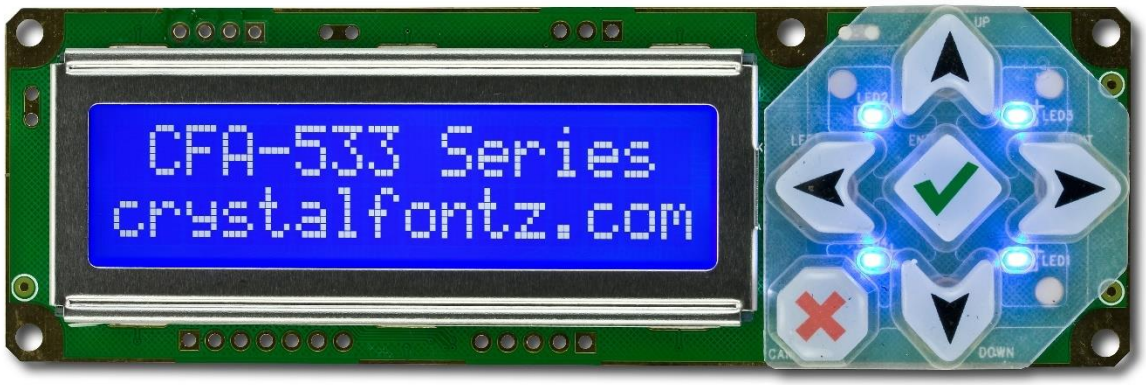
INTELLIGENT LCD MODULE SPECIFICATIONS



Datasheet Release 2019-10-08
for
CFA533-TMI-KU

Hardware Version: v1.4
Firmware Version: u1v2

Revision A1

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1. General Information

Datasheet Revision History
Datasheet Version: **2019-10-08** Hardware Version: **v1.4** Firmware Version: **u1v2** This datasheet has been updated to reflect hardware version v1.4, firmware u4v4 for the CFA533-TMI-KU LCD module. Previous datasheet Version: **2011-08-03** For reference, previous datasheets may be downloaded by clicking the “Show Previous Versions of Datasheet” link under the “Datasheets and Files” tab of the product web page.

Product Change Notifications
To check for or subscribe to “Part Change Notices” for this display module, see the Product Notices tab on the product’s webpage.

Variations
Slight variations (for example, contrast, color, or intensity) between lots are normal.

Volatility
This display module has volatile memory.

Disclaimer
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2. Introduction

2.1. Comparison to CFA633

The CFA533 series is mechanically similar to the CFA633 series. The CFA533 series command set is compatible with the CFA633 series. The CFA533 can be used as an economical “drop-in” replacement for most CFA633 series applications that do not need fan capabilities.

2.2. Main Features

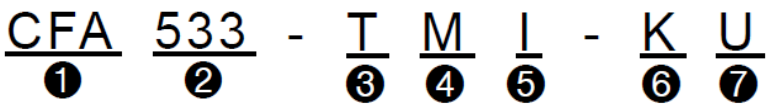
- 16 characters x 2 lines LCD with keypad and high-level interface. The display will fit nicely in a 1U rack mount case (35 mm overall height).
- A single 5v supply is needed for micro-controller, backlight, and LCD.
- Adjustable, long-life backlights are driven from the 5v supply at constant current. Their brightness is independent of power supply variations.
- Full-speed USB interface.
- Robust packet-based communications protocol with 16-bit CRC.
- Module has a 6 o’clock viewing direction. Please see Optical Characteristics.
- Integrated, LED-backlit, 6-button translucent silicon keypad has four directional arrows, Enter, and Cancel.
- Edge-lit white LED backlight with negative STN blue transmissive mode LCD. Display shows light characters on a deep blue background.
- The display can be read in normal office lighting and in dark areas. May be difficult to read in direct sunlight.
- Nonvolatile memory capability (EEPROM): Set the “power on” display screen, plus 16-bytes for storing IP, netmask, system serial number, or other data.
- These options can be added to your display after clicking on the “Customize and Add to Cart” button:
    - ATX power supply control functionality allows the keypad buttons on the CFA533 to replace the Power and Reset switches on your system, simplifying front panel design. The ATX functionality can also implement a hardware watchdog that can reset host system on host software failure,
    - Temperature monitoring: up to 32 channels at 0.5 degree Celsius absolute accuracy (using optional connector and Crystalfontz WR-DOW-Y17 cables,
    - An optional 5.25-inch half-height drive bay kit with mounting bracket is available. Please see CFA533 Kit Configurator.
- Crystalfontz America, Inc. is ISO 9001:2015 certified.
- A Declaration for Conformity, RoHS, and REACH:SVHC are available on the product page.

2.3. Build Configuration Options

We can make the modifications listed below for a small additional charge. For more information, call (888) 206-9720.

- ATX Power Supply Control
  - A 7-pin connector is installed on the back of the PCB at J8. ATX power supply control functionality allows the keypad buttons on the CFA533-TMI-KU to replace the Power and Reset switches on your system, simplifying front panel design. The ATX functionality can also implement a hardware watchdog that can reset host system on host software failure.
- Install a Molex 70543-0002 Dallas 1-Wire header to daisy chain up to 32 of our WR-DOW-Y17 Dallas Semiconductor 1-wire temperature sensor cables at up to 0.5 degrees Celsius with absolute accuracy.
  - "Live Display" shows up to four temperature readings without host intervention, allowing temperatures to be shown immediately at boot, even before the host operating system is loaded.
  - RS-232 to Dallas Semiconductor 1-Wire bridge functionality allows control of other 1-Wire compatible devices such as ADC, voltage monitoring, current monitoring, RTC, GPIO, counters, and identification/encryption. (Additional hardware required.)

2.4. Module Classification Information



❶	**Brand**	Crystalfontz America, Inc.
❷	**Model Identifier**	533
❸	**Backlight Type & Color**	T – LED, white
❹	**Fluid Type, Image (positive or negative), & LCD Glass Color**	M – STN, negative blue
❺	**Polarizer Film Type, Temperature Range, & View Angle (O 'Clock)**	I – Transmissive, Wide Temperature Range[1], 6:00
❻	**Special Code 1**	K – Manufacturer's code
❼	**Interface**	U – USB

[1] Wide Temperature Range is -20°C minimum to +70°C maximum.

2.5. Ordering Information

PART NUMBER	FLUID	LCD GLASS COLOR	IMAGE	POLARIZER FILM	BACKLIGHT COLOR/TYPE
CFA533-TMI-KU (USB)	**STN**	**blue**	**negative**	**transmissive**	**LCD: white edge LEDs Keypad: blue LEDs**
Additional variants (same form factor, different LCD mode or backlight):					
CFA533-TFH-KC (I2C)	FSTN	light gray	positive	transflective	LCD: white edge LEDs Keypad: white LEDs
CFA533-TFH-KL (“logic-level” RS-232)					
CFA533-TFH-KS (“full swing” RS-232)					
CFA533-TFH-KU (USB)					
CFA533-TMI-KC (I2C)	STN	blue	negative	transmissive	LCD: white edge LEDs Keypad: blue LEDs
CFA533-TMI-KL (“logic-level” RS-232)					
CFA533-TMI-KS (“full swing” RS-232)					
CFA533-YYH-KC (I2C)	STN	yellow-green	positive	transflective	LCD: yellow-green edge LEDs Keypad: yellow-green LEDs
CFA533-YYH-KL (“logic-level” RS-232)					
CFA533-YYH-KS (“full swing” RS-232)					
CFA533-YYH-KU (USB)					

2.6. Drive Bay Mounting Bracket

On the webpage for CFA533-TMI-KU, after you click the “Customize and Add to Cart” button, you will see a list of options for different cables, connectors and the drive bay bracket.

Figure 1. Bracket: Black Overlay with Logo

2.7. Cables

Below is a list of some of the cables we offer to make it easy to integrate the CFA533 into your system. Please note that cable lengths are approximate. Common configurations are described in USB Connection to Host.

Crystalfontz Cable	Image	Description All Cables Are RoHS Compliant
WR-PWR-Y12 ~13 inches		Cable allows you to plug a 4-pin “hard drive style” Molex power connector into the module's “floppy drive style” power connector, plus provides an additional female 4-pin Molex connector.
WR-232-Y08 ~27 inches		Use this ribbon cable to supply communications. Connect cable’s 10-pin female connector to the module’s J_RS232 male connector. Connect cable’s RS232 DB9 9-pin female connector to host’s DB9 9-pin male serial port. Default or alternate motherboard RS-232 pinouts can be accommodated by changing jumpers on the CFA533.
WR-232-Y22 ~26 inches		Use this cable to supply communications. Connect one of the 10-pin female connectors to the module’s’ J_RS232 10-pin male connector. Connect cable’s second 10-pin female connector to host’s motherboard 10-pin male connector. This cable supports standard or alternate pinout motherboard RS-232 connections without changing jumpers on the module.
WR-PWR-Y14 ~24 inches		Use this ATX power cable to turn an ATX power supply on and off, or power cycle the host through the module. Connect the cable’s male 7-pin connector to the module’s J8 female connector. (Requires optional 7-in female connector at J8 on module. Select J8 connector after you click on the module’s website page button “Customize and Add to Cart”.)
WR-DOW-Y17 ~12 inches + ~12 inches between connectors		Connect (“daisy chain”) up to 32 of these DOW (Dallas One-Wire) DS18B20 temperature sensor cables. Requires optional DOW connector at J_DOW on module. (Select DOW connector after you click on the module’s website page button “Customize and Add to Cart”.)

3. Mechanical Characteristics

3.1. Physical Characteristics

Item	Specification (mm)	Specification (inch, reference)
Module Overall Dimensions		
Width and Height	110.5 (W) x 35.0 (H)	4.35 (W) x 1.378 (H)
Depth without Keypad	16.60	0.654
Viewing Area	61.0 (W) x 15.8 (H)	2.402 (W) x 0.622 (H)
Active Area	56.20 (W) x 11.5 0(H)	2.213 (W) x 0.453 (H)
Character Size	2.95 (W) x 5.55 (H)	0.116 (W) x 0.219 (H)
Dot Size	0.55 (W) x 0.65 (H)	0.022 (W) x 0.026 (H)
Keystroke Travel (approximate)	2.4	0.094
Weight	42 grams (typical)	1.48 ounces

3.2. Jumper Locations and Functions (All Interfaces)

All jumpers are configurable, but not all jumpers will affect your interface (serial or USB). Close the jumpers by melting a ball of solder across their gap. Reopen the jumpers by removing the solder with a solder wick. Where applicable, the corresponding resistor must also be removed to open a jumper (RJP2 must be removed for JP2 to be open, for example).

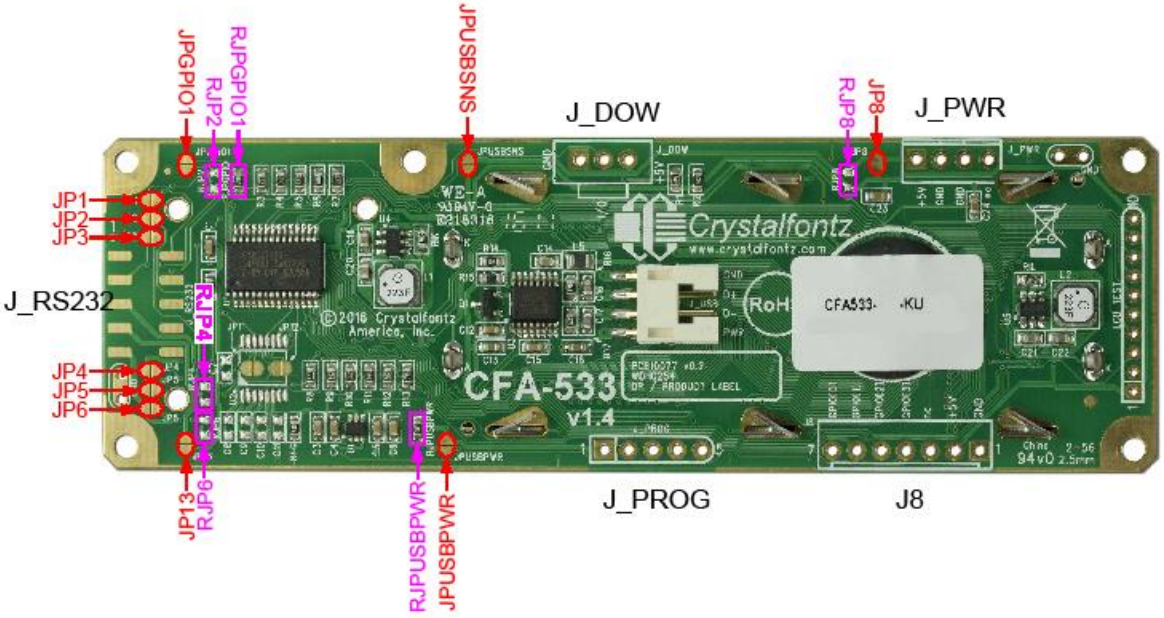


Figure 2. CFA533 HW v1.4 Jumper Locations and Functions

4. Optical Characteristics

This module has a **6 o'clock** viewing angle.

Item	Symbol	Condition	Minimum	Typical	Maximum
Viewing Angle (6 o'clock) (Vertical, Horizontal)	(V)θ	CR≥2		70	
	(H)φ	CR≥2		60	
Contrast Ratio[1]	CR			3.8	5
LCD Response Time[2]	T_{rise}	T_a=25°C		180 ms	
	T_{fall}	T_a=25°C		200 ms	

[1]Contrast Ratio = (brightness with pixels light) /(brightness with pixels dark),
[2]Response Time = The amount of time it takes a liquid crystal cell to go from active to inactive or back again.

4.1. Test Conditions and Definitions for Optical Characteristics

We work to continuously improve our products, including backlights that are brighter and last longer. Slight color variations from module to module and batch to batch are normal. If you need modules with consistent color, please ask for a custom order.

- Viewing Angle
  - Vertical (V)θ: 0°
  - Horizontal (H)φ: 0°
- Frame Frequency: 64 Hz
- Driving Waveform: 1/16 Duty, 1/5 Bias
- Ambient Temperature (T_a): 25°C

4.2. Definition of Operation Voltage (V_{op})

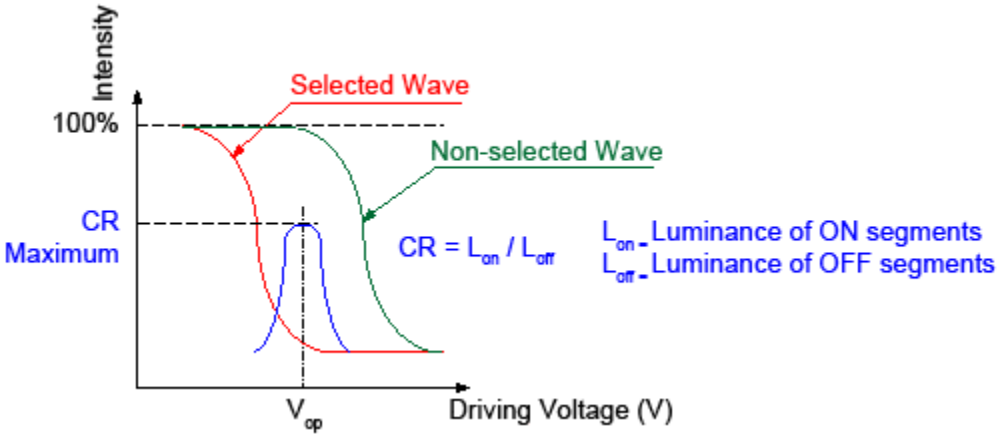


Figure 3. Definition of Operation Voltage (V_{op}) (Positive)

4.3. Definition of Response Time (Tr, Tf)

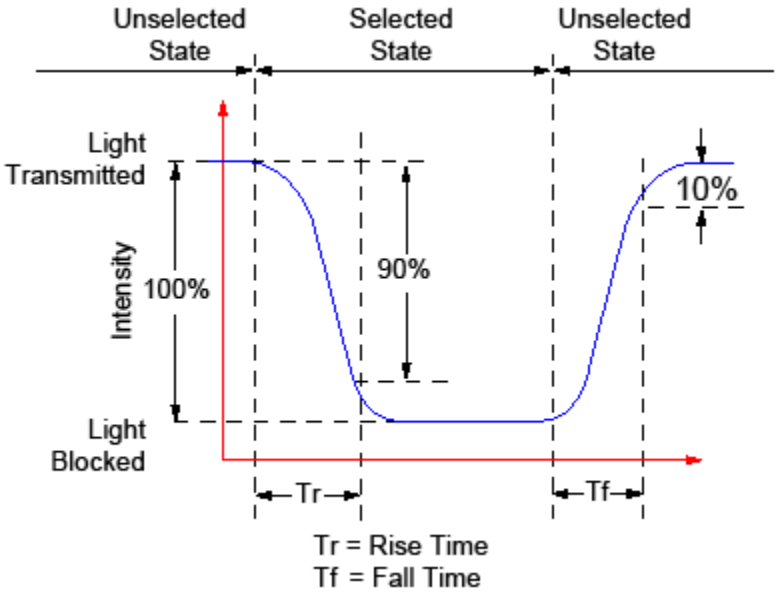


Figure 4. Definition of Response Time (Tr, Tf) (Positive)

