735_PlotNextErase](#) (void)

Used in all the plots to step the X coordinate one pixel X steps from 0 to 127, then back to 0 again It clears the vertical space into which the next pixel will be drawn.
 - void [ST7735_OutChar](#) (char ch)

Output one character to the LCD Position determined by ST7735_SetCursor command Color set by ST7735_SetTextColor.
 - void [ST7735_OutString](#) (char *ptr)

Print a string of characters to the ST7735 LCD. Position determined by ST7735_SetCursor command Color set by ST7735_SetTextColor The string will not automatically wrap.
 - void [ST7735_SetTextColor](#) (uint16_t color)

Sets the color in which the characters will be printed Background color is fixed at black.
 - void [Output_Init](#) (void)

Standard device driver initialization function for printf Initialize ST7735 LCD.
 - void [Output_Clear](#) (void)

Clear display.
 - void [Output_Off](#) (void)

Turn off display (low power)
 - void [Output_On](#) (void)

Turn on display.
 - void [Output_Color](#) (uint32_t newColor)

set the color for future output Background color is fixed at black
 - void [ST7735_Message](#) (int device, int line, char *string, int32_t value)

Display a string and number on one of two logical displays at a given line number relative to that display. The LCD display is logically divided into two displays: top and bottom. These logical displays are identified with a device ID. Device 0 is the top display, device 1 is the bottom display. Each logical device has 4 lines, numbered 0 to 3. Prints in black text on a white background. This function is not (yet) reentrant.

4.6.1 Detailed Description

This is a library for the Adafruit 1.8" SPI display.

4.6.2 Function Documentation

4.6.2.1 void Output_Color (uint32_t newColor)

set the color for future output Background color is fixed at black

Parameters

<i>newColor</i>	16-bit packed color
-----------------	---------------------

4.6.2.2 `uint16_t ST7735_Color565 (uint8_t r, uint8_t g, uint8_t b)`

Pass 8-bit (each) R,G,B and get back 16-bit packed color.

Parameters

<i>r</i>	red value
<i>g</i>	green value
<i>b</i>	blue value

Returns

`uint16_t` 16-bit color

4.6.2.3 `void ST7735_DrawBitmap (int16_t x, int16_t y, const uint16_t * image, int16_t w, int16_t h)`

Displays a 16-bit color BMP image. A bitmap file that is created by a PC image processing program has a header and may be padded with dummy columns so the data have four byte alignment. This function assumes that all of that has been stripped out, and the array `image[]` has one 16-bit halfword for each pixel to be displayed on the screen (encoded in reverse order, which is standard for bitmap files). An array can be created in this format from a 24-bit-per-pixel .bmp file using the associated converter program. (*x*,*y*) is the screen location of the lower left corner of BMP image Requires (11 + 2*w*h) bytes of transmission (assuming image fully on screen) Must be less than or equal to 128 pixels wide by 160 pixels high.

Parameters

<i>x</i>	horizontal position of the bottom left corner of the image, columns from the left edge
<i>y</i>	vertical position of the bottom left corner of the image, rows from the top edge
<i>image</i>	pointer to a 16-bit color BMP image
<i>w</i>	number of pixels wide
<i>h</i>	number of pixels tall

4.6.2.4 `void ST7735_DrawChar (int16_t x, int16_t y, char c, int16_t textColor, int16_t bgColor, uint8_t size)`

Advanced character draw function. This is similar to the function from `Adafruit_GFX.c` but adapted for this processor. However, this function only uses one call to `setAddrWindow()`, which allows it to run at least twice as fast. Requires (11 + `size*size*6*8`) bytes of transmission (assuming image fully on screen)

Parameters

<i>x</i>	horizontal position of the top left corner of the character, columns from the left edge
<i>y</i>	vertical position of the top left corner of the character, rows from the top edge

Parameters

<i>c</i>	character to be printed
<i>textColor</i>	16-bit color of the character
<i>bgColor</i>	16-bit color of the background
<i>size</i>	number of pixels per character pixel (e.g. size==2 prints each pixel of font as 2x2 square)

4.6.2.5 void ST7735_DrawCharS (int16_t x, int16_t y, char c, int16_t *textColor*, int16_t *bgColor*, uint8_t *size*)

Simple character draw function. This is the same function from Adafruit_GFX.c but adapted for this processor. However, each call to [ST7735_DrawPixel\(\)](#) calls [setAddrWindow\(\)](#), which needs to send many extra data and commands. If the background color is the same as the text color, no background will be printed, and text can be drawn right over existing images without covering them with a box. Requires (11 + 2*size*size)*6*8 (image fully on screen; textcolor != bgColor)

