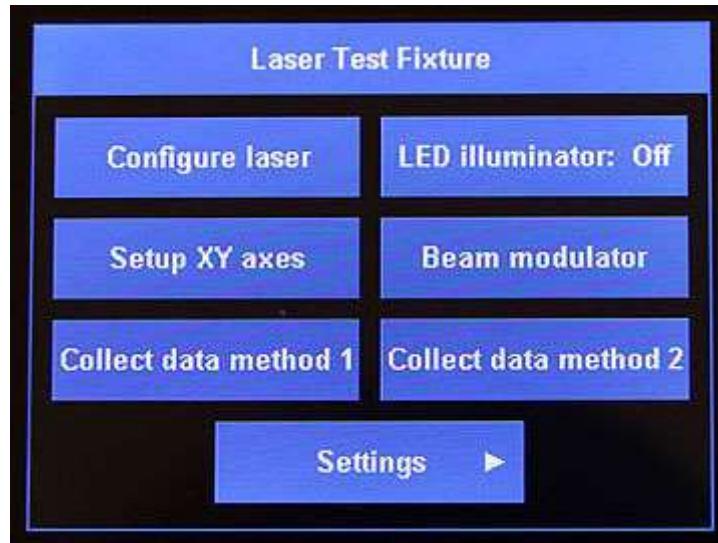


# Teensy User Interface:

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This library is a simple user interface for building Teensy applications. The user interface centers around building apps with one or more touchscreen menus. There are also many features for creating your own screens to present data or prompt the user for information.

The *Teensy User Interface* library requires a touchscreen LCD display that includes a ILI9341 controller chip. The most common version of these uses a 2.8", 320x240 display.



Documentation and code for the *Teensy User Interface* library can be found at:

<https://github.com/Stan-Reifel/TeensyUserInterface>

## Overview:

The display of the *Teensy User Interface* is divided into two sections: along the top is a *Title Bar* and below is the *Display Space*. The Display Space is where menus, message boxes, configuration screens, along with the application's main display are shown.

The heart of this user interface are menus. Menus are displayed in rows and columns of touch sensitive buttons. There are three types of menu buttons: *Commands*, *Toggles* and *Sub Menus*. Menus are displayed by creating a *Menu Table* in your source code then calling: `ui.displayAndExecuteMenu()`

## Hardware:

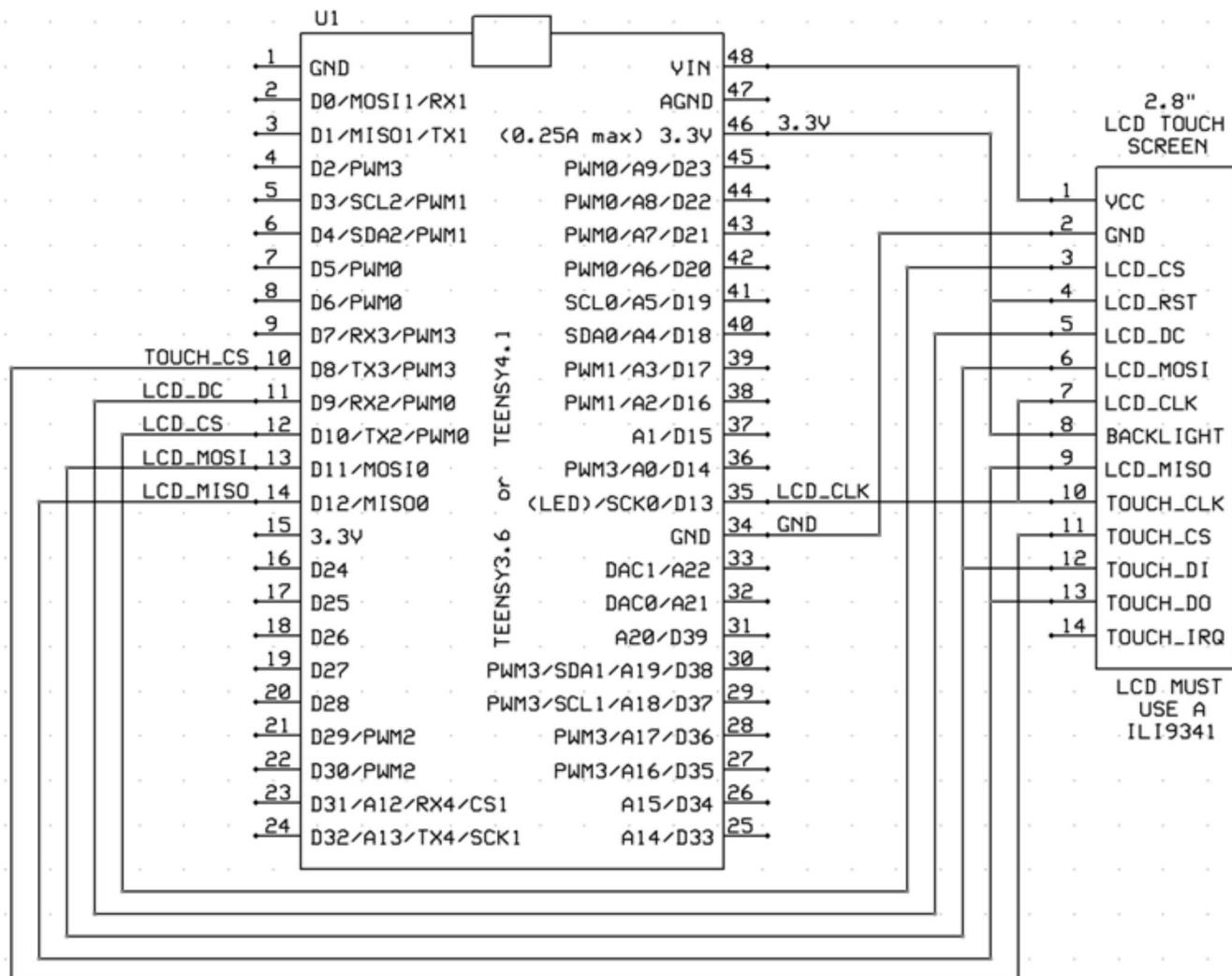
This user interface works with Teensy microcontrollers along with a 2.8" 320x240 ILI9341 LCD touch screen display. These displays are very inexpensive and easy to hookup. This library has only been tested with a *Teensy 3.6* and *Teensy 4.1* but will likely work with much of the Teensy family.