4.4. Definition of 6 o'clock and 12 o'clock Viewing Angles

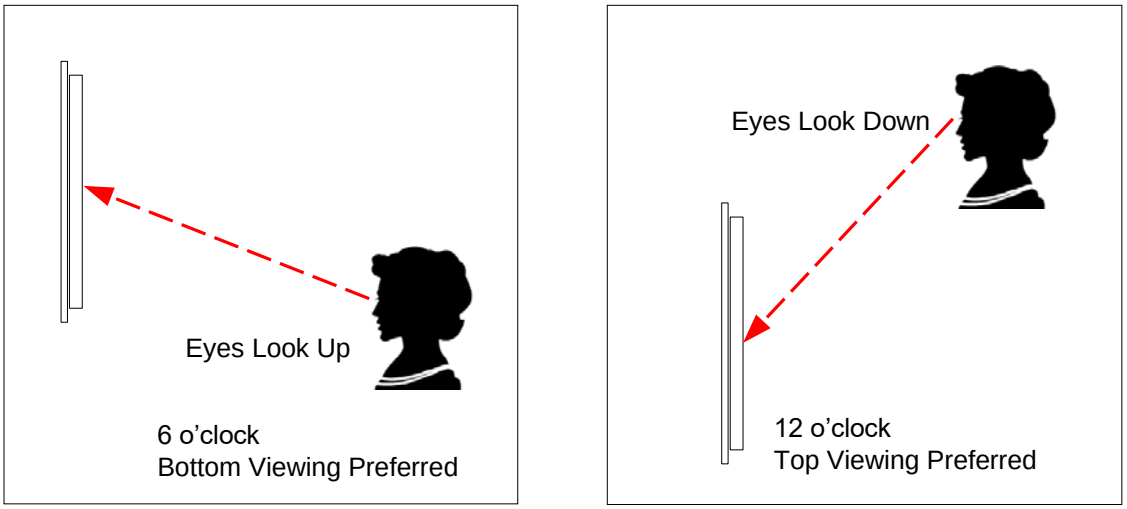


Figure 5. Definition of 6 o'clock and 12 o'clock Viewing Angles

5. Electrical Specifications

5.1. System Block Diagram

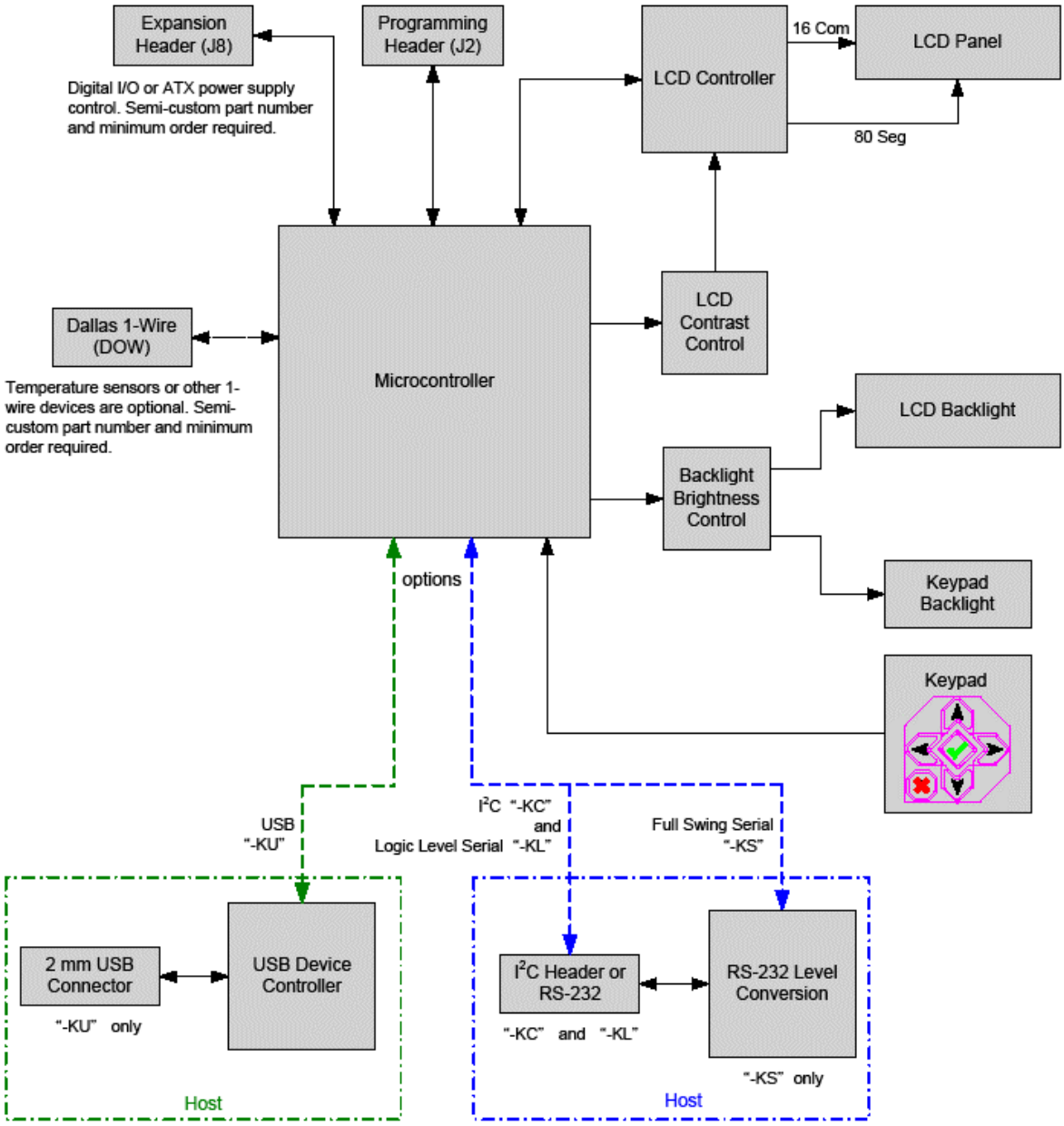


Figure 6. System Block Diagram

6. Supply Voltages and Current

6.1. Absolute Maximum Ratings

Absolute Maximum Ratings	Symbol	Minimum	Maximum
Operating Temperature	T_{OP}	-20°C	+70°C
Storage Temperature	T_{ST}	-30°C	+80°C
Humidity Range (Non-condensing)	RH	10%	90%
Please note that these are stress ratings only. Extended exposure to the absolute maximum ratings listed above may affect device reliability or cause permanent damage. Functional operation of the module at these conditions beyond those listed under DC Characteristics is not implied.			

5v Typical Current Consumption	Specification
+5v (LCD, microcontroller, with backlight **off, 0%**)	< 20mA
+5v (LCD, microcontroller, with backlight **on, 100%**)	< 100 mA

6.2. DC Characteristics

The CFA533 has 5 GPIO (General-Purpose Input/Output) pins available. These pins connect to the processor's CMOS GPIO pins. They may be set to input or output, additionally some pins have special purpose functions. When they are set as GPIO outputs, the average voltage can be controlled by PWM. Please refer to 34 (0x22): Set or Set and Configure GPIO Pins and 35 (0x23): Read GPIO Pin Levels and Configuration State for more information.

	DC Characteristics	Symbol	Minimum	Typical	Maximum
Controller and Board	Supply Voltage for Logic	V_{DD}	+4.75v	+5.0v	+5.25v
	Input High Voltage	V_{IH}	V_{DD} -1.0v		V_{DD}
	Input Low Voltage	V_{IL}	-.3v		+0.6v
	Output High Voltage	V_{OH}	+0.9V_{DD}		
	Output Low Voltage	V_{OL}			+.1V_{DD}

GPIO[0] through GPIO[4] Current Limits	Specification
Sink	25 mA
Source	10 mA

6.3. RS-232 Characteristics

Signals on Header J_RS232				
Specification	**Symbol**	**Minimum**	**Typical**	**Maximum**
RS232 Input Voltage Range		-15v		+15v
RS232 Input High Voltage	$V_{IH-RS232}$	+2.4v		
RS232 Input Low Voltage	$V_{IL-RS232}$			+0.8v
RS232 Output Voltage Swing		±5.0v	±5.4v	

ESD (Electro-Static Discharge) Specifications for Tx and Rx pins of connector J_RS232 only:

+15 kV Human Body Model

+15 kV IEC1000-4-2 Air Discharge

+8 kV IEC1000-4-2 Contact Discharge

The remainder of this circuitry is industry standard CMOS logic and susceptible to ESD damage. Please use industry standard antistatic precautions as you would for any other static sensitive devices such as expansion cards, motherboards, or integrated circuits. Ground your body, work surfaces, and equipment.

6.4. LED Backlight Information

The backlights used in the CFA533 are designed for very long life, but their lifetime is finite. To conserve the LED lifetime, you can dim or turn off the backlights during periods of inactivity.

7. USB Connection to Host

For Linux and Windows, simply connect the module's USB cable to the host. The host will install/configure the appropriate driver.

7.1. USB Connection to Host

In order to keep the CFA533-TMI-KU as thin as possible, the CFA533-TMI-KU uses a very low profile 2 mm latching polarized connector for USB connection. Crystalfontz offers two cables that make the connection between the CFA533-TMI-KU and the host. The WRUSBY03 (6-foot) has the mating 2 mm connector on one end and a standard "USB A" on the other end. The WRUSBY11 (30-inch) has the mating 2 mm connector on one end and standard single pin connectors on the opposite end. These single pin connectors are suitable to plug directly onto the USB headers typically found on motherboards. There is also the WRUSBY33, which is very similar to the WRSUBY11, except that it uses the standard pin assignment now found on most motherboards.

If you would like to make your own cable, the connector on the CFA533-TMI-KU is:

- FCI/Berg 95000-004: SMT 2mm connector, 4-position, polarized

The mating housing and crimping contact for the cable are:

- FCI/Berg 90312-004: Housing, 2 mm connector, 4-position, polarized
- FCI/Berg 77138-001: Crimping Contact (4 pieces required)

7.2. Standard Power Connection

The easiest way to provide power from a host to CFA533-TMI-KU is through J_USB, using an appropriate cable (WRUSBY03, WRUSBY11 or WRUSBY33).

Did you know? Crystalfontz can supply cables and close the appropriate jumpers so that the module and cables are pre-configured and bundled under a single part number, ready to use. Please contact technical support +1-888-206-9720 or email support@crystalfontz.com for details. A minimum order quantity may apply.

7.3. Connecting 5v Power

For a USB module, +5v power is typically supplied through J_USB. In some applications, you may want to supply +5v separately from the USB power. For instance, if you want the LCD to power on and show the boot screen immediately, and the USB power from your system is not supplied until later in the boot cycle. You may supply 5v through J_PWR, J8, or J_RS232. If you supply 5v through J_PWR, you will need to assure that JP8 is closed or RJP8 is loaded. If you supply 5v through J_RS232, you must close JP13. Be aware that when 5v is fed in one of these connections, it may also be fed out at the other connections, depending on jumper settings. Please refer to the illustration below.

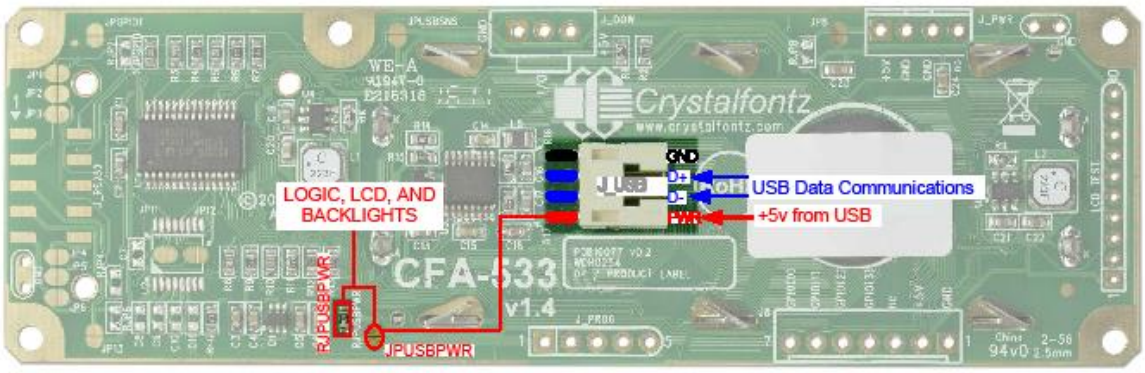


Figure 7. 5v Power Connection

7.4. Connection through J_PWR Connector

For a USB module, the primary ground is the GND of the USB cable. You may supply the ground connection through J_PWR, J8, or J_RS232. If you supply 5v through J_RS232, you must close JP6 or load RJP6. Typically, you will want to use the ground connection that is closest to the corresponding power connection. Please refer to the illustration below.

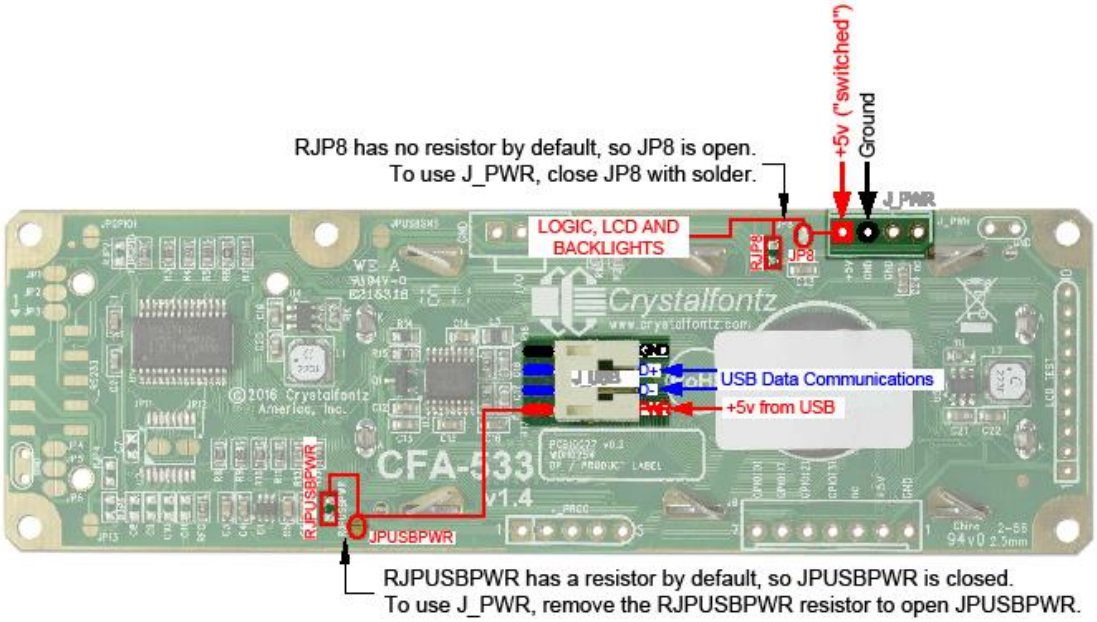


Figure 8. Connection through J_PWR Connector

7.5. Standard +5v Connection through J8 Connector

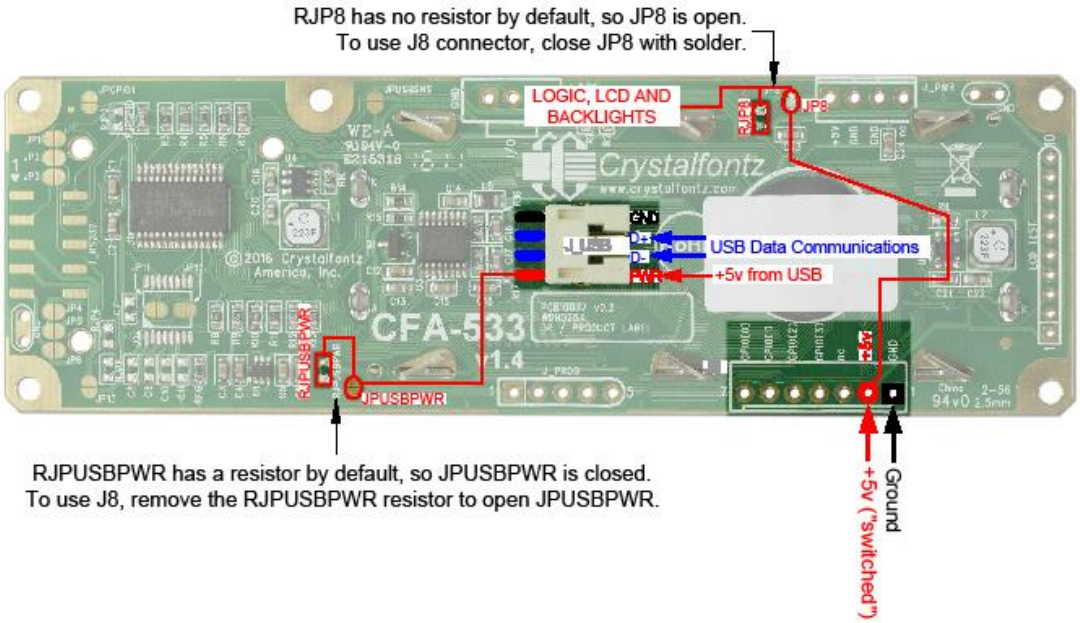


Figure 9. Standard +5v Connection through J8 Connector

8. ATX Power Supply and Control Connections

The CFA533-TMI-KU has the ability to control power on/off and reset functions of a standard ATX PC power supply.

> The GPIO pins used for ATX control must not be configured as user GPIO, and must be configured to their default drive mode in order for the ATX functions to work correctly. These settings are the default but may be changed by the user. See command 34 (0x22): Set or Set and Configure GPIO Pins.

To enable ATX functionality, the CFA533-TMI-KU is powered from the PC's V_{SB} signal (the “stand-by” or “always-on” +5v ATX power supply output) through the 5v pin of J8. Since the CFA533 is then always powered, it can detect the “on” key press even when the system is “off”.

When the host’s power is off, the CFA533 will blank the LCD and turn off the backlights. Please see command 28 (0x1C): Set ATX Power Switch Functionality. This is a low power state and from the user’s viewpoint the CFA533 and system will appear to be off. Please refer to the illustration below.

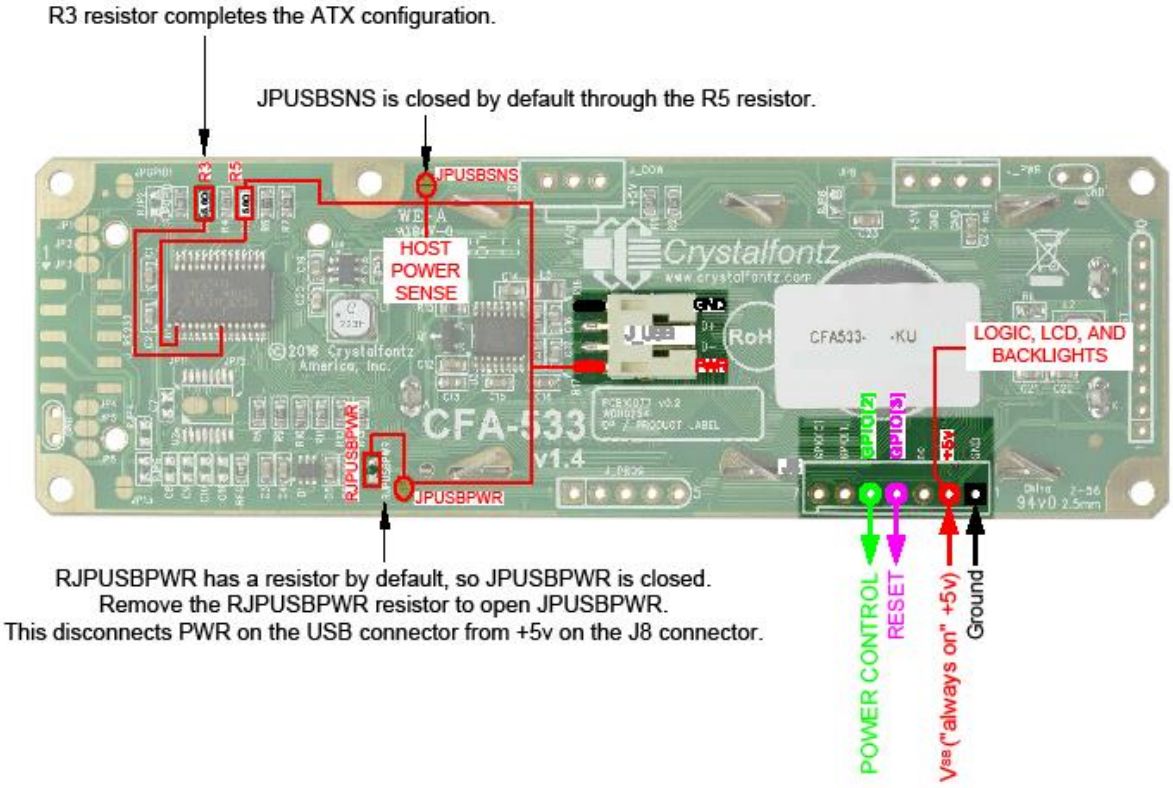


Figure 10. ATX Power Supply and Control Connections

The CFA533 needs to be able to sense if the host’s main power supply is on or off so it can act like it is off. Here are the jumper settings needed to make that work:

- Open JPGPIO0 and RJPGIO0. This inserts a series resistor so the module can safely sense the power supply pin.
- Open JP8 and RJP8. This allows the module to be powered from V_{SB} through the 5v pin of J8 independent of the 5v switched supplied on the 5v pin of J_PWR.

