Enabling a TFT LCD Display on an Intel® Galileo Board

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Executive Summary

Intel® Quark X1000 is a 32-bit sub-atom System-on-a-Chip (SoC) at one-fifth the size of the Intel® Atom™ processor and uses one-tenth of the power. The chip is targeted primarily for headless applications. Consequently, the Customer Reference Board (CRB) for Intel® Quark, the Intel® Galileo board, was purposely built without display capability. The price, power, and performance make the Intel® Quark SoC a perfect match for fixed-function, connected, embedded devices such as an Internet-of-Things (IoT) gateway with no user interface – a class of device traditionally invisible to the end-user.

It is the convergence of trends that triggered the need for some form of display and touch capabilities on the Intel® Galileo board to support increasingly demanding IoT applications.

Nevertheless, we have observed an increased blurring of the distinction between embedded devices and consumer products ranging from smartphones, tablets, and home appliances to industrial control systems and a vast array of handheld mobile devices. Additionally, there is the trend of increasing richness in features of many small system. Consequently, we ran out of space on the surface of these things to fit all buttons and switches that would be needed to operate them. It is these convergence of trends that trigger the needs for some form of display and touch capabilities on the Intel® Galileo board to support increasingly demanding IoT applications [1].
Contents

Enabling Display on Intel® Galileo ................................................................. 4
  Terminology ................................................................................................. 4
  TFT LCD Screen Selection Criteria ............................................................ 5
    Display Resolution ....................................................................................... 5
    Dot Pitch ..................................................................................................... 5
    Viewable Size ............................................................................................. 5
    Response Time ........................................................................................... 5
    Refresh Rate ............................................................................................... 6
    RGB Color Model ....................................................................................... 6
    Color Support ............................................................................................. 6
    Backlight ................................................................................................... 6
    View Angle ................................................................................................ 6
    Transmissive/Reflective/Transflective LCD ............................................... 6
    Touch Capable ............................................................................................ 7
  Display Interface .......................................................................................... 7

Hardware & Software Configuration ................................................................. 8
  Robopeak 2.8” USB TFT LCD Touch Screen ............................................... 8
  Integrating Robopeak USB Display Driver in Yocto* .................................... 9
  Adafruit 2.8” TFT Touch Shield v2 ............................................................... 10
  Using Adafruit TFT Shield on an Intel® Galileo Board via Arduino Sketch .... 10

Conclusion .................................................................................................... 12

References .................................................................................................... 13
Enabling Display on Intel® Galileo

This whitepaper explains how to connect a Thin-Film Transistor (TFT) display to an Intel® Galileo board in the absence of an on-chip graphics controller. The paper includes TFT screen selection guidelines and describes hardware and software configurations. Two examples are described. One example demonstrates the process of enabling a 2.8” Robopeak* Mini USB display on Yocto* for use with an Intel® Galileo board. Another example shows how to enable an SPI-based 2.8” TFT Display on Intel® Galileo board in Arduino* Sketch.

Terminology

This whitepaper use the following terms and definitions.

<table>
<thead>
<tr>
<th>Terminology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFT</td>
<td>Thin-Film Transistor</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid Crystal Display</td>
</tr>
<tr>
<td>MIPI</td>
<td>Mobile Industry Processor Interface</td>
</tr>
<tr>
<td>DSI</td>
<td>Display Serial Interface</td>
</tr>
<tr>
<td>GPU</td>
<td>Graphics Processing Unit</td>
</tr>
<tr>
<td>SoC</td>
<td>System-on-a-Chip</td>
</tr>
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</table>
TFT LCD Screen Selection Criteria

There is a variety of TFT screen types in the market today. This section examines the various parameters used commonly to describe a screen to help readers choose the right screen for their application.

Display Resolution

Corresponds to the number of pixels on the screen. It is usually quoted as “Width x Height” with units in pixels. Table 1 shows the display resolution found commonly in a TFT LCD screen.