The Touchscreen LCDs can be purchased online from many sources, including:

- PJRC [www.pjrc.com/store/display\\_il9341\\_touch.html](http://www.pjrc.com/store/display_il9341_touch.html)
- Amazon: Search for "HiLetgo ILI9341 2.8" TFT LCD Display"
- eBay: Search for "ILI9341 2.8" TFT LCD Display"

Here is how to wire the LCD to the Teensy 3.6 and Teensy 4.1:



<b>Teensy</b>	<b>Display</b>
VIN	LCD VCC
GND	LCD GND
D10	LCD CS
3.3V	LCD RESET
D9	LCD DC
D11	LCD SDI
D13	LCD CLK
3.3V	LCD LED
D12	LCD SDO
D13	TOUCH CLK
D8	TOUCH CS
D11	TOUCH DIN
D12	TOUCH DO

## Software Notes:

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### Getting started:

It is assumed that you have already configured the Arduino IDE to work with your Teensy micro controller. If not, look here: <https://www.pjrc.com/teensy/teensyduino.html>

To use the *TeensyUserInterface* library you will need to add it to the *Arduino IDE*, along with two other libraries. Do so by:

1. From the Arduino IDE select: *Sketch / Include Library / Manage Libraries...*
2. In the *Filter your search* field, type in *TeensyUserInterface* then click *Install*.
3. In the *Filter your search* field, type in *ILI9341\_t3* then click *Install*.
4. In the *Filter your search* field, type in *XPT2046\_Touchscreen* then click *Install*.
5. As with all Teensy applications, you must configure the Arduino IDE for the type of Teensy microcontroller that you are using. Do that from the menu: *Tools / Board*.

In your sketch, near the top, add this code:

```
#include <TeensyUserInterface.h>
#include <font_Arial.h>
#include <font_ArialBold.h>

TeensyUserInterface ui;
```

Inside your *setup()* function, add this:

```
ui.begin(LCD_ORIENTATION_LANDSCAPE_4PIN_RIGHT, Arial_9_Bold);
```

or this, depending if you want your display wide or tall:

```
ui.begin(LCD_ORIENTATION_PORTRAIT_4PIN_TOP, Arial_9_Bold);
```

## Creating the main menu:

Just below the *setup()* function you will define your *Main Menu*. A typical main menu table might look like:

```
//
// forward declarations for each menus
//
extern MENU_ITEM mainMenu[];
extern MENU_ITEM settingsMenu[];      // add this line if you have a Settings submenu

//
// the main menu table
//
MENU_ITEM mainMenu[] = {
{MENU_ITEM_TYPE_MAIN_MENU_HEADER, "My App",    MENU_COLUMNS_1,           mainMenu},
{MENU_ITEM_TYPE_COMMAND,          "Log data",   menuCommandLogData,    NULL},
{MENU_ITEM_TYPE_TOGGLE,          "Sound",       menuToggleSoundCallback, NULL},
{MENU_ITEM_TYPE_SUB_MENU,        "Settings",   NULL,                  settingsMenu},
{MENU_ITEM_TYPE_END_OF_MENU,     "",           NULL,                  NULL}
};
```

The first line in a menu table sets what type of menu it is, either a *Main Menu*, or a *Sub Menu*. Since we are building the main menu, the first column of this entry is set to: `MENU_ITEM_TYPE_MAIN_MENU_HEADER`. The three other columns in this line define more about the menu. The second field contains text printed on the LCD's Title Bar when the menu is displayed. The next column sets how the buttons are arranged on the screen and is usually set to `MENU_COLUMNS_1` or `MENU_COLUMNS_2`. The fourth field is typically set to the name of the menu, i.e. `mainMenu`.

Now you will add one line to the table for each button that you want displayed in the menu. There are three different types of buttons that can be added:

Commands: A `MENU_ITEM_TYPE_COMMAND` entry indicates that a function (written by you) will be executed when this menu button is pushed by the user. In the second column you place the text that you want displayed on the button. The third column is the name of the function that is executed when the menu button is clicked. The last column should always be `NULL`.

Toggles: A `MENU_ITEM_TYPE_TOGGLE` is used somewhat like a Radio Button in a dialog box. Toggles let the user choose one of a fixed number of choices (such as *On / Off*, or *Red / Green / Blue*). Each time the user clicks on a toggle button, it alternates the selection. In the second column is the button's text. The third column is the name of a callback function that you write to alternates the value. The last column should always be `NULL`.

Sub menus: A `MENU_ITEM_TYPE_SUB_MENU` entry is used to select a different menu. Often it is useful to group related commands into their own menu, this is what *Sub menus* are for. For example, the main menu might reference a *Settings* sub menu which would be filled with commands for configuring your app. In the second column of this entry is the text displayed on the button describing the sub menu. The fourth field is the name of the sub menu table.

A menu can have as many buttons as you like, simply by adding more entries to the menu table. Buttons are sized such that they always fill the screen, adding more causes them to be shorter in height. In many cases it is advantageous to arrange a menu's buttons in two or more columns. Columns of buttons often look better, are easier to touch, and you can fit more on a single screen.

The buttons on a menu can be arranged in 1, 2, 3 or 4 columns. The number of columns is set in the third field of the menu table's first line by inserting one of these values: `MENU_COLUMNS_1`, `MENU_COLUMNS_2`, `MENU_COLUMNS_3`, or `MENU_COLUMNS_4`

The table's last line marks the menu's end with a `MENU_ITEM_TYPE_END_OF_MENU` entry. The second column should always be `""`. The third and fourth columns are sent to `Null`.

## Creating a sub menu:

Sub-menus are menus called from the main menu, or another sub menu. Sub menus allow you to group related commands into their own menu. For example, a *Settings* sub menu might be filled with commands for configuring your app.

Sub menus are built just like the Main menu, except that the first entry must be `MENU_ITEM_TYPE_SUB_MENU_HEADER`. In the first line's fourth column is the name of the parent menu (typically the main menu). This is used to reselect the parent menu when the user presses the *Back* button, indicating they are done with the sub menu.

Here is a table for a typical sub menu:

```
//  
// the Settings menu  
//  
MENU_ITEM settingsMenu[] = {  
{MENU_ITEM_TYPE_SUB_MENU_HEADER, "Menu Name", MENU_COLUMNS_2, mainMenu},  
{MENU_ITEM_TYPE_COMMAND, "Set contrast", menuCommandSetContrast, NULL},  
{MENU_ITEM_TYPE_TOGGLE, "Power mode", menuTogglePowerCallback, NULL},  
{MENU_ITEM_TYPE_TOGGLE, "LED", menuToggleLEDCallback, NULL},  
{MENU_ITEM_TYPE_END_OF_MENU, "", NULL, NULL}  
};
```

## The Toggle call back function:

*Toggle* buttons in a menu let the user to select one of a fixed number of choices (such as *On / Off*, or *Red / Green / Blue*). Each time the user clicks on a Toggle button, it alternates the selection (i.e. toggles between *On* and *Off*, or rotates between *Red*, *Green* and *Blue*). To accomplish this, the Toggle's menu entry includes the name of a callback function that you must write. This function does several things: 1) Switches to the next state. 2) Optionally updates hardware to reflect the new state. 3) Sets the text displayed on the menu button for that state.

Here's an example of how to write the callback function for a Toggle:

```
void menuToggleLEDCallback(void)  
{  
//  
// check if menu is requesting state be changed (can have more than 2 states)  
//  
if (ui.toggleMenuChangeStateFlag)  
{  
    ledState = !ledState; // select the next state  
}  
  
//  
// turn the LED on or off as indicated by the state  
//  
if (ledState)  
    digitalWrite(LED_PIN, HIGH);  
else
```

```

digitalWrite(LED_PIN, LOW);

//
// send back text describing the current state
//
if(ledState)
    ui.toggleMenuStateText = "On";
else
    ui.toggleMenuStateText = "Off";
}

```

## Making the first screen show your application, not a menu:

Most of the examples sketches included with this library display a menu when the sketch first runs. In some cases you want to start with your application showing its own display, then let the user press a button to pull up the menu. An example sketch of this type is *Example8\_StopWatch* found in the *examples* folder.