- For a USB module, close JPUSBSNS and connect the USB cable to a switched power USB port as usual.

The motherboard's power switch input is connected to Pin 5 of the CFA533-TMI-KU's connector J8 (labeled as GPIO[2]). This pin functions as POWER CONTROL. The POWER CONTROL pin is configured as a high-impedance input until the LCD module wants to turn the host on or off, then it will change momentarily to low impedance output, driving either low or high depending on the setting of POWER_INVERT. Please see command 28 (0x1C): Set ATX Power Switch Functionality.

The motherboard's reset switch input is connected to Pin 4 of the CFA533-TMI-KU connector J8 (labeled as GPIO[3]). This pin functions as RESET. The RESET pin is configured as a high-impedance input until the LCD module wants to reset the host. Then it will change momentarily to low impedance output, driving either low or high depending on the setting of RESET_INVERT. See command 28 (0x1C): Set ATX Power Switch Functionality. This connection is also used for the hardware watchdog.

The Crystalfontz WR-PWR-Y14 cable simplifies ATX power control connections. Below is an illustration of how the optional Crystalfontz WR-PWR-Y14 cable connects to the CFA533 connector J8 and your ATX power supply:

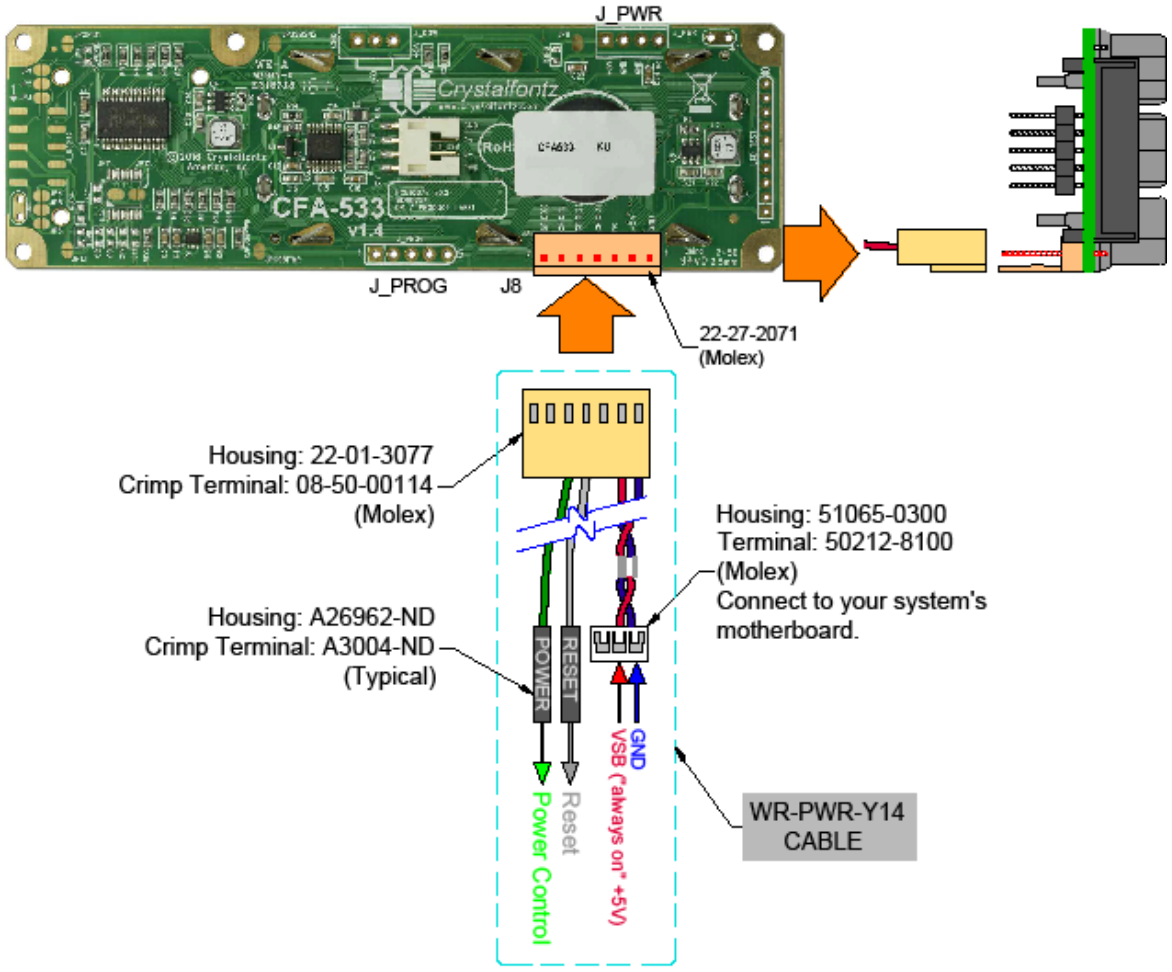


Figure 11. Power Supply and Control Using Crystalfontz WR-PWR-Y14 Cable

Once the hardware is configured, use command 28 (0x1C): Set ATX Power Switch Functionality, to enable any of the following functions:

- **System Power On.** If POWER-ON SENSE is low (0v), pressing the green check key for 0.25 seconds will turn the unit on by driving POWER CONTROL line for the pulse width set by command 28: Set ATX Power Switch Functionality (1.0 seconds default).
- **System Hard Power Off.** If POWER-ON SENSE is high (+5v) pressing the red X key for 4 seconds will turn the system off by driving the POWER CONTROL line. The line will be driven for a minimum of the pulse width set by command 28 (0x1C): Set ATX Power Switch Functionality (1.0 seconds default). If the user continues to press the key, the CFA533-TMI-KU will continue to drive the line for up to an additional 5 seconds.
- **System Hard Reset.** If POWER-ON SENSE is high (+5v) pressing the green check key for 4 seconds will reset the system off by driving the RESET line for 1 second. The CFA533-TMI-KU will reboot itself immediately after resetting the host.

8.1. ATX Host Power Sense through GPIO[1] on J8 Connector

The POWER-ON SENSE can be provided through Pin 6 of J8 (GPIO[1]). This option is only provided to allow backwards compatibility for legacy CFA633 applications. R21 is loaded with a 5kΩ 0805 SMT resistor for this functionality.

The motherboard's power switch input is connected to Pin 5 of the CFA533-TMI-KU's connector J8 (labeled as GPIO[2]). This pin functions as POWER CONTROL. The POWER CONTROL pin is configured as a high-impedance input until the LCD module wants to turn the host on or off, then it will change momentarily to low impedance output, driving either low or high depending on the setting of POWER_INVERT. Please see command 28 (0x1C): Set ATX Switch Functionality.

JP8 from connector J_PWR is closed by default. When JP8 is closed, power is connected at J8. The Crystalfontz WRPWR-Y14 cable simplifies ATX power supply control connections. When using this cable, please open jumper JP8 in order to ensure correct operation.

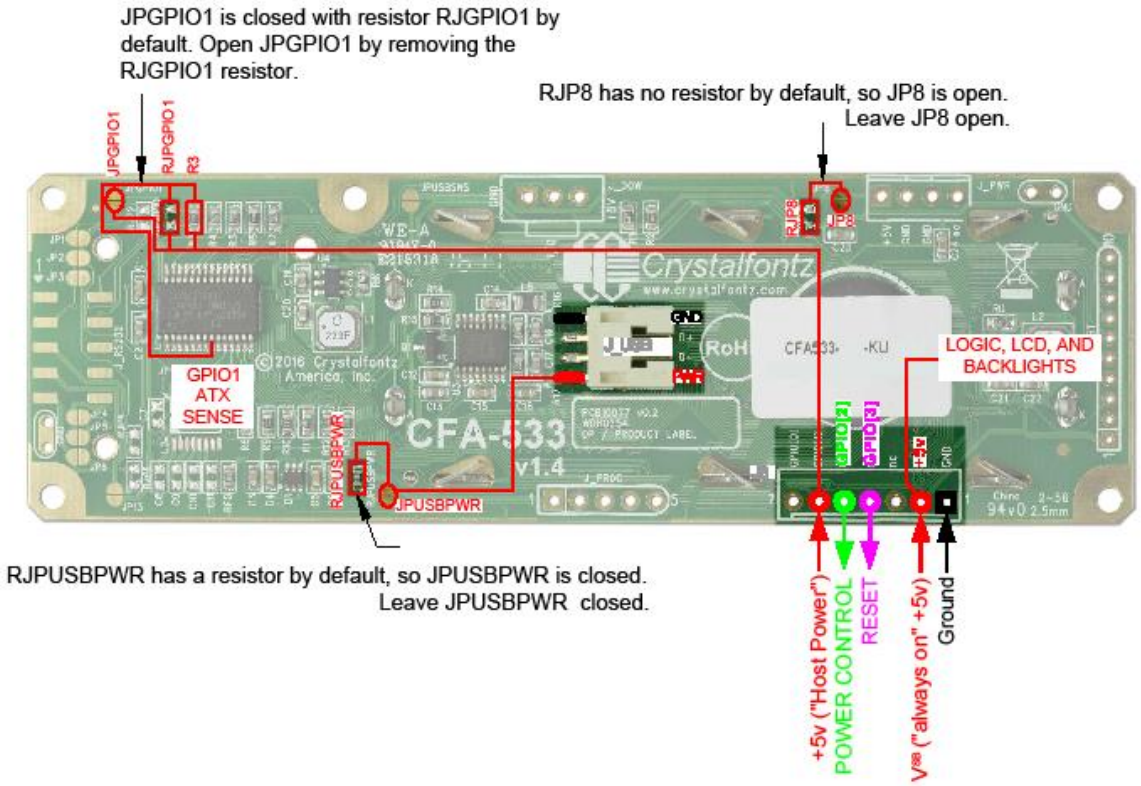


Figure 12. ATX Host Power Sense through GPIO [1] on J8 Connector

8.2. ATX Host Power Sense though +5v on J_PWR Connector

By default, the pin labeled +5v on the CFA533-TMI-KU's J_PWR connector is electrically connected to the +5v pin on the J8 connector through the normally open jumper JP8. If you want to use the CFA533-TMI-KU to do ATX power control, leave jumper JP8 open. The +5v pin of J_PWR will then function as the "Host Power Sense". The +5v pin of the J8 connector will function as VSB (standby power which is always-on) to the LCD module. To complete the ATX power supply/host power sense configuration, open JPUSBPWR so that the LCD module is not powered from the host system's USB connection.

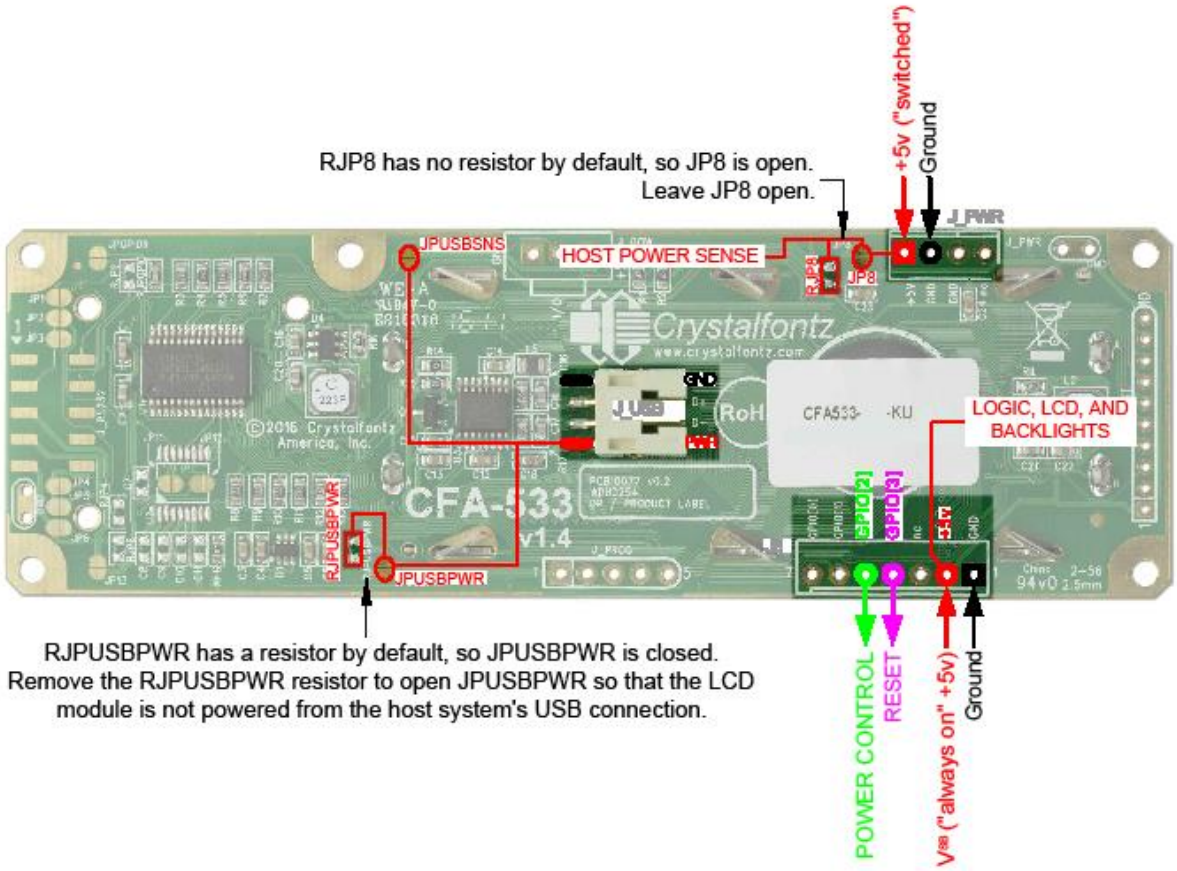


Figure 13. ATX Host Power Sense through +5v on J_PWR Connector

9. Host Communications

The CFA533 communicates with its host using an RS-232 interface. The port settings are 19200 baud, 8 data bits, no parity, 1 stop bit by factory default. The speed can be set to 115200 baud under software control, see command 33 (0x21): Set Baud Rate.

9.1. Packet Structure

All communication between the CFA533 and the host takes place in the form of a simple and robust CRC checked packet. The packet format allows for very reliable communications between the CFA533 and the host without the traditional problems that occur in a stream-based serial communication (such as having to send data in inefficient ASCII format, to “escape” certain “control characters”, or losing sync if a character is corrupted, missing, or inserted).

> Reconciling packets is recommended rather than using delays when communicating with the module. To reconcile your packets, please ensure that you have received the acknowledgement packet from the packet most recently sent before sending any additional packets to the LCD module. This practice will guarantee that you will not have any dropped packets or missed communication with the LCD module.

All packets have the following structure:

<type><data_length><data><CRC>

type is one byte, and identifies the type and function of the packet:

```
TTcc cccc
|||| ||||--Command, response, error or report code 0-63
||---------Type:
             00 = normal command from host to CFA533
             01 = normal response from CFA533 to host
             10 = normal report from CFA533 to host (not in direct response to
             a command from the host)
             11 = error response from CFA533 to host (a packet with valid
             structure but illegal content was received by the CFA533)
```

data_length specifies the number of bytes that will follow in the data field. The valid range of **data_length** is 0 to18.

data is the payload of the packet. Each type of packet will have a specified **data_length** and format for **data** as well as algorithms for decoding **data** detailed below.

CRC is a standard 16-bit CRC of all the bytes in the packet except the CRC itself. The CRC is sent LSB first. At the port, the CRC immediately follows the last used element of **data** [ ]. See Appendix A: Demonstration Software and Sample Code for details.

The following C definition may be useful for understanding the packet structure.

```
typedef struct
   {
  unsigned char  command;
  unsigned char  data length;
  unsigned char
    data[MAX_DATA_LENGTH];
  unsigned short  CRC;
  }COMMAND_PACKET;
```

On our website, Crystalfontz supplies a demonstration and test program, cfTest, along with its C source code. Included in the cfTest source is a CRC algorithm and an algorithm that detects packets. The algorithm will automatically re-synchronize to the next valid packet in the event of any communications errors. Please follow the algorithm in the sample code closely in order to realize the benefits of using the packet communications.

9.2. About Handshaking

The nature of CFA533's packets makes it unnecessary to implement traditional hardware or software handshaking.

The host should wait for a corresponding acknowledge packet from the CFA533 before sending the next command packet. The CFA533 will respond to all packets within 250 mS. The host software should stop waiting and retry the packet if the CFA533 fails to respond within 250 mS. The host software should report an error if a packet is not acknowledged after several retries. This situation indicates a hardware problem – for example, a disconnected cable.

Please note that some operating systems may introduce delays between when the data arrives at the physical port from the CFA533 until it is available to the user program. In this case, the host program may have to increase its timeout window to account for the additional overhead of the operating system.

The CFA533 can be configured to send several types of report packets along with regular acknowledge packets. The host should be able to buffer several incoming packets and must guarantee that it can process and remove packets from its input buffer faster than the packets can arrive given the baud rate and the reporting configuration of the CFA533. For any modern PC using reasonably efficient software, this requirement will not pose a challenge.

The report packets are sent asynchronously with respect to the command packets received from the host. The host should not assume that the first packet received after it sends a command is the acknowledge packet for that command. The host should inspect the **`type`** field of incoming packets and process them accordingly.

9.3. Report Codes

The CFA533 can be configured to report three items. The CFA533 sends reports automatically when the data becomes available. Reports are not sent in response to a particular packet received from the host. The report types are (1) 0x80: Key Activity, (2) 0x81: Reserved, and (3) 0x82: Temperature Sensor Report. Details are below.

