BINSFELD ENGINEERING INC.

TPM2 Analog Output Module

User Manual

802510-9_C

Contents

1 System Overview

The TPM2-AO is an optional component for the TPM2 system. It provides analog voltage outputs for shaft torque, speed and power. It also has three discrete digital transistor outputs for interfacing with PLCs, relays, etc. The TPM2-AO has a USB interface and comes with PC software for system configuration. This document provides information regarding both the hardware and configuration software.

2 Electrical Cable

The TPM2-AO module connects to the TPM2 RS-422 communications interface through a shielded twisted pair cable which can be up to 750ft long with proper cable type and installation. See section 4.2.2 for recommended cable.

The TPM2-AO module provides analog voltage outputs (see section 4.2). For best system performance and the lowest analog voltage error due to wire lengths, the AO module should be located in the control cabinet close to the analog inputs of the end user's system.

2.1 Installation

The module snaps onto a DIN rail and is approximately 23mm wide X 100mm tall X 120mm deep. The label on one side of the module details connections.

Discrete Out 1 -	
Discrete Out 1+	USB mini B
Discrete Out 2-	
Discrete Out 2+	RS422 RX+
Discrete Out 3-	RS422 RX-
Discrete Out 3+	RS422 COM
Torque Out +	RS422 TX-
Analog COM	RS422 TX+
Speed Out +	RS422 Shield
Analog COM	Power In 0V
Power Out +	Power In +24V
Analog COM	

2.1.1 Power and TPM2 Communications Connection

The top of the module has an 8 position pluggable screw terminal connector for power and TPM2 communications. The module requires 24VDC power at 2.5 watts max.

Communications connections are as follows:

AO Module

```
RS422 RX+ ----- ORN/WHT (TPM2 TX+)
RS422 RX- ----- WHT/ORN (TPM2 TX-)
RS422 COM ----- CLR     (TPM2 common)
RS422 TX- ----- WHT/BLU (TPM2 RX-)
RS422 TX+ ----- BLU/WHT (TPM2 RX+)
RS422 Shield ----- No connection
```

Note: Wire colors are based on standard TPM2 communications cable and may not apply if other cable is used.

2.1.2 USB Connection to a PC

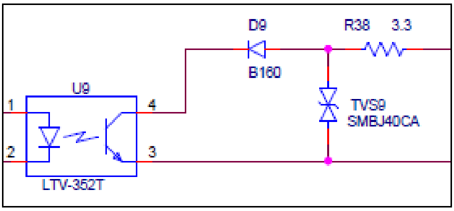
A USB type mini-B receptacle for connection to a PC is located next to the 8 position connector. Any standard USB mini B cable with the proper PC end can be used. This connection is only necessary to connect a PC for module configuration and can be removed for normal standalone operation.

2.1.3 Analog Output Connections

On the bottom of the module there is a 12 position pluggable screw terminal connector for the analog output connections. All three Analog COM connections are connected together internally but Analog COM is isolated from module input power ground (Vpwr-).

The three Discrete Outputs are optically isolated and independent.

Typical Discrete Output circuit. VceOff max = 40V, Ic max = 100mA, VceOn max = 1.5V (including 3.3 ohm resistor @100mA).



2.1.4 Front RJ-11 Connector

The RJ-11 connector behind the front panel window is for BEI production use only. DO NOT connect!

2.2 Status LED Description

The status LED is ON solid green when the module is powered and operating properly. The LED flashes a specific pattern if a problem is detected.

During power-up initialization the LED flashes rapidly at a rate of five times per second with a 50% duty cycle. Normally power-up initialization lasts for five seconds but flashing will continue indefinitely if an internal error is detected.

After successful power-up initialization the AO module attempts to establish communications with the connected TPM2. Normally the process requires less than one second but if the TPM2 is not connected correctly or not operating properly, the AO module status LED will flash slowly with a 50% duty cycle at a rate of once every two seconds until communications are established. Check for correct RS-422 wiring connections between the TPM2 and the AO module.

The AO module constantly monitors its internal regulated power supply voltage. If the voltage is detected to be too high or low, the status LED flashes one short 20msec pulse ON every second. Inaccurate analog output voltages may occur while the condition exists. Check for shorted or incorrect output wiring or a out of range input power voltage.