In this situation you will display your application when the sketch first runs. The LCD's Title bar will show a Menu button. At any time, the user can exit your display and bring up the menu by clicking on this button. There are a few things that you must do to make this all work.

- 1) In your application's main screen, you must first draw the Title Bar to include the Menu button. Do so as follows:

```
ui.drawTitleBarWithMenuBar("The Name Of Your App");
```

- 2) In your app's main loop, you must continuously check if the user has clicked the Menu button.

```

while(true)
{
    ui.getTouchEvents();                      // get new touch events on the LCD
    if (ui.checkForMenuBarClicked())          // check if Menu button was press
    {
        ui.displayAndExecuteMenu(mainMenu);   // user pressed "Menu", display it
        redrawYourApp();                   // after exiting menu, redraw app
    }
    // do other things that your app needs: update the display, check IO...
}

```

- 3) When the menu is displayed, it needs to have a *Back* button. This provides a way for the user to exit the menu and go back to your application. Normally the Main Menu doesn't show the *Back* button, so it must be enabled. To do that, the fourth column in the first line of your menu table must be set to NULL (instead of *mainMenu*, which is typical).

## Building your own screens:

Often commands executed from a menu button need to display some information, or prompt the user to enter some information. To do this you can build screens of your own design. On these screens you can draw text and display graphics. You can also place a few different widgets that are built into the *Teensy User Interface*. These widgets are: Buttons, Number Boxes, and Selection Boxes.

When you create a custom screen, you need a way for the user to exit that screen and return to the menu. There are two methods for doing this. The first is with a *Back* button on the Title Bar. This code shows how to write a complete menu command that draws the Title bar to include the Back button, and checks if the user touches it:

```
void commandBackButtonExample(void)
{
    ui.drawTitleBarWithBackButton("Back Button Example"); // include Back button
    ui.clearDisplaySpace();                                // clear the display

                                            // display some text
    ui.lcdSetCursorXY(ui.displaySpaceCenterX, ui.displaySpaceCenterY - 10);
    ui.lcdPrintCentered("We exit this screen with the Back button.");

    while(true)                                         // wait for user to press "Back" button
    {
        ui.getTouchEvents();

        if (ui.checkForBackButtonClicked())
            return;                                     // "Back" pressed, return to menu
    }
}
```

The second method for exiting a display is to place a custom button on the screen. The button can be any size, placed anywhere on the screen, and can be labeled with any text (i.e. "OK", "Cancel", "Done"). Buttons can also be used to execute custom code and might be labeled like: "Start Motor", "Enable Pump", "Collect Data".

This sample code shows how to create a complete menu command that draws an "OK" button and checks if the user presses it:

```
void commandOKButtonExample(void)
{
    ui.drawTitleBar("OK Button Example"); // draw title bar without Back button
    ui.clearDisplaySpace();                // display some text
    ui.lcdSetCursorXY(ui.displaySpaceCenterX, ui.displaySpaceCenterY - 20);
    ui.lcdPrintCentered("We exit this screen with an OK button.");
```

```

int buttonX = ui.displaySpaceCenterX;      // define and display an "OK" button
int buttonY = ui.displaySpaceBottomY-30;
int buttonWidth = 120;
int buttonHeight = 35;
BUTTON okButton = {"OK", buttonX, buttonY, buttonWidth, buttonHeight};
ui.drawButton(okButton);

while(true)                                // wait for user to press "OK" button
{
    ui.getTouchEvents();

    if (ui.checkForButtonClicked(okButton))
    {
        // optionally add more code to do the stuff you want done when
        // the button is pressed
        return;                            // OK pressed, return to menu
    }
}
}

```

## Prompting the user to enter a number:

Frequently applications need the user to input one or more numeric values. For this purpose, the library makes use of *Number Boxes*. A Number Box is a widget that can be added to a screen of your own design. You can place just one, or several as shown below. Touching the *Up* and *Down* buttons allow the user to set the number. When you place a Number Box, you specify the Min and Max values, along with a Step value. There are two types of Number Boxes, one for INTs and one for FLOATs. The designer of this screen placed two INT Number Boxes, two FLOAT Number Boxes, and two buttons.



The code below shows how to create a complete screen that includes one INT Number Box, along with OK and Cancel buttons:

```
void commandGetXOffsetInteger(void)
{
    ui.drawTitleBar("Prompt User for an Integer");
    ui.clearDisplaySpace();

    //
    // define a Number Box, specify initial value, max and min values,
    // step up/down amount, and how big the Number Box is (in pixels),
    // along with where it's placed on screen
    //
    NUMBER_BOX my_NumberBox;
    my_NumberBox.labelText      = "Set X offset";
    my_NumberBox.value          = xOffsetValue;      // Number Box's default value
    my_NumberBox.minimumValue   = -200;
    my_NumberBox.maximumValue   = 200;
    my_NumberBox.stepAmount     = 2;
    my_NumberBox.centerX        = ui.displaySpaceCenterX;
    my_NumberBox.centerY        = ui.displaySpaceCenterY - 20;
    my_NumberBox.width          = 200;
    my_NumberBox.height         = 35;
    ui.drawNumberBox(my_NumberBox);                  // display the Number Box

    //
    // define and display "OK" and "Cancel" buttons
    //
    BUTTON okButton = {"OK", ui.displaySpaceCenterX-70, ui.displaySpaceBottomY-35,
                      120, 35};
    ui.drawButton(okButton);

    BUTTON cancelButton = {"Cancel", ui.displaySpaceCenterX+70,
                          ui.displaySpaceBottomY-35, 120, 35};
    ui.drawButton(cancelButton);

    //
    // process touch events
    //
    while(true)
    {
        ui.getTouchEvents();                         // check for touch events
        ui.checkForNumberBoxTouched(my_NumberBox); // process NumberBox touch events

        if (ui.checkForButtonClicked(okButton)) // check for touches on OK button
        {
            xOffsetValue = my_NumberBox.value;      // pressed OK, get NumberBox value
            return;                                // return to the menu
        }
    }
}
```

```

    if (ui.checkForButtonClicked(cancelButton))
        return; // user pressed Cancel, return to menu
    }
}

```

Creating a FLOAT Number Box is very similar to the INT example above. The main difference is that it's declared with a *NUMBER\_BOX\_FLOAT* datatype like this:

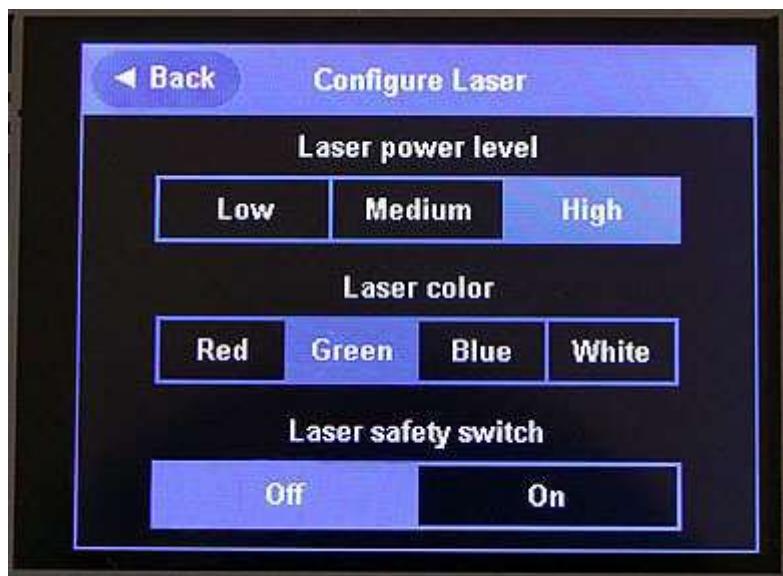
```

NUMBER_BOX_FLOAT my_NumberBox;
my_NumberBox.labelText      = "Set X scaler";
my_NumberBox.value          = xScalerValue;
my_NumberBox.minimumValue   = 0.0;
my_NumberBox.maximumValue   = 1.0;
my_NumberBox.stepAmount     = 0.01;
my_NumberBox.digitsRightOfDecimal = 2;
my_NumberBox.centerX        = ui.displaySpaceCenterX;
my_NumberBox.centerY        = ui.displaySpaceCenterY - 20;
my_NumberBox.width          = numberBoxWidth;
my_NumberBox.height         = numberBoxAndButtonsHeight;
ui.drawNumberBox(my_NumberBox);

```

## Selection Boxes:

Another widget that can be added to your screen is a *Selection Box*. Selection Boxes allow the user to pick one of 2, 3, or 4 choices. The image below shows a typical configuration screen that uses three Selection Boxes, along with the *Back* button.



Here is how to create a screen that includes a Selection Box:

```
void commandMakeAChoice(void)
{
    ui.drawTitleBarWithBackButton("Using Selection Boxes");
    ui.clearDisplaySpace();

    //
    // define and display a selection box with 3 choices
    //
    SELECTION_BOX powerSelectionBox;
    powerSelectionBox.labelText = "Laser power level";
    powerSelectionBox.value = powerSelection; // set default value, 0 is 1st choice
    powerSelectionBox.choice0Text = "Low";
    powerSelectionBox.choice1Text = "Medium";
    powerSelectionBox.choice2Text = "High";
    powerSelectionBox.choice3Text = ""; // set unused choices to: ""
    powerSelectionBox.centerX = ui.displaySpaceCenterX;
    powerSelectionBox.centerY = ui.displaySpaceCenterY - 20;;
    powerSelectionBox.width = 250;
    powerSelectionBox.height = 33;
    ui.drawSelectionBox(powerSelectionBox); // display the Selection Box

    while(true) // process touch events
    {
        ui.getTouchEvents();
        ui.checkForSelectionBoxTouched(powerSelectionBox); // process SelectionBox touches
        if (ui.checkForBackButtonClicked()) // check for Back button
        {
            powerSelection = powerSelectionBox.value; // read value from SelectionBox
            return; // return to the menu
        }
    }
}
```

Note: The Selection Box's *.value* property is an integer between 0 and 3. A value of 0 indicates the left most choice was made. In the example above, *value* set to 0 corresponds to the "Low" choice, 1 goes with "Medium", and 2 for "High".

## Displaying text and graphics:

The library includes many functions for drawing your own screens. The general approach is:

1. Draw the Title bar:

```
ui.drawTitleBar("My Screen Name")      or  
ui.drawTitleBarWithBackButton("My Other Screen Name")
```

2. Clear the Display Space:

```
ui.clearDisplaySpace()      or  
ui.clearDisplaySpace(LCD_BLUE)
```

3. Prior to drawing text, first set the cursor position with

ui.lcdSetCursorXY(X, Y). Note: (0, 0) is the upper left corner.  
X is a value from 0 to 319. Y is a value from 0 to 239.

These constants can be helpful when setting coordinates:

ui.displaySpaceWidth	ui.displaySpaceHeight
ui.displaySpaceLeftX	ui.displaySpaceRightX
ui.displaySpaceTopY	ui.displaySpaceBottomY
ui.displaySpaceCenterX	ui.displaySpaceCenterY
ui.lcdWidth	ui.lcdHeight

4. Optionally set the text color with: ui.lcdSetFontColor(LCD\_YELLOW)

5. Optionally set the text font with:

```
ui.lcdSetFont(Arial_12)  or  
ui.lcdSetFont(Arial_9_Bold)
```

All fonts are Arial or Arial Bold and available in these sizes: 8, 9, 10,  
11, 12, 13, 14, 16, 18, 20, 24, 28, 32, 40, 48, 60, 72, 96.

6. Print some text or numeric values. There are many functions for printing,  
including:

```
ui.lcdPrint()  
ui.lcdPrint()  
ui.lcdPrintCentered()  
ui.lcdPrintRightJustified()  
ui.lcdPrintCharacter()
```

You can determine the width and height of a printed string using these  
functions:

```
ui.lcdStringWidthInPixels("Hello World")  
ui.lcdGetFontHeightWithoutDecenders()  
ui.lcdGetFontHeightWithDecendersAndLineSpacing()
```

Note: The functions that print strings, expect a C String, meaning an  
array of char terminated by a 0 (as opposed to a string created using  
a String Object).

7. Print graphics using these functions:

```
ui.lcdDrawPixel(x, y, color)
ui.lcdDrawLine(x1, y1, x2, y2, color)
ui.lcdDrawHorizontalLine(x, y, length, color)
ui.lcdDrawVerticalLine(x, y, length, color)
ui.lcdDrawRectangle(x, y, width, height, color)
ui.lcdDrawRoundedRectangle(x, y, width, height, radius, color)
ui.lcdDrawTriangle(x0, y0, x1, y1, x2, y2, color)
ui.lcdDrawCircle(x, y, radius, color)
ui.lcdDrawFilledRectangle(x, y, width, height, color)
ui.lcdDrawFilledRoundedRectangle(x, y, width, height, radius, color)
ui.lcdDrawFilledTriangle(x0, y0, x1, y1, x2, y2, color)
ui.lcdDrawFilledCircle(x, y, radius, color)
```

## Display colors:

Many functions in the *Teensy User Interface* allow you to set display colors. This LCD display uses a 16 bit color format. The format is referred to as *RGB565*, meaning 5 bits of red, 6 bits of green, and 5 bits of blue.