0x80: Key Activity

If a key is pressed or released, the CFA533 sends a Key Activity report packet to the host. Key event reporting may be individually enabled or disabled by command 23 (0x17): Configure Key Reporting.

```
type = 0x80
data_length = 1
data[0] is the type of keyboard activity:
       KEY_UP_PRESS               1
       KEY_DOWN_PRESS             2
       KEY_LEFT_PRESS             3
       KEY_RIGHT_PRESS            4
       KEY_ENTER_PRESS            5
       KEY_EXIT_PRESS             6
       KEY_UP_RELEASE             7
       KEY_DOWN_RELEASE           8
       KEY_LEFT_RELEASE           9
       KEY_RIGHT_RELEASE         10
       KEY_ENTER_RELEASE         11
       KEY_EXIT_RELEASE          12
```

0x81: Reserved

0x82: Temperature Sensor Report

If any of the up to 32 temperature sensors is configured to report to the host, the CFA533 will send Temperature Sensor Reports for each selected sensor every second, see the command 19 (0x13): Set Up Temperature Reporting.

```
type = 0x82
data_length = 4
data[0] is the index of the temperature sensor being reported:
       0 = temperature sensor 1
       1 = temperature sensor 2
       . . .
       31 = temperature sensor 32
data[1]  is  the  MSB  of  Temperature_Sensor_Counts
data[2]  is  the  LSB  of  Temperature_Sensor_Counts
data[3] is DOW_crc_status
```

The following C function will decode the Temperature Sensor Report packet into °C and °F:

```
    void OnReceivedTempReport(COMMAND_PACKET *packet, char *output)
{
//First check the DOW CRC return code
from the CFA533  if(packet->data[3]==0)
  strcpy(output,"B
AD CRC"); else
  {
  double
    degc;
  degc=(*(short *)&(packet->data[1]))/16.0;

  double
    degf;
  degf=(degc*9.0)/5.0
  +32.0;

  sprintf(output,"%9.4f°C
          =%9.4f°F",  degc,
          degf);
  }
}
```

9.4. Command Codes

Below is a list of valid commands for the CFA533. Each command packet is answered by either a response packet or an error packet. The low 6 bits of the type field of the response or error packet is the same as the low 6 bits of the type field of the command packet being acknowledged.

0 (0x00): Ping Command

The CFA533 will return the Ping Command to the host.

```
type: 0x00 = 0₁₀
valid data length is 0 to 16
data[0-(data_length-1)] can be filled with any arbitrary data
```

The return packet is identical to the packet sent, except the type will be 0x40 (normal response, Ping Command):

```
type: 0x40 | 0x00 = 0x40 = 64₁₀
data_length = (identical to received packet)
data[0-(data_length-1)] = (identical to received packet)
```

1 (0x01): Get Hardware & Firmware Version

The CFA533 will return the hardware and firmware version information to the host.

```
type: 0x01 = 1(10)
valid data_length is 0
```

The return packet will be:

```
type: 0x40 | 0x01 = 0x41 = 65(10)
data_length = 16
data[] = "CFA533:XhX, YuY"

XhX is the hardware revision, "1h1" for example
YuY is the firmware version, "1u1" for example
```

NOTE: Hardware version v1.4 is printed on back of PCB.

2 (0x02): Write User Flash Area

The CFA533 reserves 16 bytes of nonvolatile memory for arbitrary use by the host. This memory can be used to store a serial number, IP address, gateway address, netmask, or any other data required. All 16 bytes must be supplied.

```
type: 0x02 = 2(10)
valid data_length is 16
data[] = 16 bytes of arbitrary user data to be stored in the CFA533's non-
         volatile memory
```

The return packet will be:

```
type: 0x40 | 0x02 = 0x42 = 66(10)
data_length = 0
```

3 (0x03): Read User Flash Area

This command will read the User Flash Area and return the data to the host.

```
type: 0x03 = 3(10)
valid data_length is 0
```

The return packet will be:

```
type: 0x40 | 0x03 = 0x43 = 67(10)
data_length = 16
data[] = 16 bytes user data recalled from the CFA533's non-volatile memory
```

4 (0x04): Store Current State as Boot State

The CFA533 loads its power-up configuration from nonvolatile memory when power is applied. The CFA533 is configured at the factory to display a “welcome” screen when power is applied. This command can be used to customize the “welcome” screen, as well as the following items:

- Characters shown on LCD, which are affected by:
  - Command 6 (0x06): Clear LCD Screen.
  - Command 7 (0x07): Set LCD Contents, Line 1.
  - Command 8 (0x08): Set LCD Contents, Line 2.
  - Command 31 (0x1F): Send Data to LCD.
- Special character font definitions (Command 9 (0x09): Set LCD Special Character Data).
- Cursor position (Command 11 (0x0B): Set LCD Cursor Position).
- Cursor style (Command 12 (0x0C): Set LCD Cursor Style).
- Contrast setting (Command 13 (0x0D): Set LCD Contrast).
- LCD backlight setting (Command 14 (0x0E): Set LCD & Keypad Backlight).

- Settings of any “live” displays (Command 21 (0x15): Set Up Temperature Display).
- Key press and release masks (Command 23 (0x17): Configure Key Reporting).
- ATX function enable and pulse length settings (command 28 (0x1C): Set ATX Power Switch).
- Baud rate (Command 33 (0x21): Set Baud Rate).
- GPIO settings (Command 34 (0x22): Set or Set and Configure GPIO Pins).

You cannot store the temperature reporting (although the live display of temperatures can be saved). You cannot store the host watchdog. The host software should enable this item once the system is initialized and it is ready to receive the data.

```
type: 0x04 = 4(10)
valid data_length is 0
```

The return packet will be:

```
type: 0x40 | 0x04 = 0x44 = 68(10)
data_length = 0
```

If the current state and the boot state do not match after saving, the module will return an error instead of an ACK. In this unlikely error case, the boot state will be undefined.

5 (0x05): Reboot CFA533, Reset Host, or Power Off Host

This command instructs the CFA533 to simulate a power-on restart of itself, reset the host, or turn the host's power off. The ability to reset the host may be useful to allow certain host operating system configuration changes to complete. The ability to turn the host's power off under software control may be useful in systems that do not have ACPI compatible BIOS.

> The GPIO pins used for ATX control must not be configured as user GPIO, and must be configured to their default drive mode in order for the ATX functions to work correctly. These settings are factory default, but may be changed by the user, see command 34 (0x22): Set or Set and Configure GPIO Pins.

Rebooting the CFA533 may be useful when testing the boot configuration. It may also be useful to re-enumerate the devices (WR-DOW-Y17 temperature sensors), on the One-Wire bus. To reboot the CFA533, send the following packet:

```
type: 0x05 = 5(10)
valid data_length is 3
data[0] = 8
data[1] = 18
data[2] = 99
```

To reset the host, assuming the host's reset line is connected to GPIO[3] as described in command 28 (0x1C): Set ATX Power Switch Functionality, send the following packet:

```
type: 0x05 = 5(10)
valid data_length is 3
data[0] = 12
data[1] = 28
data[2] = 97
```

To turn the host's power off, assuming the host's power control line is connected to GPIO[2] as described in command 28 (0x1C): Set ATX Power Switch Functionality, send the following packet:

```
type: 0x05 = 5₁₀
valid data_length is 3
data[0] = 3
data[1] = 11
data[2] = 95
```

In any of the above cases, the return packet will be:

```
type: 0x40 | 0x05 = 0x45 = 69₁₀
data_length = 0
```

6 (0x06): Clear LCD Screen

Sets the contents of the LCD screen DDRAM to ' ' = 0x20 = 32_{10} and moves the cursor to the left-most column of the top line.

```
type: 0x06 = 6₁₀
valid data_length is 0
```

The return packet will be:

```
type: 0x40 | 0x06 = 0x46 = 70₁₀
data_length = 0
```

Clear LCD Screen changes the LCD. The LCD contents is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

7 (0x07): Set LCD Contents, Line 1

Sets the center 16 characters displayed for the top line of LCD screen.

> Please use this command only if you need backwards compatibility with older CFA533 units. For new applications, please use the more flexible command 31 (0x1F): Send Data to LCD.

```
type: 0x7 = 7₁₀
 valid data_length is 16
 data[] = top line's display content (must supply 16 bytes)
```

The return packet will be:

```
type: 0x40 | 0x07 = 0x47 = 71₁₀
data_length = 0
```

Set LCD Contents, Line 1 is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

8 (0x08): Set LCD Contents, Line 2

Sets the center 16 characters displayed for the bottom line of LCD screen.

> Please use this command only if you need backwards compatibility with older CFA533 units. For new applications, please use the more flexible command 31 (0x1F): Send Data to LCD.

```
type: 0x8 = 8₁₀
 valid data_length is 16
 data[] = bottom line's display content (must supply 16 bytes)
```

The return packet will be:

```
type: 0x40 | 0x08 = 0x48 = 72(10)
data_length = 0
```

Set LCD Contents, Line 2 is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

9 (0x09): Set LCD Special Character Data

Sets the font definition for one of the special characters (CGRAM).

```
type: 0x09 = 9(10)
valid data_length is 9
data[0] = index of special character that you would like to modify, 0-
7 are valid  data[1-8] = bitmap of the new font for this character
```

data[1-8] are the bitmap information for this character. Any value is valid between 0 and 63, the msb is at the left of the character cell of the row, and the lsb is at the right of the character cell.

data[1] is at the top of the cell.
data[8] is at the bottom of the cell.

The return packet will be:

```
type: 0x40 | 0x09 = 0x49 = 73(10)
data_length = 0
```

Set LCD Special Character Data is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

10 (0x0A): Read 8 Bytes of LCD Memory

This command will return the contents of the LCD's DDRAM or CGRAM. This command is intended for debugging.

```
type: 0x0A = 10(10)
valid data_length is 1
data[0] = address code of desired data
```

data[0] is the address code native to the LCD controller:

```
      0x40 (\064) to 0x7F (\127) for CGRAM
      0x80 (\128) to 0x93 (\143) for DDRAM, line 1
      0xC0 (\192) to 0xD3 (\207) for DDRAM, line 2
```

The return packet will be:

```
type: 0x40 | 0x0A = 0x4A = 74(10)
data_length = 9
```

data[0] of the return packet will be the address code.

data[1-8] of the return packet will be the data read from the LCD controller's memory.

11 (0x0B): Set LCD Cursor Position

This command allows the cursor to be placed at the desired location on the CFA533's LCD screen. If you want the cursor to be visible, you may also need to send a command 12 (0x0C): Set LCD Cursor Style.

```
type: 0x0B = 11(10) valid
data_length is 2
data[0] = column (0-15 valid)
data[1] = row (0-1 valid)
```

The return packet will be:

```
type: 0x40 | 0x0B = 0x4B = 75(10)
data_length = 0
```

Set LCD Cursor Position is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

12 (0x0C): Set LCD Cursor Style

This command allows you to select among four hardware generated cursor options.

```
type: 0x0C = 12(10) valid
data_length is 1
data[0] = cursor style (0-3 valid)
        0 = no cursor.
        1 = blinking block cursor.
        2 = static underscore cursor.
        3 = blinking underscore cursor.
        (Note for 3: This behavior is different from the previous CFA633 series
        which is: blinking block plus underscore.)
```

The return packet will be:

```
type: 0x40 | 0x0C = 0x4C = 76(10)
data_length = 0
```

Set LCD Cursor Style is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

13 (0x0D): Set LCD Contrast

This command sets the contrast or vertical viewing angle of the display. Initiated by the host, responded to by the CFA533.

- CFA633 Compatible
  If only one byte of data is supplied, then it is the "CFA633 Compatible" version of the command. Requires 1 byte (0-200) are valid, but only (0-50) are useful for this LCD.

```
type: 0x0D = 13(10) valid
data_length is 1
data[0] = contrast setting (0-50 valid)
 0 = light
16 = about right
29 = dark
30-50 = very dark
```

The return packet will be:

```
type = 0x40 | 0x0D = 0x4D = 77(10)
data_length = 0
```

- CFA533 Enhanced
  If two bytes of data are supplied, then the command takes advantage of the CFA533's native enhanced contrast resolution. Requires 2 bytes.
    - The first byte data[0] is ignored, any value from 0 to 255 is accepted.
    - The second byte data[1] controls the CFA533 contrast with better resolution.

Set LCD Contrast is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

14 (0x0E): Set LCD & Keypad Backlight

This command sets the brightness of the LCD and keypad backlights.

- If one byte is supplied, both the keypad and LCD backlights are set to that brightness (CFA633 compatible).

```
type: 0x0E = 14(10)
valid data_length is 1
data[0] = keypad and LCD backlight power setting (0-100 valid)
          0 = off
      1-100 = variable brightness
```

- If two bytes are supplied, the LCD is set to the brightness of the first byte, the keypad is set to the brightness of the second byte.

```
type: 0x0E = 14(10)
valid data_length is 2
data[0]: LCD backlight power setting (0-100 valid)
          0 = off
    1-100 = variable brightness
data[1]: keypad backlight power setting (0-100 valid)
          0 = off
    1-100 = variable brightness
```

The return packet will be:

```
type: 0x40 | 0x0E = 0x4E = 78(10)
data_length = 0
```

Set LCD & Keypad Backlight is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

15 (0x0F-0x11): (Reserved)

18 (0x12): Read DOW Device Information

When power is applied to the CFA533, it detects any devices (WR-DOW-Y17 temperature sensors) connected to the Dallas Semiconductor One-Wire (DOW) bus and stores the device's information. This command will allow the host to read the device's information.

The first byte returned is the Family Code of the Dallas One-Wire / iButton device. For a list of the possible Dallas One-Wire / iButton device family codes available go to App Note 155: 1-Wire Software Resource Guide on the Maxim/Dallas website.

REGARDING COMMAND 18: READ DOW DEVICE INFORMATION

The GPIO pin used for DOW must not be configured as user GPIO. It must be configured to its default drive mode in order for the DOW functions to work correctly.

These settings are factory default but may be changed by the user, please see command 34 (0x22): Set or Set and Configure GPIO Pins.

In order for the DOW subsystem to be enabled and operate correctly, user GPIO[4] must be configured as:

```
DDD = "111: 1=Hi-Z, 0=Slow, Strong Drive Down".
F = "0: Port unused for user GPIO."
```

This state is the factory default, but it can be changed and saved by the user. To ensure that GPIO[4] is set correctly and the DOW operation is enabled, send the following command:

```
command = 34
length = 3
data[0] = 4
data[1] = 100
data[2] = 7
```

This setting must be saved as the boot state, so when the CFA533 reboots it will detect the DOW devices.

```
type: 0x12 = 18(10)
valid data_length is 1
data[0] = device index (0-31 valid)
```

The return packet will be:

```
type: 0x40 | 0x12 = 0x52 = 82(10)
data_length = 9
data[0] = device index (0-31 valid)
data[1-8] = ROM ID of the device
```

If **data[1]** is 0x22 (DS1822 Econo 1-Wire Digital Thermometer temperature sensor) or 0x28 (DS18B20 High Precision 1-Wire Digital Thermometer temperature sensor used on our WR-DOW-Y17), then that device can be set up to automatically convert and report the temperature every second. See the command 19 (0x13): Set Up Temperature Reporting.

19 (0x13): Set Up Temperature Reporting

This command will configure the CFA533 to report the temperature information to the host every second.

```
type: 0x13 = 19(10)
valid data_length is 4
data[0-3] = 32-bit bitmask indicating which temperature sensors are enabled to
report (0-255 valid in each location)
data[0]
08 07 06 05   04 03  02 01  Enable Reporting of sensor with
|  |  |  |    |  |   |  |   device index of:
|  |  |  |    |  |   |  |--  0: 1 = enable, 0 = disable
|  |  |  |    |  |   |-----  1: 1 = enable, 0 = disable
|  |  |  |    |  |---------  2: 1 = enable, 0 = disable
|  |  |  |    |------------  3: 1 = enable, 0 = disable
|  |  |  |------------------  4: 1 = enable, 0 = disable
|  |  |--------------------  5: 1 = enable, 0 = disable
|  |-----------------------  6: 1 = enable, 0 = disable
|--------------------------  7: 1 = enable, 0 = disable

data[1]
16 15 14 13   12 11  10 09  Enable Reporting of sensor with
|  |  |  |    |  |   |  |   device index of:
|  |  |  |    |  |   |  |--  8: 1 = enable, 0 = disable
|  |  |  |    |  |   |-----  9: 1 = enable, 0 = disable
|  |  |  |    |  |---------  10: 1 = enable, 0 = disable
|  |  |  |    |------------  11: 1 = enable, 0 = disable
|  |  |  |------------------  12: 1 = enable, 0 = disable
|  |  |--------------------  13: 1 = enable, 0 = disable
|  |-----------------------  14: 1 = enable, 0 = disable
|--------------------------  15: 1 = enable, 0 = disable

data[2]
24 23 22 21   20 19  18 17  Enable Reporting of sensor with
|  |  |  |    |  |   |  |   device index of:
|  |  |  |    |  |   |  |--  16: 1 = enable, 0 = disable
|  |  |  |    |  |   |-----  17: 1 = enable, 0 = disable
|  |  |  |    |  |---------  18: 1 = enable, 0 = disable
|  |  |  |    |------------  19: 1 = enable, 0 = disable
|  |  |  |------------------  20: 1 = enable, 0 = disable
|  |  |--------------------  21: 1 = enable, 0 = disable
|  |-----------------------  22: 1 = enable, 0 = disable
|--------------------------  23: 1 = enable, 0 = disable

data[3]
32 31 30 29   28 27  26 25  Enable Reporting of sensor with
|  |  |  |    |  |   |  |   device index of:
|  |  |  |    |  |   |  |--  24: 1 = enable, 0 = disable
|  |  |  |    |  |   |-----  25: 1 = enable, 0 = disable
|  |  |  |    |  |---------  26: 1 = enable, 0 = disable
|  |  |  |    |------------  27: 1 = enable, 0 = disable
|  |  |  |------------------  28: 1 = enable, 0 = disable
|  |  |--------------------  29: 1 = enable, 0 = disables
|  |-----------------------  30: 1 = enable, 0 = disable
|--------------------------  31: 1 = enable, 0 = disable
```

Any sensor enabled must have been detected as a 0x22 (DS1822 temperature sensor) or 0x28 (DS18B20 temperature sensor) during DOW enumeration. This can be verified by using the command 18 (0x12): Read DOW Device Information.

The return packet will be:

```
type: 0x40 | 0x13 = 0x53 = 83(10)
data_length = 0
```

20 (0x14): Arbitrary DOW Transaction

The CFA533 can function as an RS-232 to Dallas 1-Wire bridge. The CFA533 can send up to 15 bytes and receive up to 14 bytes. This will be sufficient for many devices, but some devices require larger transactions and cannot be fully used with the CFA533.

This command allows you to specify arbitrary transactions on the 1-Wire bus. 1-Wire commands follow this basic layout:

```
<bus reset       //Required
<address_phase> //Must be "Match ROM" or "Skip ROM"
<write_phase>    //optional, but at least one of write_phase or read_phase must be sent
<read_phase>     //optional, but at least one of write_phase or read_phase must be sent
```

```
type: 0x14 = 20(10)
valid data_length is 2 to 16 data[0] = device_index (0-32 valid)
data[1] = number_of_bytes_to_read (0-14 valid)
data[2-15] = data_to_be_written[data_length-2]
```

If **device_index** is 32, then no address phase will be executed. If **device_index** is in the range of 0 to 31, and a One-Wire device was detected for that **device_index** at power on, then the write cycle will be prefixed with a "Match ROM" command and the address information for that device.