Parameters

<i>x</i>	horizontal position of the top left corner of the character, columns from the left edge
<i>y</i>	vertical position of the top left corner of the character, rows from the top edge
<i>c</i>	character to be printed
<i>textColor</i>	16-bit color of the character
<i>bgColor</i>	16-bit color of the background
<i>size</i>	number of pixels per character pixel (e.g. size==2 prints each pixel of font as 2x2 square)

4.6.2.6 void ST7735_DrawFastHLine (int16_t x, int16_t y, int16_t w, uint16_t *color*)

Draw a horizontal line at the given coordinates with the given width and color. A horizontal line is parallel to the shorter side of the rectangular display Requires (11 + 2*w) bytes of transmission (assuming image fully on screen)

Parameters

<i>x</i>	horizontal position of the start of the line, columns from the left edge
<i>y</i>	vertical position of the start of the line, rows from the top edge
<i>w</i>	horizontal width of the line
<i>color</i>	16-bit color, which can be produced by ST7735_Color565()

4.6.2.7 void ST7735_DrawFastVLine (int16_t x, int16_t y, int16_t h, uint16_t *color*)

Draw a vertical line at the given coordinates with the given height and color. A vertical line is parallel to the longer side of the rectangular display Requires (11 + 2*h) bytes of transmission (assuming image fully on screen)

Parameters

<i>x</i>	horizontal position of the start of the line, columns from the left edge
<i>y</i>	vertical position of the start of the line, rows from the top edge
<i>h</i>	vertical height of the line
<i>color</i>	16-bit color, which can be produced by ST7735_Color565()

4.6.2.8 void ST7735_DrawPixel (int16_t x, int16_t y, uint16_t color)

Color the pixel at the given coordinates with the given color. Requires 13 bytes of transmission.

Parameters

<i>x</i>	horizontal position of the pixel, columns from the left edge must be less than 128 0 is on the left, 126 is near the right
<i>y</i>	vertical position of the pixel, rows from the top edge must be less than 160 159 is near the wires, 0 is the side opposite the wires
<i>color</i>	16-bit color, which can be produced by ST7735_Color565()

4.6.2.9 uint32_t ST7735_DrawString (uint16_t x, uint16_t y, char * pt, int16_t textColor, int16_t bgColor)

String draw function. 16 rows (0 to 15) and 21 characters (0 to 20) Requires (11 + size*size*6*8) bytes of transmission for each character If bgColor is same as textColor, no background will be filled in for chars.

Parameters

<i>x</i>	columns from the left edge (0 to 20)
<i>y</i>	rows from the top edge (0 to 15)
<i>pt</i>	pointer to a null terminated string to be printed
<i>textColor</i>	16-bit color of the characters
<i>bgColor</i>	16-bit color of the background

Returns

uint32_t number of characters printed

4.6.2.10 void ST7735_FillRect (int16_t x, int16_t y, int16_t w, int16_t h, uint16_t color)

Draw a filled rectangle at the given coordinates with the given width, height, and color. Requires (11 + 2*w*h) bytes of transmission (assuming image fully on screen)

Parameters

<i>x</i>	horizontal position of the top left corner of the rectangle, columns from the left edge
<i>y</i>	vertical position of the top left corner of the rectangle, rows from the top edge
<i>w</i>	horizontal width of the rectangle
<i>h</i>	vertical height of the rectangle
<i>color</i>	16-bit color, which can be produced by ST7735_Color565()

4.6.2.11 void ST7735_FillScreen (uint16_t color)

Fill the screen with the given color. Requires 40,971 bytes of transmission.

Parameters

<i>color</i>	16-bit color, which can be produced by ST7735_Color565()
--------------	--

4.6.2.12 void ST7735_InitR (enum initRFlags *option*)

Initialization for ST7735R screens (green or red tabs).

Parameters

<i>initRFlags</i>	one of the enumerated options depending on tabs
-------------------	---

4.6.2.13 void ST7735_InvertDisplay (int *i*)

Send the command to invert all of the colors. Requires 1 byte of transmission.