When you call a function that wants a color value, you have two choices: you can used a pre-defined color constant, or create your own value. The color constants built into the *Teensy User Interface* are:

LCD_BLACK	LCD_WHITE	LCD_RED	LCD_BLUE	LCD_GREEN
LCD_YELLOW	LCD_ORANGE	LCD_PURPLE	LCD_DARKBLUE	LCD_DARKGREEN
LCD_MAROON	LCD_MAGENTA	LCD_CYAN	LCD_LIGHTBLUE	LCD_OLIVE
LCD_DARKGREY	LCD_LIGHTGREY	LCD_DARKCYAN	LCD_NAVY	LCD_GREENYELLOW

The easiest way to create your own color is with the *ui.lcdMakeColor()* function. It takes red, green and blue values then returns a color in the RGB565 format. Call it with a red value between 0-31, green between 0-63, and a blue value between 0-31. Here is an example:

```
uint16_t red = 10;
uint16_t green = 20;
uint16_t blue = 10;
uint16_t grayColor = ui.lcdMakeColor(red, green, blue);
ui.lcdDrawFilledCircle(160, 120, 30, grayColor); // draw a gray circle in middle of screen
```

## Saving configuration settings:

*Number Boxes* and *Selection Boxes* are often used to configure your project at runtime. Values set with these widgets can be saved in the Teensy's EEPROM so the project defaults to the configured values when powered up.

The *Teensy User Interface* library has these functions for saving/reading configuration values:

writeConfigurationByte()	and	readConfigurationByte()	for 8 bit values
writeConfigurationShort()	and	readConfigurationShort()	for 16 bit values
writeConfigurationInt()	and	readConfigurationInt()	for 32 bit values
writeConfigurationFloat()	and	readConfigurationFloat()	for 32 bit floats

Below is example code for writing and reading two different configuration settings, an *Int* and a *Float*.

```
//  
// storage locations in EEPROM for configuration values  
//  
const int EEPROM_X_OFFSET = 0; // int uses 5 bytes of EEPROM  
const int EEPROM_X_SCALER = EEPROM_X_OFFSET+5; // float uses 5 bytes  
  
//  
// defaults configuration values, these are used if they have never been set  
//  
const int DEFAULT_X_OFFSET = 50;  
const float DEFAULT_X_SCALER = 0.57;  
  
//  
// save configuration values in EEPROM  
//  
ui.writeConfigurationInt(EEPROM_X_OFFSET, valueXOffset);  
ui.writeConfigurationFloat(EEPROM_X_SCALER, valueXScaler);  
  
//  
// read configuration values from EEPROM, if EEPROM has never saved, use  
// default values  
//  
int valueXOffset = ui.readConfigurationInt(EEPROM_X_OFFSET, DEFAULT_X_OFFSET);  
float valueXScaler = ui.readConfigurationFloat(EEPROM_X_SCALER, DEFAULT_X_SCALER);
```

Note 1: The functions that read a configuration value take a *Default value*. This number is returned if no value has ever been saved for that setting (i.e. The first time the app is runs, the user will have never saved any configuration settings).

Note 2: You need to manage where in EEPROM each of your values is stored. Your first value is saved at location 0. When determining the position for the following values it is important to note that they take one more byte than the data type requires (i.e. 2 EEPROM bytes are needed for a *byte*, 3 for a *short*, 5 for a *int*, 5 for a *float*). See how this is done with the *const* declarations above.

# The Library of Functions:

## Setup functions:

```
//  
// initialize the UI, display hardware and touchscreen hardware  
// Enter: lcdCSPin = pin number for the LCD's CS pin  
//         LcdDCPIn = pin number for the LCD's DC pin  
//         TouchScreenCSPin = pin number for the touchscreen's CS pin  
//         lcdOrientation =  
//                         LCD_ORIENTATION_PORTRAIT_4PIN_TOP  
//                         LCD_ORIENTATION_LANDSCAPE_4PIN_LEFT  
//                         LCD_ORIENTATION_PORTRAIT_4PIN_BOTTOM  
//                         LCD_ORIENTATION_LANDSCAPE_4PIN_RIGHT  
//         font -> the font typeface to load, ei: Arial_10  
//  
void TeensyUserInterface::begin(int lcdCSPin, int LcdDCPIn, int TouchScreenCSPin,  
                                int lcdOrientation, const ui_font &font)  
  
//  
// set color palette to Blue  
//  
void TeensyUserInterface::setColorPaletteBlue(void)  
  
//  
// set color palette to Gray  
//  
void TeensyUserInterface::setColorPaletteGray(void)  
  
//  
// set the orientation of the lcd and touch screen, this can be called to change  
// the orientation after it is initially set  
// Enter: lcdOrientation =  
//         LCD_ORIENTATION_PORTRAIT_4PIN_TOP  
//         LCD_ORIENTATION_LANDSCAPE_4PIN_LEFT  
//         LCD_ORIENTATION_PORTRAIT_4PIN_BOTTOM  
//         LCD_ORIENTATION_LANDSCAPE_4PIN_RIGHT  
//  
void TeensyUserInterface::setOrientation(int lcdOrientation)
```

## Menu functions:

```
//  
// set the menu colors  
// Enter: _menuBackgroundColor = RGB565 color for background of the menu  
//         _menuButtonColor = RGB565 color for menu buttons  
//         _menuButtonSelectedColor = RGB565 color for menu buttons that are selected  
//         _menuButtonFrameColor = RGB565 color for highlight around the menu buttons  
//         _menuButtonTextColor = RGB565 color for text of the buttons  
  
void TeensyUserInterface::setMenuColors(uint16_t _menuBackgroundColor,  
    uint16_t _menuButtonColor, uint16_t _menuButtonSelectedColor,  
    uint16_t _menuButtonFrameColor, uint16_t _menuButtonTextColor)  
  
  
//  
// set the menu font  
// Enter: font -> the font to use when drawing the title bar  
//         ie: Arial_8, Arial_8_Bold, Arial_9, Arial_9_Bold, Arial_10,  
//              Arial_10_Bold, Arial_11, Arial_11_Bold, Arial_12, 13, 14,  
//              16, 18, 20, 24, 28, 32, 40, 48, 60, 72, 96  
  
void TeensyUserInterface::setMenuFont(const ui_font &font)  
  
  
//  
// display the top level menu, then execute the commands selected by the user  
// Enter: menu -> the menu to display  
  
void TeensyUserInterface::displayAndExecuteMenu(MENU_ITEM *menu)  
  
  
//  
// select and display a menu or submenu, for most applications this function is not used  
// Enter: menu -> the menu to display  
//         drawMenuFlg = true if should draw the new menu  
  
void TeensyUserInterface::selectAndDrawMenu(MENU_ITEM *menu, boolean drawMenuFlg)  
  
  
//  
// set a callback function that's periodically executed while the application  
// is showing a menu, for most applications setting a callback function is not needed  
// Enter: callbackFunction -> function to execute continuously while a menu is presented,  
//         set to NULL to disable
```

```
//  
void TeensyUserInterface::setInMenuCallbackFunction(void (*callbackFunction)())
```