If **data_length** is two, then no specific write phase will be executed (although address information may be written independently of **data_length** depending on the value of **device_index**).

If **data_length** is greater than two, then **data_length-2** bytes of **data_to_be_written** will be written to the One-Wire bus immediately after the address phase.

If **number_of_bytes_to_read** is zero, then no read phase will be executed. If **number_of_bytes_to_read** is not zero, then **number_of_bytes_to_read** will be read from the bus and loaded into the response packet.

The return packet will be:

```
type: 0x40 | 0x14 = 0x54 = 84(10)
data_length = 2 to 16
data[0] = device index (0-31 valid)
data[data_length-2] = Data read from the 1-Wire bus. This is the same
                      as number_of_bytes_to_read from the command.
data[data_length-1] = 1-Wire CRC
```

21 (0x15): Set Up Live Temperature Display

You can configure the CFA533 to automatically update a portion of the LCD with a “live” temperature reading. Once the display is configured using this command, the CFA533 will continue to display the live reading on the LCD without host intervention. The Set Up Live Temperature Display is one of the items stored by command 4 (0x04): Store Current State as Boot State, so you can configure the CFA533 to immediately display system temperatures as soon as power is applied.

The live display is based on a concept of display slots. There are 8 slots, and each of the 8 slots may be enabled or disabled independently.

Any slot may be requested to display any data that is available. For instance, slot 0 could display temperature sensor 3 in °C, while slot 1 could simultaneously display temperature sensor 3 in °F.

Any slot may be positioned at any location on the LCD, as long as all the digits of that slot fall fully within the display area. It is legal to have the display area of one slot overlap the display area of another slot, but senseless. This situation should be avoided in order to have meaningful information displayed

```
type: 0x15 = 21(10)
valid data_length is 7 or 2 (for turning a slot off)
data[0]: display slot (0-7)
data[1]: type of item to display in this slot
          0 = nothing (data_length then must be 2)
2 = temperature (data_length then must be 7)
data[2]:  index of the sensor to display in this slot:
          0-31 are valid for temperatures (and the temperature
               device must be attached)
data[3]: number of digits
          for a temperature: 3 digits (  -XX or   XXX)
          for a temperature: 5 digits (-XX.X or XXX.X)
data[4]: display column
          0-13 valid for a 3-digit temperature
          0-11 valid for a 5-digit temperature  data[5]:
display row (0-1 valid)
data[6]: pulses_per_revolution or temperature units
          for a temperature: units (0 = deg C, 1 = deg F)
```

If a One-Wire CRC error is detected, the temperature will be displayed as "ERR" or "ERROR".

The return packet will be:

```
type: 0x40 | 0x15 = 0x55 = 85(10)
data_length = 0
```

22 (0x16): Send Command Directly to the LCD Controller

The controller on the CFA533 is HD44780 compatible. Generally, you will not need low-level access to the LCD controller but some arcane functions of the HD44780 are not exposed by the CFA533's command set. This command allows you to access the CFA533's LCD controller directly.

IMPORTANT: It is possible to corrupt the CFA533 display using this command.

```
type: 0x16 = 22(10)
data_length: 2
data[0]: location code
       0 = "Data" register
       1 = "Control" register
data[1]: data to write to the selected register
```

The return packet will be:

```
type: 0x40 | 0x16 = 0x56 = 86(10)
data_length = 0
```

23 (0x17): Configure Key Reporting

By default, the CFA533 reports any key event to the host. This command allows the key events to be enabled or disabled on an individual basis. The key events set to report are one of the items stored by the command 4 (0x04): Store Current State as Boot State.

```
#define KP_UP     0x01
#define KP_ENTER  0x02
#define KP_CANCEL 0x04
#define KP_LEFT   0x08
#define KP_RIGHT  0x10
#define KP_DOWN   0x20

type: 0x17 = 23₁₀
data_length = 2
data[0]: press mask
data[1]: release mask
```

The return packet will be:

```
type: 0x40 | 0x17 = 0x57 = 87₁₀
data_length = 0
```

Configure Key Reporting is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

24 (0x18): Read Keypad, Polled Mode

In some situations, it may be convenient for the host to poll the CFA533 for key activity. This command allows the host to detect which keys are currently pressed, which keys have been pressed since the last poll, and which keys have been released since the last poll.

This command is independent of the key reporting masks set by command 23 (0x17): Configure Key Reporting. All keys are always visible to this command. Typically, both masks of command 23 would be set to "0" if the host is reading the keypad in polled mode.

```
#define KP_UP     0x01
#define KP_ENTER  0x02
#define KP_CANCEL 0x04
#define KP_LEFT   0x08
#define KP_RIGHT  0x10
#define KP_DOWN   0x20

type: 0x18 = 24₁₀
data_length = 0
```

The return packet will be:

```
type: 0x40 | 0x18 = 0x58 = 88₁₀
data_length = 3
data[0] = bit mask showing the keys currently pressed
data[1] = bit mask showing the keys that have been pressed since
          the last poll
data[2] = bit mask showing the keys that have been released since
          the last poll
```

25 (0x19-0x1B): Reserved

28 (0x1C): Set ATX Power Switch Functionality

The combination of the CFA533 with the Crystalfontz WR-PWR-Y14 cable can be used to replace the function of the power and reset switches in a standard ATX-compatible system. The ATX Power Switch Functionality is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

REGARDING COMMAND 28: SET ATX SWITCH FUNCTIONALITY

The GPIO pins used for ATX control must not be configured as user GPIO. The pins must be configured to their default drive mode in order for the ATX functions to work correctly.

These settings are factory default but may be changed by the user. Please see command 34 (0x22): Set or Set and Configure GPIO Pins. These settings must be saved as the boot state.

To ensure that GPIO[1] will operate correctly as ATX SENSE, user GPIO[1] must be configured as:

```
DDD = "011: 1=Resistive Pull Up, 0=Fast, Strong Drive Down". F = "0:
Port unused for user GPIO."
```

This configuration can be assured by sending the following command:

```
command = 34
length = 3
data[0] = 1
data[1] = 0
data[2] = 3
```

To ensure that GPIO[2] will operate correctly as ATX POWER, user GPIO[2] must be configured as:

DDD = "010: Hi-Z, use for input".

F = "0: Port unused for user GPIO."

This configuration can be assured by sending the following command:

```
command = 34
length = 3
data[0] = 2
data[1] = 0
data[2] = 2
```

To ensure that GPIO[3] will operate correctly as ATX RESET, user GPIO[3] must be configured as:

DDD = "010: Hi-Z, use for input".

F = "0: Port unused for user GPIO."

This configuration can be assured by sending the following command:

```
command = 34
length = 3
data[0] = 3
data[1] = 0
data[2] = 2
```

These settings must be saved as the boot state.

The RESET (GPIO[3]) and POWER CONTROL (GPIO[2]) lines on the CFA533 are normally high-impedance. Electrically, they appear to be disconnected or floating. When the CFA533 asserts the RESET or POWER CONTROL lines, they are momentarily driven high or low (as determined by the AUTO_POLARITY, RESET_INVERT or POWER_INVERT bits, detailed below). To end the power or reset pulse, the CFA533 changes the lines back to high-impedance.

Four Functions may be Enabled by Command 28

Function 1: KEYPAD_RESET

If POWER-ON SENSE (GPIO[1]) is high, holding the green check key for 4 seconds will pulse RESET (GPIO[3]) pin for 1 second. During the 1-second pulse, the CFA533 will show "RESET", and then the CFA533 will reset itself, showing its boot state as if it had just powered on. Once the pulse has finished, the CFA533 will not respond to any commands until after it has reset the host and itself.

Function 2: KEYPAD_POWER_ON

If POWER-ON SENSE (GPIO[1]) is low, pressing the green check key for 0.25 seconds will pulse POWER CONTROL (GPIO[2]) for the duration specified by in data[1] or the default of 1 second. During this time the CFA533 will show "POWER ON", then the CFA533 will reset itself.

Function 3: KEYPAD_POWER_OFF

If POWER-ON SENSE (GPIO[1]) is high, holding the red X key for 4 seconds will pulse POWER CONTROL (GPIO[2]) for the duration specified by in data[1] or the default of 1 second. If the user continues to hold the power key down, then the CFA533 will continue to drive the line for a maximum of 5 additional seconds. During this time the CFA533 will show "POWER OFF".

Function 4: LCD_OFF_IF_HOST_IS_OFF

If LCD_OFF_IF_HOST_IS_OFF is set, the CFA533 will blank its screen and turn off its backlight to simulate its power being off any time POWER-ON SENSE is low.

> By default, there is an internal POWER-ON-SENSE connected to the +5v pin of J_PWR, selected by setting data [2] to 1. Alternatively, GPIO[1] may be configured to act as POWER-ON-SENSE through R21 of 5K, and specifying data[2] as 0. The CFA533 will still be active (since it is powered by VSB, standby power which is always-on), monitoring the keypad for a power-on keystroke. Once POWER- ON SENSE goes high, the CFA533 will reboot as if power had just been applied to it.

```
#define AUTO_POLARITY              0x01 //Automatically detects polarity for reset
                                        and//power (recommended)
#define RESET_INVERT               0x02 //Reset pin drives high instead of low
#define POWER_INVERT               0x04 //Power pin drives high instead of low
#define LCD_OFF_IF_HOST_IS_OFF     0x10
#define KEYPAD_RESET               0x20
#define KEYPAD_POWER_ON            0x40
#define KEYPAD_POWER_OFF           0x80

type: 0x1C = 28(10)
data_length: 1 or 2
data[0]: bit mask of enabled functions
data[1]: (optional) length of power on & off pulses in 1/32 second
       1 = 1/32 sec
       2 = 1/16 sec
      16 = 1/2 sec
     254 = 7.9 seconds
     255 = Assert power control line until host power state changes
```

The return packet will be:

```
type: 0x40 | 0x1C = 0x5C = 92(10)
data_length: 0
```

29 (0x1D): Enable/Disable and Reset the Watchdog

Some high-availability systems use hardware watchdog timers to ensure that a software or hardware failure does not result in an extended system outage. Once the host system has booted, a system monitor program is started. The system monitor program would enable the watchdog timer on the CFA533. If the system monitor program fails to reset the CFA533's watchdog timer, the CFA533 will reset the host system.

> The GPIO pins used for ATX control must not be configured as user GPIO. They must be configured to their default drive mode in order for the ATX functions to work correctly. These settings are factory default, but may be changed by the user. See the note under command 28 (0x1C): Set ATX Power Switch Functionality or command 34 (0x22): Set or Set and Configure GPIO Pins.

```
type: 0x1D = 29(10)
data_length = 1
data[0] = enable/timeout

If timeout is 0, the watchdog is disabled.

If timeout is 1-255, then this command must be issued again within timeout seconds to
avoid a watchdog reset.

To turn the watchdog off once it has been enabled, simply set timeout to 0.

If the command is not re-issued within timeout seconds, then the CFA533 will reset
the host (see command 28 for details). Since the watchdog is off by default when the
CFA533 powers up, the CFA533 will not issue another host reset until the host has
once again enabled the watchdog.
```

The return packet will be:

```
type: 0x40 | 0x1D = 0x5D = 93(10)
data_length = 0
```

30 (0x1E): Read Reporting & Status

This command can be used to verify the current items configured to report to the host, as well as some other miscellaneous status information. Please note that the information returned by other modules is not identical to this.

```
type = 0x1E = 30
data_length = 0
```

The return packet will be:

```
type = 0x40 | 0x1E = 0x5E = 94(10)
data_length = 15
data[0] = reserved
data[1] = temperatures 1-8 reporting status (as set by command 19)
data[2] = temperatures 9-15 reporting status (as set by command 19)
data[3] = temperatures 16-23 reporting status (as set by command 19)
data[4] = temperatures 24-32 reporting status (as set by command 19)
data[5] = key presses (as set by command 23)
data[6] = key releases (as set by command 23)
data[7] = ATX Power Switch Functionality (as set by command 28)
data[8] = current watchdog counter (as set by command 29)
data[9] = User Contrast Adjust[0] (as set by command 13, data[1])
data[10] = Key backlight setting (as set by command 14, data[1])
data[11] = atx sense on floppy (as set by command 28)
data[12] = 0 (reserved)
data[13] = CFA633-style contrast setting (as set by command 13,data[0])
data[14] = LCD backlight setting (as set by command 14, data[0])
```

NOTE: Previous and future firmware versions may return fewer or additional bytes.

31 (0x1F): Send Data to LCD

This command allows data to be placed at any position on the LCD.

```
type: 0x1F = 31(10)
data_length = 3 to 18
data[0]: col = x = 0 to 15
data[1]: row = y = 0 to 1
data[2-21]: text to place on the LCD, variable from 1 to 16 characters
```

The return packet will be:

```
type: 0x40 | 0x1F = 0x5F = 95(10)
data_length = 0
```

Send Data to LCD is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

32 (0x20): Reserved for CFA631 Key Legends

33 (0x21): Set Baud Rate

This command will change the CFA533's baud rate. The CFA533 will send the acknowledge packet for this command and change its baud rate to the new value. The host should send the baud rate command, wait for a positive acknowledge from the CFA533 at the old baud rate, and then switch itself to the new baud rate. The baud rate must be saved by the command 4 (0x04): Store Current State as Boot State if you want the CFA533 to power up at the new baud rate.

The factory default baud rate is 19200.

```
type: 0x21 = 33(10)
data_length = 0
data[0]: 0 = 19200 baud
         1 = 115200 baud
```

The return packet will be:

```
type: 0x40 | 0x21 = 0x61 = 97(10)
data_length = 0
```

34 (0x22): Set or Set and Configure GPIO Pins

The CFA533 (hardware versions v1.4 and up, firmware versions 1.9 and up) has five pins for user-definable general purpose input / output (GPIO). These pins are shared with the DOW and ATX functions. Be careful when you configure the GPIO if you want to use the ATX or DOW at the same time.

The architecture of the CFA533 allows great flexibility in the configuration of the GPIO pins. They can be set as input or output. They can output constant high or low signals or a variable duty cycle 100 Hz PWM signal.

In output mode using the PWM (and a suitable current limiting resistor), an LED may be turned on or off and even dimmed under host software control. With suitable external circuitry, the GPIOs can also be used to drive external logic or power transistors.

The CFA533 continuously polls the GPIOs as inputs at 32 Hz. The present level can be queried by the host software at a lower rate. The CFA533 also keeps track of whether there were rising or falling edges since the last host query (subject to the resolution of the 32 Hz sampling). This means that the host is not forced to poll quickly in order to detect short events. The algorithm used by the CFA533 to read the inputs is inherently "bounce-free".

The GPIOs also have “pull-up” and “pull-down” modes. These modes can be useful when using the GPIO as an input connected to a switch since no external pull-up or pull-down resistor is needed. For instance, the GPIO can be set to pull up. Then when a switch connected between the GPIO and ground is open, reading the GPIO will return a "1". When the switch is closed, the input will return a "0".

Pull-up/pull-down resistance values are approximately 5kΩ. Do not exceed current of 25 mA per GPIO.

REGARDING SETTING AND CONFIGURING GPIO PINS

The GPIO pins may also be used for ATX control through header J8 and temperature sensing through the CFA533’s DOW header. By factory default, the GPIO output setting, function, and drive mode are set correctly to enable operation of the ATX and DOW functions. **The GPIO output setting, function, and drive mode must be set to the correct values in order for the ATX and DOW functions to work. Improper use of this command can disable the ATX and DOW functions**. The cfTest may be used to easily check and reset the GPIO configuration to the default state so the ATX and DOW functions will work.

The GPIO configuration is one of the items stored by the command 4 (0x04): Store Current State as Boot State.

```
type: 0x22 = 34(10)
data_length:
  2 bytes to change value only
  3 bytes to change value and configure function and drive mode

data[0]: index of GPIO to modify  0 =
       GPIO[0] = J8, Pin 7
       1 = GPIO[1] = J8, Pin 6 (default is ATX Host Power Sense)
       2 = GPIO[2] = J8, Pin 5 (default is ATX Host Power Control)
       3 = GPIO[3] = J8, Pin 4 (default is ATX Host Reset Control)
       4 = GPIO[4] = J9, Pin 2 (default is DOW I/O--always has 1kΩ hardware
       pull-up)
   5-255 = reserved
```

NOTE: Future versions of this command on future hardware models may accept additional values for data [0], which would control the state of future additional GPIO pins.

```
data[1] = Pin output state (actual behavior depends on drive mode):
       0 = Output set to low
    1-99 = Output duty cycle percentage (100 Hz nominal)
     100 = Output set to high
 101-255 = invalid
data[2] = Pin function select and drive mode (optional, 0-15 valid)
```

```
---- FDDD
|||| ||||-- DDD = Drive Mode (based on output state of 1 or 0)
|||| |      ========================================================
|||| |      000: 1=Fast, Strong Drive Up, 0=Resistive Pull Down
|||| |      001: 1=Fast, Strong Drive Up, 0=Fast, Strong Drive Down
|||| |      010: Hi-Z, use for input
|||| |      011: 1=Resistive Pull Up,     0=Fast, Strong Drive Down
|||| |      100: 1=Slow, Strong Drive Up, 0=Hi-Z
|||| |      101: 1=Slow, Strong Drive Up, 0=Slow, Strong Drive Down
|||| |      110: reserved, do not use
|||| |      111: 1=Hi-Z,                  0=Slow, Strong Drive Down
|||| |
|||| |----- F = Function
||||        ========================================================
||||        0: Port unused for GPIO. It will take on the default
||||           function such as ATX, DOW or unused. The user is
||||           responsible for setting the drive to the correct
||||           value in order for the default function to work
||||           correctly.
||||        1: Port used for GPIO under user control. The user is
||||           responsible for setting the drive to the correct
||||           value in order for the desired GPIO mode to work
||||           correctly.
||||------- reserved, must be 0
```

The return packet will be:

```
type = 0x40 | 0x22 = 0x62 = 98₁₀
data_length = 0
```

35 (0x23): Read GPIO Pin Levels and Configuration State

See command 34 (0x22): Set or Set and Configure GPIO Pins for details on the GPIO architecture.

```
type: 0x23 = 35₁₀
data_length: 1
data[0]: index of GPIO to query
       0 = GPIO[0] = J8, Pin 7
       1 = GPIO[1] = J8, Pin 6 (default is ATX Host Power Sense)
       2 = GPIO[2] = J8, Pin 5 (default is ATX Host Power Control)
       3 = GPIO[3] = J8, Pin 4 (default is ATX Host Reset Control)
       4 = GPIO[4] = J9, Pin 2 (default is DOW I/O--always has 1KΩ hardware
          pull-up on SCAB.)
  5-255 = reserved
```

NOTE: Future versions of this command on future hardware models may accept additional values for data [0], which would return the status of future additional GPIO pins.