<table>
<thead>
<tr>
<th>Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGA</td>
<td>320 x 200</td>
</tr>
<tr>
<td>QVGA</td>
<td>320 x 240</td>
</tr>
<tr>
<td>VGA</td>
<td>640 x 480</td>
</tr>
<tr>
<td>WVGA</td>
<td>850 x 480</td>
</tr>
<tr>
<td>SVGA</td>
<td>800 x 600</td>
</tr>
<tr>
<td>HD720</td>
<td>1280 x 720</td>
</tr>
<tr>
<td>HD1080</td>
<td>1920 x 1080</td>
</tr>
<tr>
<td>UXGA</td>
<td>1600 x 1200</td>
</tr>
<tr>
<td>WQXGA</td>
<td>2560 x 1600</td>
</tr>
</tbody>
</table>

Dot Pitch

The distance between the centers of two adjacent pixels. A smaller dot pitch results in a sharper image. Dot pitch is commonly found to be the same horizontally and vertically.

Viewable Size

Also known as the active display area. It is the size of a display panel measured on its diagonal. Common sizes on typical mobile devices are 1.5”, 2.0”, 2.8”, 3.2”, 5” and 7”.

Response Time

The amount of time a pixel in a display takes to change its state (that is, brightness, colors, and so on).
Refresh Rate

Not to be confused with "Frame Rate". This parameter indicates the number of times in a second that the display hardware updates its buffer.

RGB Color Model

A display hardware that uses the RGB model to represent the color of a pixel by adding the three additive primary colors, red, green, blue components to reproduce a broad array of colors. It is the most commonly used method to represent a color in computing.

Color Support

Represents the number of distinct colors supported by the display hardware. For example, an 8-bit color code supports a maximum of 256 unique colors. 16-bit color (High Color) supports a total of 65536 colors, and 24-bit color (True Color) supports a maximum of 16,777,216 color variations.

Backlight

The form of illuminations used in a Liquid Crystal Display (LCD) since LCDs do not produce light themselves.

View Angle

This is the maximum angle at which a display can be viewed with acceptable visual performance.

Transmissive/Reflective/Transflective LCD

This refers to the viewing modes of the LCD display:

- Transmissive LCDs use a backlight for the image to be visible. It gives better brightness at the expense of higher power consumption. This type of screen is not suitable for outdoor use without shades as direct sunlight overwhelms the backlight.

- Reflective LCDs require a light source (that is, natural light) from the front to illuminate the display. The main advantages are low power and light weight since there is no backlight. However, viewing is difficult when used in a dark room or outside at night.

- Transflective LCDs combine both the Transmissive and Reflective modes. It uses a backlight mechanism with the addition of a reflective mirror to let light pass through from the back.
**Touch Capable**

Some TFT LCD screens come with a Resistive/Capacitive touch sensor where the touch controller is integrated into screen's flex cable. This feature is useful for the implementation of a human machine interface.

**Display Interface**

Graphical data is usually transferred to a TFT LCD screen from where it is stored through either a serial (reduced pin configuration) or a parallel data interface. The choice of display interface is dependent on the data communication modes made available by the TFT LCD controller.

- Serial interface examples include: SPI (3-wire or 4-wire), I²C, USB, MIPI DSI, HDMI, LVDS, andDP.

- Parallel transfer requires more I/O pins, and commonly uses the 8/9/16/18-bit Intel® 8080 & Motorola* 6800 system interface.

**Note:** TFT display hardware with a serial interface such as SPI/I²C/USB is more appropriate for an Intel® Galileo board than using parallel transfer due to the lack of native GPIOs. However, the operating frequency of the serial transport interface will determine the maximum pixel resolution at a designated frame rate and the number of bits per pixel (BPP) or vice versa. For example, assuming an SPI interface operating at 20 MHz, a TFT display supporting a pixel resolution of 320 x 240 @ 18 bpp will have a frame rate of approximately 14 fps (20 MHz/[320 x 240 x 18 bpp]).
Since Intel® Quark SoCs do not have a built-in GPU, there is no display interface available on the Intel® Galileo board. Nonetheless, the growth in the smartphone and tablet segments has spurred the growth of a TFT LCD driver IC that will eventually enable a low-cost TFT LCD panel solution for small systems that do not have a GPU such as the Intel® Galileo board. In this section, we show how to configure an Intel® Galileo board to display graphics. Two different TFT LCD screen options are explored to illustrate the idea: the Robopeak* 2.8” USB TFT LCD Touch Screen (enabled as a frame-buffer device in Yocto*) and the Adafruit* 2.8” TFT Touch Shield for Arduino v2 (drawing graphics in Arduino* sketch).

**Note:** Please refer to the Intel® Galileo Datasheet [3] for more detailed technical information about the board.

### Robopeak 2.8” USB TFT LCD Touch Screen

The display hardware is available from http://www.dfrobot.com. See Table 2 for the screen specification.