## Title Bar functions:

```
//  
// set the title bar colors  
// Enter: _titleBarColor = RGB565 color for the title bar background  
//         _titleBarTextColor = RGB565 color for the title bar's text  
//         _titleBarBackButtonColor = RGB565 color for the back button on the title bar  
//  
void TeensyUserInterface::setTitleBarColors(uint16_t _titleBarColor,  
    uint16_t _titleBarTextColor, uint16_t _titleBarBackButtonColor,  
    uint16_t _titleBarBackButtonSelectedColor)  
  
//  
// set the title bar font  
// Enter: font -> the font to use when drawing the title bar  
//        ie: Arial_8, Arial_8_Bold, Arial_9, Arial_9_Bold, Arial_10,  
//             Arial_10_Bold, Arial_11, Arial_11_Bold, Arial_12, 13, 14,  
//             16, 18, 20, 24, 28, 32, 40, 48, 60, 72, 96  
//  
void TeensyUserInterface::setTitleBarFont(const ui_font &font)  
  
//  
// draw the title bar (without the back or hamburger button)  
//  
void TeensyUserInterface::drawTitleBar(const char *titleBarText)  
  
//  
// draw the title bar with the back button  
//  
void TeensyUserInterface::drawTitleBarWithBackButton(const char *titleBarText)  
  
//  
// draw the title bar with the Menu button  
//  
void TeensyUserInterface::drawTitleBarWithMenuButton(const char *titleBarText)  
  
//  
// check if user has touched and released the title bar's Back button, this also  
// highlights the button when the user first touches it
```

```

// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Exit:  true returned if user has touched and released the Back button,
//        else false
//
boolean TeensyUserInterface::checkForBackButtonClicked(void)

//


// check if user has touched and released the title bar's Menu button, this also
// highlights the button when the user first touches it
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Exit:  true returned if user has touched and released the Menu button,
//        else false
//
boolean TeensyUserInterface::checkForMenuButtonClicked(void)

```

## Display Space functions:

```

//


// clear the screen's "display space" using the menu's background color and draw
// a frame around it
//
void TeensyUserInterface::clearDisplaySpace(void)

//


// clear the screen's "display space" using the given background color and draw
// a frame around it
// Enter:  backgroundColor = color to fill the display space
//
void TeensyUserInterface::clearDisplaySpace(uint16_t backgroundColor)

```

## Button functions:

```
//  
// draw a rectangular button using the colors and font defined for the menu  
// Enter: uiButton -> the specifications for the button to draw  
//  
void TeensyUserInterface::drawButton(BUTTON &uiButton)  
  
//  
// draw a rectangular button using the colors and font defined for the menu  
// Enter: uiButton -> the specifications for the button to draw  
// showButtonTouchedFlg = true to draw button showing it's being  
// touched, false to draw normal  
//  
void TeensyUserInterface::drawButton(BUTTON &uiButton, boolean showButtonTouchedFlg)  
  
//  
// draw a rectangular button with extended options for setting color and font  
// Enter: uiButton -> the specifications for the button to draw  
//  
void TeensyUserInterface::drawButton(BUTTON_EXTENDED &uiButtonExt)  
  
//  
// draw a rectangular button with extended options for setting color and font  
// Enter: uiButton -> the specifications for the button to draw  
// showButtonTouchedFlg = true to draw button showing it's being  
// touched, false to draw normal  
//  
void TeensyUserInterface::drawButton(BUTTON_EXTENDED &uiButtonExt, boolean showButtonTouchedFlg)  
  
//  
// check if user has touched and released the given button, this also highlights  
// the button when the user first touches it  
// Note: getTouchEvents() must be called at the top of the loop that calls this  
// function  
// Enter: uiButton -> the button to test  
// Exit: true returned if user has touched and released this button,  
// else false  
//  
boolean TeensyUserInterface::checkForButtonClicked(BUTTON &uiButton)  
  
//  
// check if user has touched and released the given button, this also highlights  
// the button when the user first touches it
```

```
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Enter: uiButton -> the button to test
// Exit: true returned if user has touched and released this button,
//       else false
//
boolean TeensyUserInterface::checkForButtonClicked(BUTTON_EXTENDED &uiButton)

//
// check if user is holding down the given button and it's now "Auto repeating"
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Enter: uiButton -> the button to test
// Exit: true returned if there's an Auto Repeat event for this button,
//       else false
//
boolean TeensyUserInterface::checkForButtonAutoRepeat(BUTTON &uiButton)

//
// check if user is holding down the given button and it's now "Auto repeating"
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Enter: uiButton -> the button to test
// Exit: true returned if there's an Auto Repeat event for this button,
//       else false
//
boolean TeensyUserInterface::checkForButtonAutoRepeat(BUTTON_EXTENDED &uiButton)

//
// check if user has just touched the given button, this happens once each time a
// button is pressed, in most cases using checkForButtonClicked() is preferred
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Enter: uiButton -> the button to test
// Exit: true returned if user has touched and released this button,
//       else false
//
boolean TeensyUserInterface::checkForButtonFirstTouched(BUTTON &uiButton)

//
// check if user has just touched the given button, this happens once each time
// a button is pressed, in most cases using checkForButtonClicked() is preferred
// Note: getTouchEvents() must be called at the top of the loop that calls this
// function
// Enter: uiButton -> the button to test
// Exit: true returned if user has touched and released this button,
```

```

//           else false
//
boolean TeensyUserInterface::checkForButtonFirstTouched(BUTTON_EXTENDED &uiButton)

//


// definition of a Button, the menu's colors and font are used
//
typedef struct
{
    const char *labelText;
    int centerX;
    int centerY;
    int width;
    int height;
} BUTTON;

//


// definition of a Button with extended options
//
typedef struct
{
    const char *labelText;
    int centerX;
    int centerY;
    int width;
    int height;
    uint16_t buttonColor;
    uint16_t buttonSelectedColor;
    uint16_t buttonFrameColor;
    uint16_t buttonTextColor;
    const ui_font &buttonFont;
} BUTTON_EXTENDED;

```

## Number Box functions:

```

//
// draw a Number Box
// Enter: numberBox -> the specifications of the Number Box to draw
//
void TeensyUserInterface::drawNumberBox(NUMBER_BOX &numberBox)

```

```

//  

// draw a Number Box (FLOAT)  

// Enter: numberBox -> the specifications of the Number Box to draw  

//  

void TeensyUserInterface::drawNumberBox(NUMBER_BOX_FLOAT &numberBox)  

//  

// check if user is touching the Number Box, pressing Up or Down  

// Note: getTouchEvents() must be called at the top of the loop that calls  

// this function  

// Enter: numberBox -> the Number Box to check  

// Exit: true returned if the Number Box's Value changed  

//  

boolean TeensyUserInterface::checkForNumberBoxTouched(NUMBER_BOX &numberBox)  

//  

// check if user is touching the Number Box, pressing Up or Down (FLOAT)  

// Note: getTouchEvents() must be called at the top of the loop that calls  

// this function  

// Enter: numberBox -> the Number Box to check  

// Exit: true returned if the Number Box's Value changed  

//  

boolean TeensyUserInterface::checkForNumberBoxTouched(NUMBER_BOX_FLOAT &numberBox)  

//  

// definition of a integer Number Box  

//  

typedef struct  

{  

    const char *labelText;  

    int value;  

    int minValue;  

    int maxValue;  

    int stepAmount;  

    int centerX;  

    int centerY;  

    int width;  

    int height;  

} NUMBER_BOX;  

//  

// definition of a float Number Box  

//  

typedef struct  

{