The return packet will be:

```
type = 0x40 | 0x23 = 0x63 = 99₁₀
data_length = 4
returns:
  data[0] = index of GPIO read
  data[1] = Pin state & changes since last poll

    ---- -RFS Enable Reporting of this Fan's Tach Input
    |||| ||||-- S = state at the last reading
    |||| |||--- F = at least one falling edge has
    |||| ||         been detected since the last poll
    |||| ||---- R = at least one rising edge has
    |||| |          been detected since the last poll
    |||| |----- reserved

        (This reading is the actual pin state, which may or may not agree with
   the pin setting, depending on drive mode and the load presented by external
   circuitry. The pins are polled at approximately 32 Hz asynchronously with
   respect to this command. Transients that happen between polls will not be
   detected.)
  data[2] = Requested Pin level/PWM level
      0-100: Output duty cycle percentage
          (This value is the requested PWM duty cycle. The actual pin may or
   may    not be toggling in agreement with this value, depending on the drive
   mode   and the load presented by external circuitry)
  data[3] = Pin function select and drive mode
    ---- FDDD
    |||| ||||-- DDD = Drive Mode
    |||| |      ========================================================
    |||| |      000: 1=Fast, Strong Drive Up, 0=Resistive Pull Down
    |||| |      001: 1=Fast, Strong Drive Up, 0=Fast, Strong Drive Down
    |||| |      010: Hi-Z, use for input
    |||| |      011: 1=Resistive Pull Up,     0=Fast, Strong Drive Down
    |||| |      100: 1=Slow, Strong Drive Up, 0=Hi-Z
    |||| |      101: 1=Slow, Strong Drive Up, 0=Slow, Strong Drive Down
    |||| |      110: reserved
    |||| |      111: 1=Hi-Z,                  0=Slow, Strong Drive Down
    |||| |
    |||| |----- F = Function
    ||||        ========================================================
    ||||        0: Port unused for GPIO. It will take on the default
    ||||           function such as ATX, DOW or unused. The user is
    ||||           responsible for setting the drive to the correct
    ||||           value in order for the default function to work
    ||||           correctly.
    ||||        1: Port used for GPIO under user control. The user is
    ||||           responsible for setting the drive to the correct
    ||||           value in order for the desired GPIO mode to work
    ||||           correctly.
    ||||------- reserved, will return 0
```

10. Character Generator ROM (CGROM)

To find the code for a given character, add the two numbers that are shown in bold for its row and column. For example, the Greek letter "β" is in the column labeled “224d” and in the row labeled “2d”. Add 224 + 2 to get 226. When you send a byte with the value of 226 to the display, the Greek letter "β" will be shown.

Figure 14: Character Generator ROM (CGROM)

11. LCD Module Reliability and Longevity

We work to continuously improve our products, including backlights that are brighter and last longer. Slight color variations from module to module and batch to batch are normal. ***If you need modules with consistent color, please ask for a custom order.***

ITEM	SPECIFICATION	
LCD portion (excluding Keypad and Backlights)	50,000 to 100,000 hours (typical)	
Keypad	1,000,000 keystrokes	
White LED Display and Blue LED Keypad Backlights **NOTE**: We recommend that the backlight of the white LED backlit modules be dimmed or turned off during periods of inactivity to conserve the white LED backlight lifetime.	Power-On Hours	% of Initial Brightness
	<10,000	>90%
	<50,000	>50%

11.1. Module Longevity (EOL / Replacement Policy)

Crystalfontz is committed to making all of our LCD modules available for as long as possible. For each module that we introduce, we intend to offer it indefinitely. We do not preplan a module's obsolescence. The majority of modules we have introduced are still available.

We recognize that discontinuing a module may cause problems for some customers. However, rapidly changing technologies, component availability, or low customer order levels may force us to discontinue ("End of Life", EOL) a module. For example, we must occasionally discontinue a module when a supplier discontinues a component or a manufacturing process becomes obsolete. When we discontinue a module, we will do our best to find an acceptable replacement module with the same fit, form, and function.

In most situations, you will not notice a difference when comparing a "fit, form, and function" replacement module to the discontinued module it replaces. However, sometimes a change in component or process for the replacement module results in a slight variation, perhaps an improvement, over the previous design.

Although the replacement module is still within the stated Datasheet specifications and tolerances of the discontinued module, changes may require modification to your circuit and/or firmware. Possible changes include:

- Backlight LEDs. Brightness may be affected (perhaps the new LEDs have better efficiency) or the current they draw may change (new LEDs may have a different VF).
- Controller. A new controller may require minor changes in your code.
- Component tolerances. Module components have manufacturing tolerances. In extreme cases, the tolerance stack can change the visual or operating characteristics.

Please understand that we avoid changing a module whenever possible; we only discontinue a module if we have no other option. We post Part Change Notices (PCN) on the product's website page as soon as possible. If interested, you can subscribe to future Part Change Notices on the product page.

12. Care and Handling Precautions

For optimum operation of the CFA533-TMI-KU and to prolong its life, please follow the precautions described below.

12.1. ESD (Electrostatic Discharge)

This circuitry is industry standard CMOS logic and susceptible to ESD damage. Please use industry standard antistatic precautions as you would for any other static sensitive devices such as expansion cards, motherboards, or integrated circuits. Ground your body, work surfaces, and equipment.

12.2. Design and Mounting

- The exposed surface of the “glass” is actually a polarizer laminated on top of the glass. To protect the soft plastic polarizer from damage, the module ships with a protective film over the polarizer. Please peel off the protective film slowly. Peeling off the protective film abruptly may generate static electricity.
- The polarizer is made out of soft plastic and is easily scratched or damaged. When handling the module, avoid touching the polarizer. Finger oils are difficult to remove.
- CFA533-TMI-KU without Crystalfontz overlay: To protect the soft plastic polarizer from damage, place a transparent plate (for example, acrylic, polycarbonate or glass) in front of the module, leaving a small gap between the plate and the display surface.
- Do not disassemble or modify the module.
- Do not modify the six tabs of the metal bezel or make connections to them.
- Do not reverse polarity to the power supply connections. Reversing polarity will immediately ruin the module.

12.3. Avoid Shock, Impact, Torque, or Tension

- Do not expose the CFA533-TMI-KU to strong mechanical shock, impact, torque, or tension.
- Do not drop, toss, bend, or twist the CFA533-TMI-KU.
- Do not place weight or pressure on the CFA533-TMI-KU.
- If the LCD panel breaks, be careful to not get the liquid crystal fluid in your mouth or eyes. If the liquid crystal fluid touches your skin, clothes, or work surface, wash it off immediately using soap and plenty of water.

12.4. If LCD Panel Breaks

- If the LCD panel breaks, be careful to not get the liquid crystal fluid in your mouth or eyes.
- If the liquid crystal fluid touches your skin, clothes, or work surface, wash it off immediately using soap and plenty of water.

12.5. Cleaning

- The polarizer (laminated to the glass) is soft plastic. The soft plastic is easily scratched or damaged. Be very careful when you clean the polarizer.
- Do not clean the polarizer with liquids. Do not wipe the polarizer with any type of cloth or swab (for example, Q-tips).
- Use the removable protective film to remove smudges (for example, fingerprints) and any foreign matter. If you no longer have the protective film, use standard transparent office tape (for example, Scotch® brand “Crystal Clear Tape”). If the polarizer is dusty, you may carefully blow it off with clean, dry, oil-free compressed air.
- CFA533-TMI-KU without Crystalfontz overlay: The exposed surface of the LCD “glass” is actually the front polarizer laminated to the glass. The polarizer is made out of a fairly soft plastic and is easily scratched or damaged. The polarizer will eventually become hazy if you do not take great care when cleaning it. Long contact with moisture (from condensation or cleaning) may permanently spot or stain the polarizer.

12.6. Operation

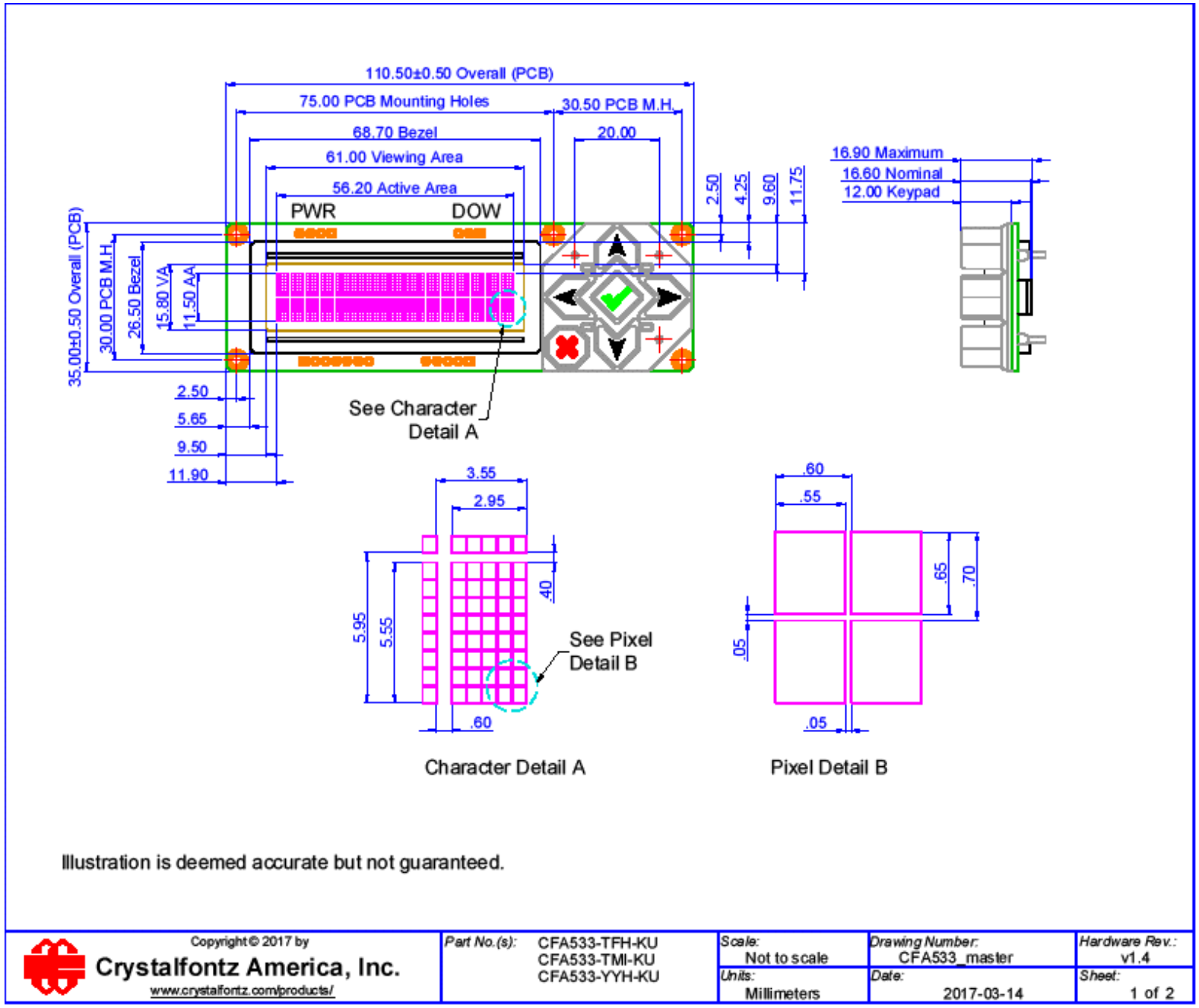
- Your circuit should be designed to protect the CFA533-TMI-KU from ESD and power supply transients.
- Observe the operating temperature limitations: a minimum of -20°C to a maximum of +70°C with minimal fluctuation. Operation outside of these limits may shorten life and/or harm display.
- At lower temperatures of this range, response time is delayed.
- At higher temperatures of this range, display becomes dark. (You may need to adjust the contrast.)
- Operate away from dust, moisture, and direct sunlight.
- Adjust backlight brightness so the display is readable but not too bright. Dim or turn off the backlight during periods of inactivity to conserve the white LED backlight lifetime.

12.7. Storage and Recycling

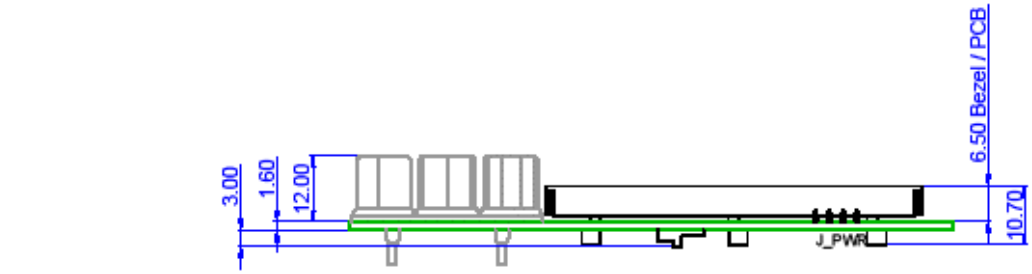
- Store in an ESD-approved container away from dust, moisture, and direct sunlight.
- Observe the storage temperature limitations: -30°C minimum, +80°C maximum with minimal fluctuation. Rapid temperature changes can cause moisture to form, resulting in permanent damage.
- Do not allow weight to be placed on the CFA533-TMI-KU while they are in storage.
- Please recycle your outdated Crystalfontz modules at an approved facility.

13. Mechanical Drawings

CFA533 Module Outline Drawing (1 of 2)



CFA533 Module Outline Drawing (2 of 2)



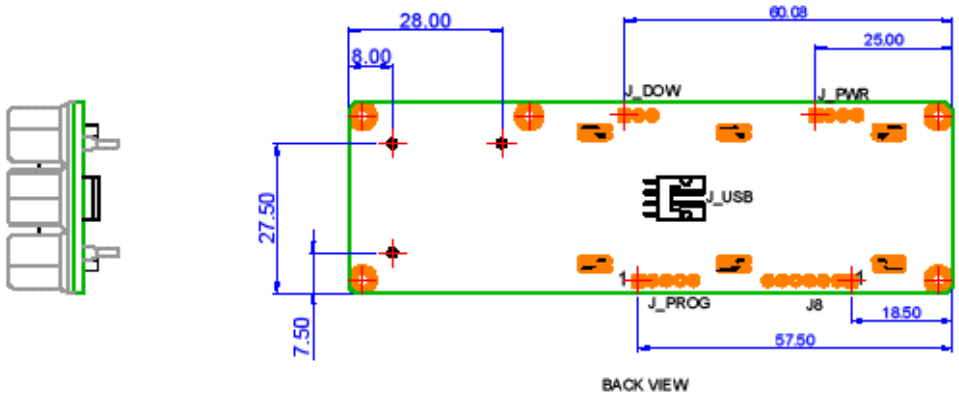


Illustration is deemed accurate but not guaranteed.

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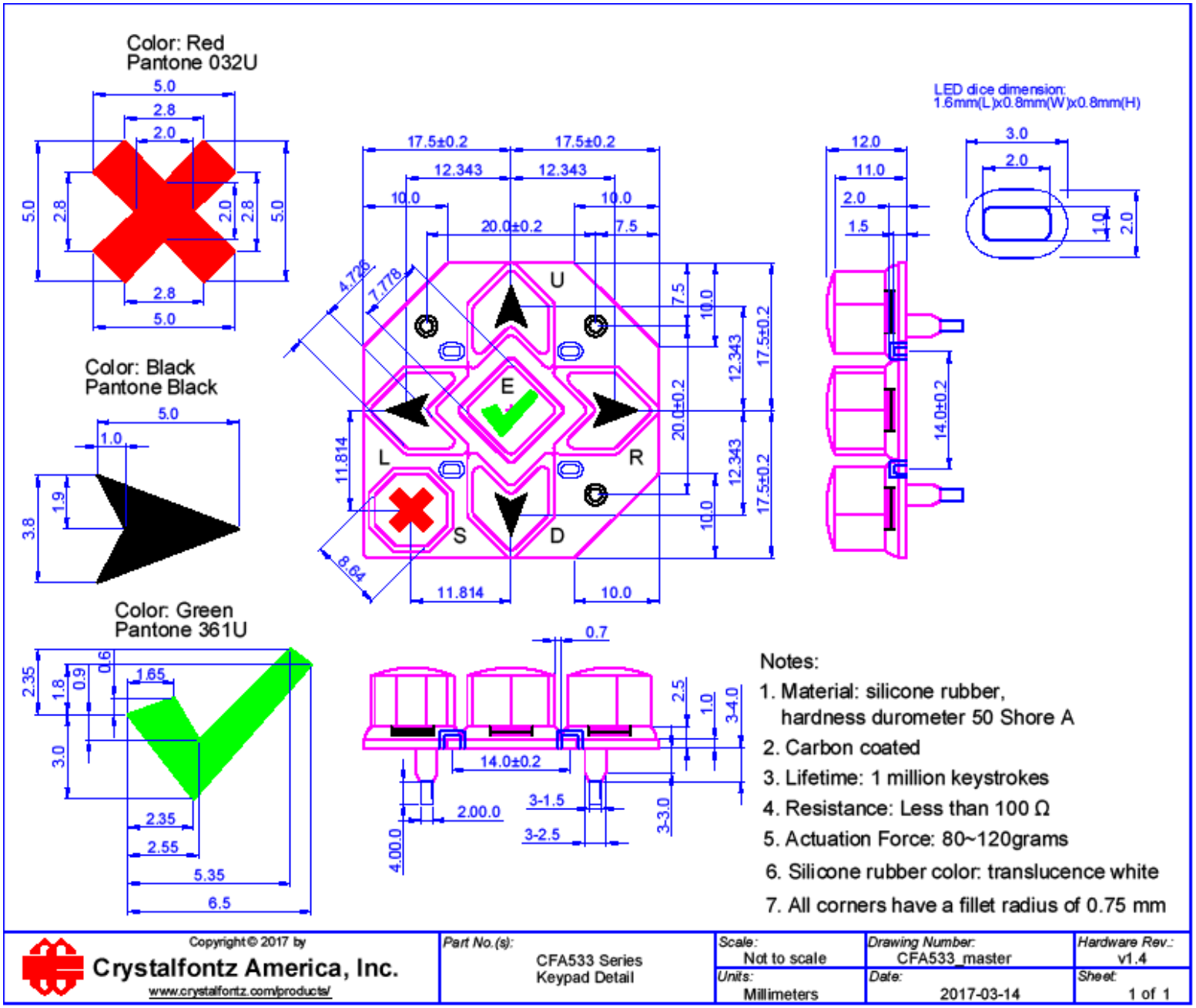
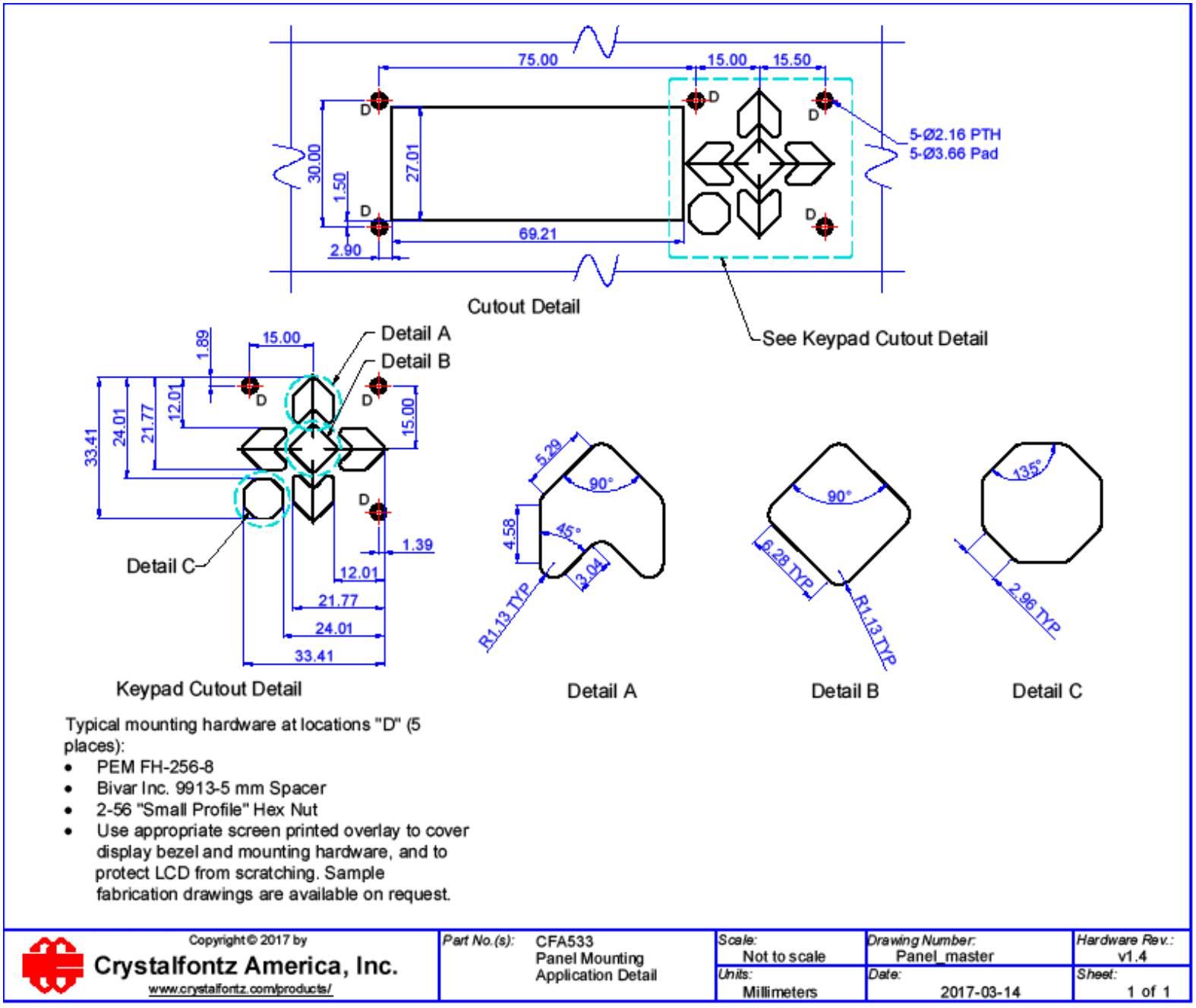
Part No.(s): CFA533-TFH-KU, CFA533-TMI-KU, CFA533-YYH-KU	Scale: Not to scale	Drawing Number: CFA533_master	Hardware Rev.: v1.4
	Units: Millimeters	Date: 2017-03-14	Sheet: 2 of 2