Parameters

<i>i</i>	0 to disable inversion; non-zero to enable inversion
----------	--

4.6.2.14 void ST7735_Message (int *device*, int *line*, char * *string*, int32_t *value*)

Display a string and number on one of two logical displays at a given line number relative to that display. The LCD display is logically divided into two displays: top and bottom. These logical displays are identified with a device ID. Device 0 is the top display, device 1 is the bottom display. Each logical device has 4 lines, numbered 0 to 3. Prints in black text on a white background. This function is not (yet) reentrant.

Parameters

<i>device</i>	Device ID, 0 or 1
<i>line</i>	Line number, 0 to 3, relative to the logical display.
<i>string</i>	Null-terminated string to print on the select logical display and line.
<i>value</i>	Integer value printed after the string.

4.6.2.15 void ST7735_OutChar (char *ch*)

Output one character to the LCD Position determined by ST7735_SetCursor command Color set by ST7735_Set↵ TextColor.

Parameters

<i>ch</i>	8-bit ASCII character
-----------	-----------------------

4.6.2.16 void ST7735_OutString (char * *ptr*)

Print a string of characters to the ST7735 LCD. Position determined by ST7735_SetCursor command Color set by ST7735_SetTextColor The string will not automatically wrap.

Parameters

<i>ptr</i>	pointer to NULL-terminated ASCII string
------------	---

4.6.2.17 void ST7735_OutUDec (uint32_t *n*)

Output a 32-bit number in unsigned decimal format Position determined by ST7735_SetCursor command Color set by ST7735_SetTextColor.

Parameters

<i>n</i>	32-bit number to be transferred
----------	---------------------------------

4.6.2.18 void ST7735_PlotBar (int32_t *y*)

Used in the voltage versus time bar, plot one bar at *y* It does not output to display until RIT128x96x4ShowPlot called.

Parameters

<i>y</i>	the <i>y</i> coordinate of the bar plotted
----------	--

4.6.2.19 void ST7735_PlotClear (int32_t *ymin*, int32_t *ymax*)

Clear the graphics buffer, set X coordinate to 0 This routine clears the display.

Parameters

<i>ymin</i>	Lower bound of plot
<i>ymax</i>	Upper bound of plot

4.6.2.20 void ST7735_PlotdBfs (int32_t *y*)

Used in the amplitude versus frequency plot, plot bar point at *y* 0 to 0.625V scaled on a log plot from min to max It does output to display.

Parameters

<i>y</i>	the <i>y</i> ADC value of the bar plotted
----------	---

4.6.2.21 void ST7735_PlotLine (int32_t y)

Used in the voltage versus time plot, plot line to new point It does output to display.

Parameters

<i>y</i>	the y coordinate of the point plotted
----------	---------------------------------------

4.6.2.22 void ST7735_PlotPoint (int32_t y)

Used in the voltage versus time plot, plot one point at y It does output to display.

Parameters

<i>y</i>	the y coordinate of the point plotted
----------	---------------------------------------

4.6.2.23 void ST7735_PlotPoints (int32_t y1, int32_t y2)

Used in the voltage versus time plot, plot two points at y1, y2 It does output to display.

Parameters

<i>y1</i>	the y coordinate of the first point plotted
<i>y2</i>	the y coordinate of the second point plotted

4.6.2.24 void ST7735_SetCursor (uint32_t newX, uint32_t newY)

Move the cursor to the desired X- and Y-position. The next character will be printed here. X=0 is the leftmost column. Y=0 is the top row.

Parameters

<i>newX</i>	new X-position of the cursor (0<=newX<=20)
<i>newY</i>	new Y-position of the cursor (0<=newY<=15)

4.6.2.25 void ST7735_SetRotation (uint8_t m)

Change the image rotation. Requires 2 bytes of transmission.

Parameters

<i>m</i>	new rotation value (0 to 3)
----------	-----------------------------

4.6.2.26 void ST7735_SetTextColor (uint16_t *color*)

Sets the color in which the characters will be printed Background color is fixed at black.

Parameters

<i>color</i>	16-bit packed color
--------------	---------------------

4.6.2.27 uint16_t ST7735_SwapColor (uint16_t *x*)

Swaps the red and blue values of the given 16-bit packed color; green is unchanged.

Parameters

<i>x</i>	16-bit color in format B, G, R
----------	--------------------------------

Returns

uint16_t 16-bit color in format R, G, B

4.7 inc/UART.h File Reference

Runs on LM4F120/TM4C123 Use UART0 to implement bidirectional data transfer to and from a computer running HyperTerminal. This time, interrupts and FIFOs are used.