```

```

const char *labelText;
float value;
float minValue;
float maxValue;
float stepAmount;
int digitsRightOfDecimal;
int centerX;
int centerY;
int width;
int height;
} NUMBER_BOX_FLOAT;

```

## Selection Box functions:

```

//  

// draw a Selection Box  

// Enter: selectionBox -> the specifications of the Selection Box to draw  

//  

void TeensyUserInterface::drawSelectionBox(SELECTION_BOX &selectionBox)  

//  

// check if user is touching the Selection Box, pressing one of the choices  

// Note: getTouchEvents() must be called at the top of the loop that calls  

// this function  

// Enter: selectionBox -> the selection Box to check  

// Exit: true returned if the Selection Box's Value changed  

//  

boolean TeensyUserInterface::checkForSelectionBoxTouched(SELECTION_BOX &selectionBox)  

//  

// definition of a Selection Box  

//  

typedef struct  

{  

    const char *labelText;  

    int value;  

    const char *choice0Text;  

    const char *choice1Text;  

    const char *choice2Text;  

    const char *choice3Text;  

    int centerX;  

    int centerY;  

    int width;  

    int height;  

} SELECTION_BOX;

```

## Touchscreen functions:

```
//  
// check if the most recent touch event happened inside the given rectangle  
// Enter: eventType = the type of event to look for  
//         (ie TOUCH_PUSHED_EVENT, TOUCH_RELEASED_EVENT, TOUCH_REPEAT_EVENT)  
//         rectX1, rectY1 = upper left corner of the test area  
//         rectX2, rectY2 = lower right corner of the test area  
// Exit:   true returned if most recent touch event matches the given parameters  
  
boolean TeensyUserInterface::checkForTouchEventInRect(int eventType, int rectX1,  
int rectY1, int rectX2, int rectY2)  
  
//  
// check touch screen for new events  
// Exit:   touchEventType = touch event type, TOUCH_NO_EVENT if no event  
//         touchEventX, touchEventY = LCD coordinates of touch event  
  
void TeensyUserInterface::getTouchEvents(void)  
  
//  
// set default calibration constants for converting to LCD coordinates  
// Enter: lcdOrientation = LCD_ORIENTATION_PORTRAIT_4PIN_TOP,  
//         LCD_ORIENTATION_LANDSCAPE_4PIN_LEFT  
//         LCD_ORIENTATION_PORTRAIT_4PIN_BOTTOM,  
//         LCD_ORIENTATION_LANDSCAPE_4PIN_RIGHT  
  
void TeensyUserInterface::setDefaultTouchScreenCalibrationConstants(int lcdOrientation)  
  
//  
// set the touch screen calibration constants used for converting from  
// touch coordinates to LCD coordinates  
// Enter: tsToLCDOffsetX = touch screen X offset calibration constant  
//         tsToLCDScalerX = touch screen X scaler calibration constant  
//         tsToLCDOffsetY = touch screen Y offset calibration constant  
//         tsToLCDScalerY = touch screen Y scaler calibration constant  
  
void TeensyUserInterface::setTouchScreenCalibrationConstants(int tsToLCDOffsetX,  
float tsToLCDScalerX, int tsToLCDOffsetY, float tsToLCDScalerY)  
  
//  
// get the XY values of where to touch screen is being touched (in LCD space)
```

```

// Enter: xLCD, yLCD -> storage to return X and Y coordinates
// Exit: true returned if touch screen is currently being touch, else false
//
boolean TeensyUserInterface::getTouchScreenCoords(int *xLCD, int *yLCD)

//


// types of touch events
//
const int TOUCH_NO_EVENT      = 0;      // no event from touch screen (nothing touched)
const int TOUCH_PUSHED_EVENT   = 1;      // touch screen just touched
const int TOUCH_RELEASED_EVENT = 2;      // touch screen just released
const int TOUCH_REPEAT_EVENT   = 3;      // touch screen touched & event repeating

```

## LCD drawing functions:

```

//


// fill the entire lcd screen with the given color
// Enter: color = 16 bit color, bit format: rrrrrgggggbbbb
//
void TeensyUserInterface::lcdClearScreen(uint16_t color)

//


// draw one pixel with the given coords and color
// Enter: x, y = coords of the pixel to draw
//         color = 16 bit color, bit format: rrrrrgggggbbbb
//
void TeensyUserInterface::lcdDrawPixel(int x, int y, uint16_t color)

//


// draw a line with the given coords and color
// Enter: x1, y1 = first endpoint of line
//         x2, y2 = second endpoint of line
//         color = 16 bit color, bit format: rrrrrgggggbbbb
//
void TeensyUserInterface::lcdDrawLine(int x1, int y1, int x2, int y2,
    uint16_t color)

//


// draw a horizontal line with the given coords, length and color
// Enter: x, y = first endpoint of line
//         length = length of line
//         color = 16 bit color, bit format: rrrrrgggggbbbb
//

```

```

void TeensyUserInterface::lcdDrawHorizontalLine(int x, int y, int length,
    uint16_t color)

//  

// draw a vertical line with the given coords, length and color  

// Enter: x, y = first endpoint of line  

//         length = length of line  

//         color = 16 bit color, bit format: rrrrrgggggbbbb  

//  

void TeensyUserInterface::lcdDrawVerticalLine(int x, int y, int length,
    uint16_t color)

//  

// draw rectangle at the given coords, length, width and color  

// Enter: x, y = upper left corner of rect  

//         width = width of rectangle  

//         height = height of rectangle  

//         color = 16 bit color, bit format: rrrrrgggggbbbb  

//  

void TeensyUserInterface::lcdDrawRectangle(int x, int y, int width, int height,
    uint16_t color)

//  

// draw rounded rectangle at the given coords, length, width and color  

// Enter: x, y = upper left corner of rect  

//         width = width of rectangle  

//         height = height of rectangle  

//         radius = radius of the corners  

//         color = 16 bit color, bit format: rrrrrgggggbbbb  

//  

void TeensyUserInterface::lcdDrawRoundedRectangle(int x, int y, int width,
    int height, int radius, uint16_t color)

//  

// draw a circle at the given coords, radius and color  

// Enter: x0, y0 = endpoint 0 of the triangle  

//         x1, y1 = endpoint 1 of the triangle  

//         x2, y2 = endpoint 2 of the triangle  

//         color = 16 bit color, bit format: rrrrrgggggbbbb  

//  

void TeensyUserInterface::lcdDrawTriangle(int x0, int y0, int x1, int y1,
    int x2, int y2, uint16_t color)

//  

// draw a filled circle at the given coords, radius and color