Keypad Detail Drawing



Panel Mounting Application Cutout Drawing



Typical mounting hardware at locations "D" (5 places):

- PEM FH-256-8
- Bivar Inc. 9913-5 mm Spacer
- 2-56 "Small Profile" Hex Nut
- Use appropriate screen printed overlay to cover display bezel and mounting hardware, and to protect LCD from scratching. Sample fabrication drawings are available on request.

Copyright © 2017 by Crystalfontz America, Inc. www.crystalfontz.com/products/	Part No.(s): CFA533 Panel Mounting Application Detail	Scale: Not to scale	Drawing Number: Panel_master	Hardware Rev.: v1.4
		Units: Millimeters	Date: 2017-03-14	Sheet: 1 of 1

14. Appendix A: Demonstration Software and Sample Code

Sample Code

We encourage you to use the free sample code listed below. Please leave the original copyrights in the code.

- Windows compatible test/demonstration program and source.
  https://www.crystalfontz.com/product/cftest
- Linux compatible command-line demonstration program with C source code. 8K.
  https://www.crystalfontz.com/product/linuxexamplecode
- Supported by CrystalControl freeware.
  https://www.crystalfontz.com/product/CrystalControl2.html

In addition, see http://lcdproc.org/index.php3 for Linux LCD drivers. LCDproc is an open source project that supports many of the Crystalfontz displays.

Algorithms to Calculate the CRC

Below are eight sample algorithms that will calculate the CRC of a CFA533 packet. Some of the algorithms were contributed by forum members and originally written for CFA631 and CFA635. The CRC used in the CFA533 is the same one that is used in IrDA, which came from PPP, which seems to be related to a CCITT (ref: Network Working Group Request for Comments: 1171) standard. At that point, the trail was getting a bit cold and diverged into several referenced articles and papers, dating back to 1983.

The polynomial used is $X^{16} + X^{12} + X^5 + X^0$ (0x8408)

The result is bit-wise inverted before being returned.

Algorithm 1: "C" Table Implementation

This algorithm is typically used on the host computer, where code space is not an issue.

```
//This code is from the IRDA LAP documentation, which appears to
//have been copied from PPP:
//
//    http://irda.affiniscape.com/associations/2494/files/Specifications/
IrLAP11_Plus_Errata.zip
//
//I doubt that there are any worries about the legality of this code,
//searching for the first line of the table below, it appears that
//the code is already included in the linux 2.6 kernel "Driver for
//ST5481 USB ISDN modem". This is an "industry standard" algorithm
//and I do not think there are ANY issues with it
at all.  typedef unsigned char ubyte;
typedef unsigned short word;
word get_crc(ubyte *bufptr,word len)
  {
  //CRC lookup table to avoid bit-shifting loops.
  static const word crcLookupTable[256] =
    {0x00000,0x01189,0x02312,0x0329B,0x04624,0x057AD,0x06536,0x074BF,
     0x08C48,0x09DC1,0x0AF5A,0x0BED3,0x0CA6C,0x0DBE5,0x0E97E,0x0F8F7,
     0x01081,0x00108,0x03393,0x0221A,0x056A5,0x0472C,0x075B7,0x0643E,
     0x09CC9,0x08D40,0x0BFDB,0x0AE52,0x0DAED,0x0CB64,0x0F9FF,0x0E876,
     0x02102,0x0308B,0x00210,0x01399,0x06726,0x076AF,0x04434,0x055BD,
     0x0AD4A,0x0BCC3,0x08E58,0x09FD1,0x0EB6E,0x0FAE7,0x0C87C,0x0D9F5,
     0x03183,0x0200A,0x01291,0x00318,0x077A7,0x0662E,0x054B5,0x0453C,
     0x0BDCB,0x0AC42,0x09ED9,0x08F50,0x0FBEF,0x0EA66,0x0D8FD,0x0C974,
     0x04204,0x0538D,0x06116,0x0709F,0x00420,0x015A9,0x02732,0x036BB,
     0x0CE4C,0x0DFC5,0x0ED5E,0x0FCD7,0x08868,0x099E1,0x0AB7A,0x0BAF3,
     0x05285,0x0430C,0x07197,0x0601E,0x014A1,0x00528,0x037B3,0x0263A,
     0x0DECD,0x0CF44,0x0FDDF,0x0EC56,0x098E9,0x08960,0x0BBFB,0x0AA72,
     0x06306,0x0728F,0x04014,0x0519D,0x02522,0x034AB,0x00630,0x017B9,
     0x0EF4E,0x0FEC7,0x0CC5C,0x0DDD5,0x0A96A,0x0B8E3,0x08A78,0x09BF1,
```

```
    0x07387,0x0620E,0x05095,0x0411C,0x035A3,0x0242A,0x016B1,0x00738,
    0x0FFCF,0x0EE46,0x0DCDD,0x0CD54,0x0B9EB,0x0A862,0x09AF9,0x08B70,
    0x08408,0x09581,0x0A71A,0x0B693,0x0C22C,0x0D3A5,0x0E13E,0x0F0B7,
    0x00840,0x019C9,0x02B52,0x03ADB,0x04E64,0x05FED,0x06D76,0x07CFF,
    0x09489,0x08500,0x0B79B,0x0A612,0x0D2AD,0x0C324,0x0F1BF,0x0E036,
    0x018C1,0x00948,0x03BD3,0x02A5A,0x05EE5,0x04F6C,0x07DF7,0x06C7E,
    0x0A50A,0x0B483,0x08618,0x09791,0x0E32E,0x0F2A7,0x0C03C,0x0D1B5,
    0x02942,0x038CB,0x00A50,0x01BD9,0x06F66,0x07EEF,0x04C74,0x05DFD,
    0x0B58B,0x0A402,0x09699,0x08710,0x0F3AF,0x0E226,0x0D0BD,0x0C134,
    0x039C3,0x0284A,0x01AD1,0x00B58,0x07FE7,0x06E6E,0x05CF5,0x04D7C,
    0x0C60C,0x0D785,0x0E51E,0x0F497,0x08028,0x091A1,0x0A33A,0x0B2B3,
    0x04A44,0x05BCD,0x06956,0x078DF,0x00C60,0x01DE9,0x02F72,0x03EFB,
    0x0D68D,0x0C704,0x0F59F,0x0E416,0x090A9,0x08120,0x0B3BB,0x0A232,
    0x05AC5,0x04B4C,0x079D7,0x0685E,0x01CE1,0x00D68,0x03FF3,0x02E7A,
    0x0E70E,0x0F687,0x0C41C,0x0D595,0x0A12A,0x0B0A3,0x08238,0x093B1,
    0x06B46,0x07ACF,0x04854,0x059DD,0x02D62,0x03CEB,0x00E70,0x01FF9,
    0x0F78F,0x0E606,0x0D49D,0x0C514,0x0B1AB,0x0A022,0x092B9,0x08330,
    0x07BC7,0x06A4E,0x058D5,0x0495C,0x03DE3,0x02C6A,0x01EF1,0x00F78};

register word
  newCrc;
newCrc=0xFFFF;
//This algorithm is based on the IrDA LAP example.
while(len--)
  newCrc = (newCrc >> 8) ^ crcLookupTable[(newCrc ^ *bufptr++) & 0xff];

//Make this crc match the one's complement that is sent in the packet.
return(~newCrc);
}
```

Algorithm 2: "C" Bit Shift Implementation

This algorithm was mainly written to avoid any possible legal issues about the source of the routine (at the request of the LCDproc group). This routine was "clean" coded from the definition of the CRC. It is ostensibly smaller than the table-driven approach but will take longer to execute. This routine is offered under the GPL.

```
typedef unsigned char ubyte;
typedef unsigned short word;
word get_crc(ubyte *bufptr,word len)
  {
  register unsigned int
    newCRC;
  //Put the current byte in here.
  ubyte
     data;
  int
     bit_count;
  //This seed makes the output of this shift based algorithm match
  //the table based algorithm. The center 16 bits of the 32-bit
  //"newCRC" are used for the CRC. The MSb of the lower byte is used
  //to see what bit was shifted out of the center 16 bit CRC
  //accumulator ("carry flag analog");
  newCRC=0x00F32100;
  while(len--)
    {
    //Get the next byte in the stream.
    data=*bufptr++;

    //Push this byte's bits through a software
    //implementation of a hardware shift & xor.
    for(bit_count=0;bit_count<=7;bit_count++)
      {
      //Shift the CRC accumulator
      newCRC>>=1;
```

```
      //The new MSB of the CRC accumulator comes
      //from the LSB of the current data byte.
      if(data&0x01)
        newCRC|=0x00800000;

      //If the low bit of the current CRC accumulator was set
      //before the shift, then we need to XOR the accumulator
      //with the polynomial (center 16 bits of 0x00840800)
      if(newCRC&0x00000080)
        newCRC^=0x00840800;
      //Shift the data byte to put the next bit of the stream
      //into position 0.
      data>>=1;
      }
    }

  //All the data has been done. Do 16 more bits of 0 data.
  for(bit_count=0;bit_count<=15;bit_count++)
    {
    //Shift the CRC accumulator
    newCRC>>=1;

    //If the low bit of the current CRC accumulator was set
    //before the shift we need to XOR the accumulator with
    //0x00840800.
    if(newCRC&0x00000080)
      newCRC^=0x00840800;
    }
  //Return the center 16 bits, making this CRC match the one's
  //complement that is sent in the packet.
  return((~newCRC)>>8);
  }
```

Algorithm 2B: "C" Improved Bit Shift Implementation

This is a simplified algorithm that implements the CRC.

```
unsigned short get_crc(unsigned char count,unsigned char *ptr)
  {
  unsigned short
    crc;    //Calculated CRC
  unsigned char
    i;      //Loop count, bits in byte
  unsigned char
    data;   //Current byte being shifted

  crc = 0xFFFF; // Preset to all 1's, prevent loss of leading zeros

  while(count--)
    {
    data = *ptr++;
    i = 8;
    do
      {
      if((crc ^ data) & 0x01)
        {
        crc >>= 1; crc ^= 0x8408;
        }
      else
        crc >>= 1;
```

```
          data >>= 1;
          } while(--i != 0);
        }
      return (~crc);
    }
```

Algorithm 3: "PIC Assembly" Bit Shift Implementation

This routine was graciously donated by one of our customers.

```
;*********************************************************************
; Crystalfontz CFA533 PIC CRC Calculation Example
;
; This example calculates the CRC for the hard coded example provided in the
documentation.
;
; It uses "This is a test. " as input and calculates the proper CRC of 0x93FA.
;*********************************************************************
#include "p16f877.inc"
;*********************************************************************
; CRC16 equates and storage
;---------------------------------------------------------------------

accuml      equ         40h         ; BYTE - CRC result register high byte
accumh      equ         41h         ; BYTE - CRC result register high low byte
datareg           equ         42h         ; BYTE - data register for shift
j           equ         43h         ; BYTE - bit counter for CRC 16 routine
Zero        equ         44h         ; BYTE - storage for string memory read
index       equ         45h         ;BYTE - index for string memory read
savchr      equ         46h         ;BYTE - temp storage for CRC routine
;
seedlo      equ         021h        ;initial seed for CRC reg lo byte
seedhi      equ         0F3h        ;initial seed for CRC reg hi byte
;
polyL       equ         008h        ;polynomial low byte
polyH       equ         084h        ;polynomial high byte
;*********************************************************************
;     CRC Test Program
;---------------------------------------------------------------------
            org         0           ; reset vector = 0000H
;
            clrf        PCLATH      ; ensure upper bits of PC are cleared
            clrf        STATUS      ; ensure page bits are cleared
            goto        main        ; jump to start of program
;
; ISR Vector
;
            org         4           ; start of ISR
            goto        $           ; jump to ISR when coded
;
            org         20          ; start of main program
main
            movlw       seedhi      ; setup intial CRC seed value.
            movwf       accumh      ; This must be done prior to
            movlw       seedlo      ; sending string to CRC routine.
            movwf       accuml      ;
            clrf        index       ; clear string read variables
;
main1
```

```
            movlw       HIGH InputStr       ; point to LCD test string
            movwf       PCLATH          ; latch into PCL
            movfw       index           ; get index
            call        InputStr        ; get character
            movwf       Zero            ; setup for terminator test
            movf        Zero,f          ; see if terminator
            btfsc       STATUS,Z        ; skip if not terminator
            goto        main2           ; else terminator reached, jump out of loop
            call        CRC16           ; calculate new    crc
            call        SENDUART        ; send data to LCD
            incf        index,f         ; bump index
            goto        main1           ; loop
;
main2
            movlw       00h             ; shift accumulator 16 more bits.
            call        CRC16           ; This must be done after sending
            movlw       00h             ; string to CRC routine.
            call        CRC16           ;
;
            comf        accumh,f        ; invert result
            comf        accuml,f        ;
;
            movfw       accuml          ; get CRC low byte
            call        SENDUART        ; send to LCD
            movfw       accumh          ; get CRC hi byte
            call        SENDUART        ; send to LCD
;
stop        goto        stop            ; word result of 0x93FA is in accumh/accuml
;=====================================================================
; calculate CRC of input byte
;---------------------------------------------------------------------
CRC16
             movwf      savchr          ; save the input character
            movwf       datareg         ; load data register
            movlw  .    8               ; setup number of bits to test
            movwf       j               ; save to incrementor
_loop
            clrc                        ; clear carry for CRC register shift
            rrf         datareg,f       ; perform shift of data into CRC register
            rrf         accumh,f        ;
            rrf         accuml,f        ;
            btfss       STATUS,C        ; skip jump if if carry
            goto        _notset         ; otherwise goto next bit
            movlw       polyL           ; XOR poly mask with CRC register
            xorwf       accuml,F        ;
            movlw       polyH           ;
            xorwf       accumh,F        ;
_notset
            decfsz      j,F             ; decrement bit counter
            goto        _loop           ; loop if not complete
            movfw       savchr          ; restore the input character
            return                      ; return to calling routine
;=====================================================================
; USER SUPPLIED Serial port transmit routine
;---------------------------------------------------------------------
SENDUART
            return                      ; put serial xmit routine here
;=====================================================================
; test string storage
```

```
;-----------------------------------------------------------------------
            org         0100h
;
InputStr
            addwf       PCL,f
            dt          7h,10h,"This is a test. ",0
;
;=======================================================================
            end
```