**Table 2 Robopeak USB Display Specification**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Resolution</td>
<td>320 x 240</td>
</tr>
<tr>
<td>Color Depth</td>
<td>16 bpp</td>
</tr>
<tr>
<td>Screen Size</td>
<td>2.8”</td>
</tr>
<tr>
<td>Communication Interface</td>
<td>USB 2.0 Full-Speed via Micro USB</td>
</tr>
<tr>
<td>Touch Screen</td>
<td>Single Point Touch</td>
</tr>
</tbody>
</table>

The Robopeak USB display is connected to the Intel® Galileo board by simply plugging the display into the USB host interface of the Intel® Galileo board.
Integrating Robopeak USB Display Driver in Yocto*

The Intel® Galileo board is powered by a Yocto* based OS. Like any other custom hardware, a driver is needed for the software to interact with the display hardware. The Robopeak USB driver is installed into the Yocto based OS as a kernel module providing frame buffer support. The source code (a fork of the Robopeak/rpusbdisplay project) can be downloaded from https://github.com/wallacezq/rpusbdisp [4].

Please refer to the Readme for complete build and installation instructions.

Figure 1 shows a working Intel® Galileo board configured to run and display Yocto Reference UI (Sato) on a Robopeak USB display hardware.

Figure 1 Yocto Reference UI (Sato) Running on an Intel® Galileo Board
A guide to adding a TFT display to an Intel® Galileo board

**Adafruit 2.8” TFT Touch Shield v2**

The display hardware is available from [http://www.adafruit.com](http://www.adafruit.com). See Table 3 for the screen specification.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Resolution</td>
<td>320 x 240</td>
</tr>
<tr>
<td>Color Depth</td>
<td>18 bpp</td>
</tr>
<tr>
<td>Screen Size</td>
<td>2.8”</td>
</tr>
<tr>
<td>Communication Interface</td>
<td>SPI</td>
</tr>
<tr>
<td>Touch Screen</td>
<td>4-wire Resistive Single Point Touch attached to STMPE610</td>
</tr>
<tr>
<td>TFT LCD Driver</td>
<td>ILI9341</td>
</tr>
</tbody>
</table>

The screen can be connected to Intel® Galileo board through the Arduino Shield interface.

**Using Adafruit TFT Shield on an Intel® Galileo Board via Arduino Sketch**

The Adafruit TFT LCD library made it possible for an Arduino Sketch project to interact with the display hardware without the need of a frame buffer driver in the kernel. This is especially true for microcontroller-based Arduino device which lacks the capability to run the Linux* OS. The API is simple and easy-to-understand. Together with its companion library, the Adafruit GFX library, it provides a common set of graphics primitives for drawing points, lines, circles, rotation, and additionally makes it very easy to draw text or shapes for various fonts, colors and sizes. Figure 2 shows output from the Adafruit sample sketch.

A fork of the Adafruit TFT LCD for the Intel® Galileo board can be downloaded from [https://github.com/wallacezq/Adafruit_ILI9341](https://github.com/wallacezq/Adafruit_ILI9341) [5].
Figure 2 Adafruit Sample Sketch Running on an Intel® Galileo Board
Conclusion

Many TFT displays today come with a quality display driver equipped with various communication interfaces (such as. I²C, SPI, USB, and so on) suitable for devices, such as the Intel® Galileo board, that lack a GPU to produce a graphical human interface. This paper described two off-the-shelf small TFT displays, namely the Robopeak® USB 2.8” TFT display and the Adafruit® 2.8” TFT Shield v2 hardware and demonstrated how the device can be configured as a kernel driver or a library for use in an Arduino sketch project.
References

[1] Trends and Implications in Embedded Systems Development:

[2] Intel® Galileo board software download:

[3] Intel® Galileo board datasheet & schematics:
https://communities.intel.com/community/makers/documentation/galileo_documents

[4] Robopeak Framebuffer Driver for the Intel® Galileo board:
https://github.com/wallacezq/rpusbdisp

[5] Adafruit ILI9341 Library for the Intel® Galileo board:
https://github.com/wallacezq/Adafruit_ILI9341
A guide to adding a TFT display to an Intel® Galileo board


Authors

Wallace Lee is a Platform Application Engineer (PAE) with the Intel Internet of Things Group (IOTG).
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