```

```

// Enter: x, y = upper left corner of rect
//         radius = radius of the circle
//         color = 16 bit color, bit format: rrrrrgggggbbbb
//
void TeensyUserInterface::lcdDrawFilledCircle(int x, int y, int radius,
    uint16_t color)

//


// draw an image
// Enter: x, y = coords of upper left corner on LCD where the image will be displayed
//         width, height = size of the image, this must be the same as the image data
//         image -> image data, 2 bytes/pixel in the RGB565 format stored in PROGMEM
// Note: use this utility to convert an image to C source code:
//       www.rinkydinkelectronics.com/_t_doimageconverter565.php
//
void TeensyUserInterface::lcdDrawImage(int x, int y, int width, int height,
    const uint16_t *image)

//


// set the text font for the "print" functions
// Enter: font -> the font typeface to load
//         ie: Arial_8, Arial_8_Bold, Arial_9, Arial_9_Bold, Arial_10,
//              Arial_10_Bold, Arial_11, Arial_11_Bold, Arial_12, 13, 14,
//              16, 18, 20, 24, 28, 32, 40, 48, 60, 72, 96

//
void TeensyUserInterface::lcdSetFont(const ui_font &font)

//


// set the foreground color for the "print" functions
// Enter: color = 16 bit color, bit format: rrrrrgggggbbbb
//
void TeensyUserInterface::lcdSetFontColor(uint16_t color)

//


// print a string to the LCD display
// Enter: s -> a null terminated string
//
void TeensyUserInterface::lcdPrint(char *s)

//


// print a signed int at location of the cursor
// Enter: n = signed number to print
//

```

```
void TeensyUserInterface::lcdPrint(int n)

//  
// print a float or double at location of the cursor  
// Enter: n = signed number to print  
// digitsRightOfDecimal = # digits to display right of decimal  
// point (optional)  
//  
void TeensyUserInterface::lcdPrint(double n, int digitsRightOfDecimal)

//  
// print a string to the LCD, right justified at the cursor  
// Enter: s -> string to print  
//  
void TeensyUserInterface::lcdPrintRightJustified(char *s)

//  
// print a signed int on the LCD, right justify at the cursor  
// Enter: n = signed number to print  
//  
void TeensyUserInterface::lcdPrintRightJustified(int n)

//  
// print a float on the LCD, right justify at the cursor  
// Enter: n = signed number to print  
// digitsRightOfDecimal = # digits to display right of decimal  
// point (optional)  
//  
void TeensyUserInterface::lcdPrintRightJustified(double n, int digitsRightOfDecimal)

//  
// print a string to the LCD, centered side-to-side at the cursor  
// Enter: s -> string to print  
//  
void TeensyUserInterface::lcdPrintCentered(char *s)

//  
// print a signed int to the LCD, centered side-to-side at the cursor  
// Enter: n = signed number to print  
//  
void TeensyUserInterface::lcdPrintCentered(int n)

//
```

```
// print a float to the LCD, centered side-to-side at the cursor
//           digitsRightOfDecimal = # digits to display right of decimal
//           point (optional)
// Enter: n = signed number to print
//
void TeensyUserInterface::lcdPrintCentered(double n, int digitsRightOfDecimal)

//
// print one ASCII character to the LCD, at location of the cursor
// Enter: c = character to display
//
void TeensyUserInterface::lcdPrintCharacter(byte character)

//
// get the width of a string in pixels
//
int TeensyUserInterface::lcdStringWidthInPixels(char *s)

//
// get the height of the selected font in pixels, excluding descenders
//
int TeensyUserInterface::lcdGetFontHeightWithoutDecenders(void)

//
// get the height of the selected font in pixels, including descenders and
// line spacing
//
int TeensyUserInterface::lcdGetFontHeightWithDecendersAndLineSpacing(void)

//
// set the cursor coords in pixels
// Enter: x 0 = left most pixel
//         y 0 = left most pixel
//
void TeensyUserInterface::lcdSetCursorXY(int x, int y)

//
// get the cursor coords in pixels
// Enter: x -> storage to return X, 0 = left most pixel
//         y -> storage to return Y, 0 = left most pixel
//
void TeensyUserInterface::lcdGetCursorXY(int *x, int *y)
```

```

//  

// make a RGB565 color  

// Enter: red (0 to 31)  

//         green (0 to 63) Note: 0x20 green has same intensity as 0x10 blue  

//         blue (0 to 31)  

// Exit: 16 bit color returned, bit format: rrrrrgggggbbbb  

//  

uint16_t TeensyUserInterface::lcdMakeColor(int red, int green, int blue)

```

## Reading/writing configuration values:

```

//  

// write a configuration byte (8 bit) to the EEPROM  

// Enter: EEPROMAddress = address in EEPROM to write  

//         value = 8 bit value to write to EEPROM  

//         note: 2 bytes of EEPROM space are used  

//  

void TeensyUserInterface::writeConfigurationByte(int EEPROMAddress, byte value)

//  

// read a configuration byte (8 bit) from the EEPROM  

// Enter: EEPROMAddress = address in EEPROM to read from  

//         defaultValue = default value to return if value has never been  

//                     written to the EEPROM  

//         note: 2 bytes of EEPROM space are used  

// Exit:  byte value from EEPROM (or default value) returned  

//  

byte TeensyUserInterface::readConfigurationByte(int EEPROMAddress,  

                                              byte defaultValue)

//  

// write a configuration short (16 bit) to the EEPROM  

// Enter: EEPROMAddress = address in EEPROM to write  

//         value = 16 bit value to write to EEPROM  

//         note: 3 bytes of EEPROM space are used  

//  

void TeensyUserInterface::writeConfigurationShort(int EEPROMAddress, short value)

//  

// read a configuration short (16 bit) from the EEPROM  

// Enter: EEPROMAddress = address in EEPROM to read from  

//         defaultValue = default value to return if value has never been  

//                     written to the EEPROM

```

```

//           note: 3 bytes of EEPROM space are used
// Exit:    short value from EEPROM (or default value) returned
//
short TeensyUserInterface::readConfigurationShort(int EEPROMAddress,
    short defaultValue)

//


// write a configuration int (32 bit) to the EEPROM
// Enter:  EEPROMAddress = address in EEPROM to write
//          value = 32 bit value to write to EEPROM
//          note: 5 bytes of EEPROM space are used
//
void TeensyUserInterface::writeConfigurationInt(int EEPROMAddress, int value)

//


// read a configuration int (32 bit) from the EEPROM
// Enter:  EEPROMAddress = address in EEPROM to read from
//          defaultValue = default value to return if value has never been
//                      written to the EEPROM
//          note: 5 bytes of EEPROM space are used
// Exit:    long value from EEPROM (or default value) returned
//
int TeensyUserInterface::readConfigurationInt(int EEPROMAddress, int defaultValue)

//


// write a configuration float (32 bit) to the EEPROM
// Enter:  EEPROMAddress = address in EEPROM to write
//          value = 32 bit float to write to EEPROM
//          note: 5 bytes of EEPROM space are used
//
void TeensyUserInterface::writeConfigurationFloat(int EEPROMAddress, float value)

//


// read a configuration float (32 bit) from the EEPROM
// Enter:  EEPROMAddress = address in EEPROM to read from
//          defaultValue = default value to return if value has never been
//                      written to the EEPROM
//          note: 5 bytes of EEPROM space are used
// Exit:    float value from EEPROM (or default value) returned
//
float TeensyUserInterface::readConfigurationFloat(int EEPROMAddress,
    float defaultValue)

```