Algorithm 4: "Visual Basic" Table Implementation

Visual BASIC has its own challenges as a language (such as initializing static arrays), and it is also challenging to use Visual BASIC to work with "binary" (arbitrary length character data possibly containing nulls—such as the "data" portion of the CFA533 packet) data. This routine was adapted from the C table implementation. The complete project can be found in our forums.

```
'Written by Crystalfontz America, Inc. 2004 http://www.crystalfontz.com

'Free code, not copyright copy left or anything else.

'Some visual basic concepts taken from:

'http://www.planet-source-
code.com/vb/scripts/ShowCode.asp?txtCodeId=21434&lngWId=1

'most of the algorithm is from functions in 633_WinTest:
'http://www.crystalfontz.com/products/633/633_WinTest.zip

'Full zip of the project is available in our forum:
'https://www.crystalfontz.com/forum/showthread.php?postid=9921#post9921


 Private Type WORD
    Lo As Byte
    Hi As Byte
 End Type

 Private Type PACKET_STRUCT
    command As Byte
    data_length As Byte
    data(22) As Byte
    crc As WORD
 End Type

 Dim crcLookupTable(256) As WORD

 Private Sub MSComm_OnComm()
 'Leave this here

 End Sub

 'My understanding of visual basic is very limited--however it appears
 that there is no way to initialize an array of structures.
 Sub Initialize_CRC_Lookup_Table()
   crcLookupTable(0).Lo = &H0
   crcLookupTable(0).Hi = &H0
   . . .
 'For purposes of brevity in this Datasheet, I have removed 251 entries of this
 table, the  'full source is available in our forum:
 'https://www.crystalfontz.com/forum/showthread.php?postid=9921#post9921
   . . .
   crcLookupTable(255).Lo = &H78
   crcLookupTable(255).Hi = &HF
 End Sub
```

```
'This function returns the CRC of the array at data for length positions
Private Function Get_Crc(ByRef data() As Byte, ByVal length As Integer) As WORD
  Dim Index As Integer
  Dim Table_Index As Integer
  Dim newCrc As WORD newCrc.Lo = &HFF
  newCrc.Hi = &HFF
  For Index = 0 To length - 1
    'exclusive-or the input byte with the low-order byte of the CRC register
    'to get an index into crcLookupTable
    Table_Index = newCrc.Lo Xor data(Index)
    'shift the CRC register eight bits to
    the right newCrc.Lo = newCrc.Hi
    newCrc.Hi = 0
    ' exclusive-or the CRC register with the contents of Table at Table_Index
    newCrc.Lo = newCrc.Lo Xor crcLookupTable(Table_Index).Lo
    newCrc.Hi = newCrc.Hi Xor crcLookupTable(Table_Index).Hi
    Next Index
  'Invert & return newCrc
  Get_Crc.Lo = newCrc.Lo Xor &HFF
  Get_Crc.Hi = newCrc.Hi Xor &HFF
End Function

Private Sub Send_Packet(ByRef packet As PACKET_STRUCT)
  Dim Index As Integer
  'Need to put the whole packet into a linear array
  'since you can't do type overrides. VB, gotta love it.
  Dim linear_array(26) As Byte
  linear_array(0) = packet.command
  linear_array(1) = packet.data_length
  For Index = 0 To packet.data_length - 1
    linear_array(Index + 2) = packet.data(Index)
  Next Index
  packet.crc = Get_Crc(linear_array, packet.data_length + 2)
  'Might as well move the CRC into the linear array too
  linear_array(packet.data_length + 2) = packet.crc.Lo
  linear_array(packet.data_length + 3) = packet.crc.Hi
  'Now a simple loop can dump it out the port.
  For Index = 0 To packet.data_length + 3
    MSComm.Output = Chr(linear_array(Index))
  Next Index
End Sub
```

Algorithm 5: "Java" Table Implementation

This code was posted in our forum by user "norm" as a working example of a Java CRC calculation.

```
public class CRC16 extends Object
  {
  public static void main(String[] args)

    {
    byte[] data = new byte[2];
    // hw - fw
    data[0] = 0x01;
    data[1] = 0x00;
    System.out.println("hw -fw req");
    System.out.println(Integer.toHexString(compute(data)));

    // ping
    data[0]  = 0x00;
    data[1]  = 0x00;
    System.out.println("ping");
    System.out.println(Integer.toHexString(compute(data)));

    // reboot
    data[0] = 0x05;
    data[1] = 0x00;
```

```
  System.out.println("reboot");
  System.out.println(Integer.toHexString(compute(data)));
  // clear lcd
  data[0] = 0x06;
  data[1] = 0x00;
  System.out.println("clear lcd");
  System.out.println(Integer.toHexString(compute(data)));

  // set line 1
  data = new byte[18];
  data[0] = 0x07;
  data[1] = 0x10;
  String text = "Test Test Test   ";
  byte[] textByte = text.getBytes();
  for (int i=0; i < text.length(); i++) data[i+2] = textByte[i];
  System.out.println("text 1");
  System.out.println(Integer.toHexString(compute(data)));
  }
private CRC16()
  {
  }
private static final int[] crcLookupTable =
  {
  0x00000,0x01189,0x02312,0x0329B,0x04624,0x057AD,0x06536,0x074BF,
  0x08C48,0x09DC1,0x0AF5A,0x0BED3,0x0CA6C,0x0DBE5,0x0E97E,0x0F8F7,
  0x01081,0x00108,0x03393,0x0221A,0x056A5,0x0472C,0x075B7,0x0643E,
  0x09CC9,0x08D40,0x0BFDB,0x0AE52,0x0DAED,0x0CB64,0x0F9FF,0x0E876,
  0x02102,0x0308B,0x00210,0x01399,0x06726,0x076AF,0x04434,0x055BD,
  0x0AD4A,0x0BCC3,0x08E58,0x09FD1,0x0EB6E,0x0FAE7,0x0C87C,0x0D9F5,
  0x03183,0x0200A,0x01291,0x00318,0x077A7,0x0662E,0x054B5,0x0453C,
  0x0BDCB,0x0AC42,0x09ED9,0x08F50,0x0FBEF,0x0EA66,0x0D8FD,0x0C974,
  0x04204,0x0538D,0x06116,0x0709F,0x00420,0x015A9,0x02732,0x036BB,
  0x0CE4C,0x0DFC5,0x0ED5E,0x0FCD7,0x08868,0x099E1,0x0AB7A,0x0BAF3,
  0x05285,0x0430C,0x07197,0x0601E,0x014A1,0x00528,0x037B3,0x0263A,
  0x0DECD,0x0CF44,0x0FDDF,0x0EC56,0x098E9,0x08960,0x0BBFB,0x0AA72,
  0x06306,0x0728F,0x04014,0x0519D,0x02522,0x034AB,0x00630,0x017B9,
  0x0EF4E,0x0FEC7,0x0CC5C,0x0DDD5,0x0A96A,0x0B8E3,0x08A78,0x09BF1,
  0x07387,0x0620E,0x05095,0x0411C,0x035A3,0x0242A,0x016B1,0x00738,
  0x0FFCF,0x0EE46,0x0DCDD,0x0CD54,0x0B9EB,0x0A862,0x09AF9,0x08B70,
  0x08408,0x09581,0x0A71A,0x0B693,0x0C22C,0x0D3A5,0x0E13E,0x0F0B7,
  0x00840,0x019C9,0x02B52,0x03ADB,0x04E64,0x05FED,0x06D76,0x07CFF,
  0x09489,0x08500,0x0B79B,0x0A612,0x0D2AD,0x0C324,0x0F1BF,0x0E036,
  0x018C1,0x00948,0x03BD3,0x02A5A,0x05EE5,0x04F6C,0x07DF7,0x06C7E,
  0x0A50A,0x0B483,0x08618,0x09791,0x0E32E,0x0F2A7,0x0C03C,0x0D1B5,
  0x02942,0x038CB,0x00A50,0x01BD9,0x06F66,0x07EEF,0x04C74,0x05DFD,
  0x0B58B,0x0A402,0x09699,0x08710,0x0F3AF,0x0E226,0x0D0BD,0x0C134,
  0x039C3,0x0284A,0x01AD1,0x00B58,0x07FE7,0x06E6E,0x05CF5,0x04D7C,
  0x0C60C,0x0D785,0x0E51E,0x0F497,0x08028,0x091A1,0x0A33A,0x0B2B3,
  0x04A44,0x05BCD,0x06956,0x078DF,0x00C60,0x01DE9,0x02F72,0x03EFB,
  0x0D68D,0x0C704,0x0F59F,0x0E416,0x090A9,0x08120,0x0B3BB,0x0A232,
  0x05AC5,0x04B4C,0x079D7,0x0685E,0x01CE1,0x00D68,0x03FF3,0x02E7A,
  0x0E70E,0x0F687,0x0C41C,0x0D595,0x0A12A,0x0B0A3,0x08238,0x093B1,
  0x06B46,0x07ACF,0x04854,0x059DD,0x02D62,0x03CEB,0x00E70,0x01FF9,
  0x0F78F,0x0E606,0x0D49D,0x0C514,0x0B1AB,0x0A022,0x092B9,0x08330,
  0x07BC7,0x06A4E,0x058D5,0x0495C,0x03DE3,0x02C6A,0x01EF1,0x00F78
  };
public static int compute(byte[] data)
  {
  int newCrc = 0x0FFFF;
  for (int i = 0; i < data.length; i++ )
    {
    int lookup = crcLookupTable[(newCrc ^ data[i]) & 0xFF];
    newCrc = (newCrc >> 8) ^ lookup;
    }
  return(~newCrc);
  }
}
```

Algorithm 6: "Perl" Table Implementation

This code was translated from the C version by one of our customers.

```
#!/usr/bin/perl

use strict;

my @CRC_LOOKUP =
 (0x00000,0x01189,0x02312,0x0329B,0x04624,0x057AD,0x06536,0x074BF,
  0x08C48,0x09DC1,0x0AF5A,0x0BED3,0x0CA6C,0x0DBE5,0x0E97E,0x0F8F7,
  0x01081,0x00108,0x03393,0x0221A,0x056A5,0x0472C,0x075B7,0x0643E,
  0x09CC9,0x08D40,0x0BFDB,0x0AE52,0x0DAED,0x0CB64,0x0F9FF,0x0E876,
  0x02102,0x0308B,0x00210,0x01399,0x06726,0x076AF,0x04434,0x055BD,
  0x0AD4A,0x0BCC3,0x08E58,0x09FD1,0x0EB6E,0x0FAE7,0x0C87C,0x0D9F5,
  0x03183,0x0200A,0x01291,0x00318,0x077A7,0x0662E,0x054B5,0x0453C,
  0x0BDCB,0x0AC42,0x09ED9,0x08F50,0x0FBEF,0x0EA66,0x0D8FD,0x0C974,
  0x04204,0x0538D,0x06116,0x0709F,0x00420,0x015A9,0x02732,0x036BB,
  0x0CE4C,0x0DFC5,0x0ED5E,0x0FCD7,0x08868,0x099E1,0x0AB7A,0x0BAF3,
  0x05285,0x0430C,0x07197,0x0601E,0x014A1,0x00528,0x037B3,0x0263A,
  0x0DECD,0x0CF44,0x0FDDF,0x0EC56,0x098E9,0x08960,0x0BBFB,0x0AA72,
  0x06306,0x0728F,0x04014,0x0519D,0x02522,0x034AB,0x00630,0x017B9,
  0x0EF4E,0x0FEC7,0x0CC5C,0x0DDD5,0x0A96A,0x0B8E3,0x08A78,0x09BF1,
  0x07387,0x0620E,0x05095,0x0411C,0x035A3,0x0242A,0x016B1,0x00738,
  0x0FFCF,0x0EE46,0x0DCDD,0x0CD54,0x0B9EB,0x0A862,0x09AF9,0x08B70,
  0x08408,0x09581,0x0A71A,0x0B693,0x0C22C,0x0D3A5,0x0E13E,0x0F0B7,
  0x00840,0x019C9,0x02B52,0x03ADB,0x04E64,0x05FED,0x06D76,0x07CFF,
  0x09489,0x08500,0x0B79B,0x0A612,0x0D2AD,0x0C324,0x0F1BF,0x0E036,
  0x018C1,0x00948,0x03BD3,0x02A5A,0x05EE5,0x04F6C,0x07DF7,0x06C7E,
  0x0A50A,0x0B483,0x08618,0x09791,0x0E32E,0x0F2A7,0x0C03C,0x0D1B5,
  0x02942,0x038CB,0x00A50,0x01BD9,0x06F66,0x07EEF,0x04C74,0x05DFD,
  0x0B58B,0x0A402,0x09699,0x08710,0x0F3AF,0x0E226,0x0D0BD,0x0C134,
  0x039C3,0x0284A,0x01AD1,0x00B58,0x07FE7,0x06E6E,0x05CF5,0x04D7C,
  0x0C60C,0x0D785,0x0E51E,0x0F497,0x08028,0x091A1,0x0A33A,0x0B2B3,
  0x04A44,0x05BCD,0x06956,0x078DF,0x00C60,0x01DE9,0x02F72,0x03EFB,
  0x0D68D,0x0C704,0x0F59F,0x0E416,0x090A9,0x08120,0x0B3BB,0x0A232,
  0x05AC5,0x04B4C,0x079D7,0x0685E,0x01CE1,0x00D68,0x03FF3,0x02E7A,
  0x0E70E,0x0F687,0x0C41C,0x0D595,0x0A12A,0x0B0A3,0x08238,0x093B1,
  0x06B46,0x07ACF,0x04854,0x059DD,0x02D62,0x03CEB,0x00E70,0x01FF9,
  0x0F78F,0x0E606,0x0D49D,0x0C514,0x0B1AB,0x0A022,0x092B9,0x08330,
  0x07BC7,0x06A4E,0x058D5,0x0495C,0x03DE3,0x02C6A,0x01EF1,0x00F78);

#  our test packet read from an enter key press over the serial line:
   #    type = 80        (key press)
   #    data_length = 1      (1 byte of data)
   #    data = 5

   my $type = '80';
   my $length = '01';
   my $data = '05';

   my $packet = chr(hex $type) .chr(hex $length) .chr(hex $data);

   my $valid_crc = '5584' ;

   print "A CRC of Packet ($packet) Should Equal($valid_crc)\n";

   my $crc = 0xFFFF ;

   printf("%x\n", $crc);

   foreach my $char (split //, $packet)
     {
     # newCrc = (newCrc >> 8) ^ crcLookupTable[(newCrc ^ *bufptr++) & 0xff];
     # & is bitwise AND
     # ^ is bitwise XOR
     # >> bitwise shift right
```

```
      $crc = ($crc >> 8) ^ $CRC_LOOKUP[($crc ^ ord($char) ) & 0xFF] ;
      # print out the running crc at each byte
      printf("%x\n", $crc);
      }

    # get the complement
    $crc = ~$crc ;
    $crc = ($crc & 0xFFFF) ;

    # print out the crc in hex
    printf("%x\n", $crc);
```

Algorithm 7: For PIC18F8722 or PIC18F2685

This code was written by customer Virgil Stamps of ATOM Instrument Corporation for our CFA635 module.

```
;CRC Algorithm for CrystalFontz CFA635 display (DB535)
; This code written for PIC18F8722 or PIC18F2685
;
; Your main focus here should be the ComputeCRC2 and
; CRC16_ routines
;
;=====================================================================
ComputeCRC2:
      movlb       RAM8
      movwf       dsplyLPCNT          ;w has the byte count
nxt1_dsply:
      movf        POSTINC1            ;w
      call        CRC16
      decfsz      dsplyLPCNT
      goto        nxt1_dsply
      movlw       .0                  ;shift accumulator 16 more bits
      call        CRC16
      movlw       .0
      call        CRC16
      comf        dsplyCRC,F          ;invert result
      comf        dsplyCRC+1,F
      return
;=====================================================================
CRC16 movwf:
      dsplyCRCData                    ;w has the byte crc
      movlw       .8
      movwf       dsplyCRCCount
_cloop:
      bcf         STATUS,C            ; clear carry for CRC register shift
      rrcf        dsplyCRCData,f      ; perform shift of data into CRC
                                      ; register
      rrcf        dsplyCRC,F
      rrcf        dsplyCRC+1,F
      btfss       STATUS,C            ; skip jump if carry
      goto    _   notset              ; otherwise goto next bit
      movlw       0x84                ; XOR poly mask with CRC register
      xorwf       dsplyCRC,F
_notset:
      decfsz      dsplyCRCCount,F     ; decrement bit counter
      bra   cloop                     ; loop if not complete
      return
;=====================================================================
; example to clear screen
dsplyFSR1_TEMP    equ   0x83A ;       ; 16-bit save for FSR1 for display
                                      ; message handler
dsplyCRC          equ   0x83C         ; 16-bit CRC (H/L)
dsplyLPCNT        equ   0x83E         ; 8-bit save for display message
                                      ; length - CRC
dsplyCRCData      equ   0x83F         ; 8-bit CRC data for display use
```

```
dsplyCRCCount       equ    0x840        ; 8-bit CRC count for display use
SendCount           equ    0x841        ; 8-bit byte count for sending to
                                        ; display
RXBUF2              equ    0x8C0        ; 32-byte receive buffer for
                                        ; Display
TXBUF2              equ    0x8E0        ; 32-byte transmit buffer for
                                        ; Display
;---------------------------------------------------------------
ClearScreen:
      movlb         RAM8
      movlw         .0
      movwf         SendCount
      movlw         0xF3
      movwf         dsplyCRC     ; seed ho for CRC calculation
      movlw         0x21
      movwf         dsplyCRC+1         ; seen lo for CRC calculation
      call          ClaimFSR1
      movlw         0x06
      movwf         TXBUF2
      LFSR          FSR1,TXBUF2
      movf          SendCount,w
      movwf         TXBUF2+1           ; message data length
      call          BMD1
      goto          SendMsg
;=================================================================
;send message via interrupt routine. The code is made complex due
; to the limited FSR registers and extended memory space used
;
; example of sending a string to column 0, row 0
;---------------------------------------------------------------
SignOnL1:
      call          ClaimFSR1
      lfsr          FSR1,TXBUF2+4      ; set data string position
      SHOW          C0R0,BusName       ; move string to TXBUF2
      movlw         .2                 ;
      addwf         SendCount          ;
      movff         SendCount,TXBUF2+1
                                       ; insert message data length
      call          BuildMsgDSPLY
      call          SendMsg
      return
;=================================================================
; BuildMsgDSPLY used to send a string to LCD
;---------------------------------------------------------------
BuildMsgDSPLY:
      movlw         0xF3
      movwf         dsplyCRC           ; seed hi for CRC calculation
      movlw         0x21
      movwf         dsplyCRC+1         ; seed lo for CRC calculation
      LFSR          FSR1,TXBUF2        ; point at transmit buffer
      movlw         0x1F               ; command to send data to LCD
      movwf         TXBUF2             ; insert command byte from us to
                                       ; CFA635
      BMD1          movlw .2
      ddwf          SendCount,w        ; + overhead
      call          ComputeCRC2        ; compute CRC of transmit message
      movf          dsplyCRC+1,w
      movwf         POSTINC1           ; append CRC byte
      movf          dsplyCRC,w
      movwf         POSTINC1           ; append CRC byte
      return
;=================================================================
```

```
SendMsg:
      call        ReleaseFSR1
      LFSR        FSR0,TXBUF2
      movff       FSR0H,irptFSR0
      movff       FSR0L,irptFSR0+1
                                    ; save interrupt use of FSR0
      movff       SendCount,TXBUSY2
      bsf         PIE2,TX2IE
                                    ; set transmit interrupt enable
                                    ; (bit 4)
      return
;=====================================================================
; macro to move string to transmit buffer
SHOW macro    src,  stringname
      call        src
      MOVLF       upper stringname, TBLPTRU
      MOVLF       high stringname, TBLPTRH
      MOVLF       low stringname, TBLPTRL
      call        MOVE_STR
      endm
;=====================================================================
MOVE_STR:
      tblrd       *+
      movf        TABLAT,w
      bz          ms1b
      movwf       POSTINC1
      incf        SendCount
      goto        MOVE_STR

ms1b:
      return
;=====================================================================
```