Macros

- #define **CR** 0x0D
- #define **LF** 0x0A
- #define **BS** 0x08
- #define **ESC** 0x1B
- #define **SP** 0x20
- #define **DEL** 0x7F

Functions

- void [UART_Init](#) (void)
Initialize the UART for 115,200 baud rate (assuming 50 MHz clock), 8 bit word length, no parity bits, one stop bit, FIFOs enabled.
- char [UART_InChar](#) (void)
Wait for new serial port input.
- void [UART_OutChar](#) (char data)
8-bit to serial port
- void [UART_OutString](#) (char *pt)
Output String (NULL termination)
- uint32_t [UART_InUDec](#) (void)

InUDec accepts ASCII input in unsigned decimal format and converts to a 32-bit unsigned number valid range is 0 to 4294967295 ($2^{32}-1$) If you enter a number above 4294967295, it will return an incorrect value Backspace will remove last digit typed.

- void [UART_OutUDec](#) (uint32_t n)

Output a 32-bit number in unsigned decimal format.

- uint32_t [UART_InUHex](#) (void)

Accepts ASCII input in unsigned hexadecimal (base 16) format No '\$' or '0x' need be entered, just the 1 to 8 hex digits It will convert lower case a-f to uppercase A-F and converts to a 16 bit unsigned number value range is 0 to FFFFFFFF If you enter a number above FFFFFFFF, it will return an incorrect value Backspace will remove last digit typed.

- void [UART_OutUHex](#) (uint32_t number)

Output a 32-bit number in unsigned hexadecimal format Variable format 1 to 8 digits with no space before or after.

- void [UART_InString](#) (char *bufPt, uint16_t max)

Accepts ASCII characters from the serial port and adds them to a string until <enter> is typed or until max length of the string is reached. It echoes each character as it is inputted. If a backspace is inputted, the string is modified and the backspace is echoed terminates the string with a null character uses busy-waiting synchronization on RDRF Modified by Agustinus Darmawan + Mingjie Qiu.

4.7.1 Detailed Description

Runs on LM4F120/TM4C123 Use UART0 to implement bidirectional data transfer to and from a computer running HyperTerminal. This time, interrupts and FIFOs are used.

Author

Daniel Valvano

4.7.2 Function Documentation

4.7.2.1 char UART_InChar (void)

Wait for new serial port input.

Returns

char ASCII code for key typed

4.7.2.2 void UART_InString (char * bufPt, uint16_t max)

Accepts ASCII characters from the serial port and adds them to a string until <enter> is typed or until max length of the string is reached. It echoes each character as it is inputted. If a backspace is inputted, the string is modified and the backspace is echoed terminates the string with a null character uses busy-waiting synchronization on RDRF Modified by Agustinus Darmawan + Mingjie Qiu.

Parameters

<i>bufPt</i>	pointer to empty buffer
<i>max</i>	size of buffer

4.7.2.3 uint32_t UART_InUDec (void)

InUDec accepts ASCII input in unsigned decimal format and converts to a 32-bit unsigned number valid range is 0 to 4294967295 ($2^{32}-1$) If you enter a number above 4294967295, it will return an incorrect value Backspace will remove last digit typed.

Returns

uint32_t 32-bit unsigned number

4.7.2.4 uint32_t UART_InUHex (void)

Accepts ASCII input in unsigned hexadecimal (base 16) format No '\$' or '0x' need be entered, just the 1 to 8 hex digits It will convert lower case a-f to uppercase A-F and converts to a 16 bit unsigned number value range is 0 to FFFFFFFF If you enter a number above FFFFFFFF, it will return an incorrect value Backspace will remove last digit typed.

Returns

uint32_t 32-bit unsigned number

4.7.2.5 void UART_OutChar (char *data*)

8-bit to serial port

Parameters

<i>data</i>	letter is an 8-bit ASCII character to be transferred
-------------	--

4.7.2.6 void UART_OutString (char * *pt*)

Output String (NULL termination)

Parameters

<i>pt</i>	pointer to a NULL-terminated string to be transferred
-----------	---

4.7.2.7 void UART_OutUDec (uint32_t *n*)

Output a 32-bit number in unsigned decimal format.

Parameters

<i>n</i>	32-bit number to be transferred
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4.7.2.8 void UART_OutUHex (uint32_t *number*)

Output a 32-bit number in unsigned hexadecimal format Variable format 1 to 8 digits with no space before or after.

Parameters

<i>number</i>	32-bit number to be transferred
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