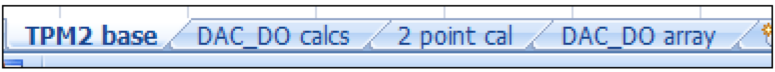
3 TPM2AO Configuration Program

The TPM2AO Configuration program is a LabVIEW PC program that communicates with a TPM2AO module through a USB connection and allows setting of configuration parameters. It is only needed for configuration as the AO module stores the parameters and operates standalone.

To help calculate hexadecimal AO parameter values for entry, use the TPM2&AOcalcs.xls spreadsheet.

3.1 TPM2&AOcalcs.xls spreadsheet

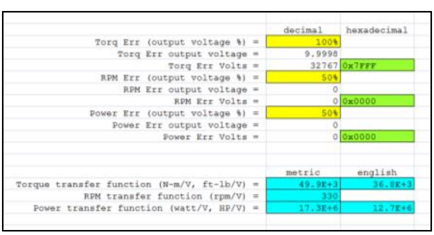
The `818008_TPM2&AOcalcs_Rx.xls` spreadsheet has four sheets; *TPM2 base*, *DAC_DO calcs*, *2 point cal*, and *DAC_DO array*.



The spreadsheet operates standalone and can be used before hardware is up and running. Generally, it is best to have the spreadsheet open to the *DAC_DO array* sheet when entering hexadecimal parameter values into the configuration program to make transferring the values easier.

The *2 point cal* sheet is only used if a two point calibration is performed on the system using an applied reference load. This may be necessary if physical shaft parameters are unknown or to achieve a more accurate transfer function for torque to output voltage. This method requires additional custom mechanical components and instrumentation.

The Yellow boxes in the spreadsheet are parameter values to be entered by the user. The Green boxes are calculated hexadecimal configuration values to be programmed into the AO module using the configuration PC program. There are a few Cyan boxes that contain important calculated values.



	decimal	hexadecimal
Torq Err (output voltage %) =	100%	
Torq Err output voltage =	9.9998	
Torq Err Volts =	32767	0x7FFF
RPM Err (output voltage %) =	50%	
RPM Err output voltage =	0	
RPM Err Volts =	0	0x0000
Power Err (output voltage %) =	50%	
Power Err output voltage =	0	
Power Err Volts =	0	0x0000
	metric	**english**
Torque transfer function (N-m/V, ft-lb/V) =	49.9E+3	36.8E+3
RPM transfer function (rpm/V) =	330	
Power transfer function (watt/V, HP/V) =	17.3E+6	12.7E+6

It is typical to start by entering physical shaft parameter values on the *TPM2 base* sheet, then to move to the *DAC_DO calcs* sheet to finish parameter entry and to generate hexadecimal configuration values.

All hexadecimal values calculated on the *DAC_DO calcs* sheet also appear on the *DAC_DO array* sheet to make copying the values to the array in the configuration program easier.

If the two point calibration method is used, follow the process outlined on the *2 point cal* sheet.

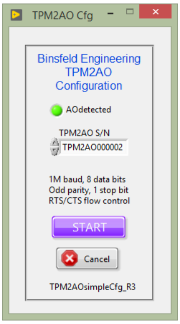
3.2 Program Installation

Unzip the installer program file `TPM2AOsimpleInstaller_Rx.zip` file to any location. Note that the `_Rx` refers to the program revision where the '`x`' represents the revision number. After installation the installer file can be deleted. In the unzipped `TPM2AOsimpleInstaller_Rx` folder open the `Volume` sub folder. Find and run (double-click) the `setup.exe` file. Follow the on-screen instructions to install the program.

3.3 Starting the program

Before starting the program, connect the TPM2 to the TPM2AO. Connect the TPM2AO to a USB port on the PC with the TPM2AO Configuration and Monitoring program installed. Apply 24VDC power to the system. At power-up the TPM2AO green status LED flashes for about five seconds and then should turn solid green to indicate that it is functioning correctly. The TPM2 status lights take a little longer to settle but all status LEDs (except the Speed LED) should turn solid green in less than one minute after power-up. If any LEDs are Red, a problem is detected. Once all status LEDs are solid green, continue with configuration.

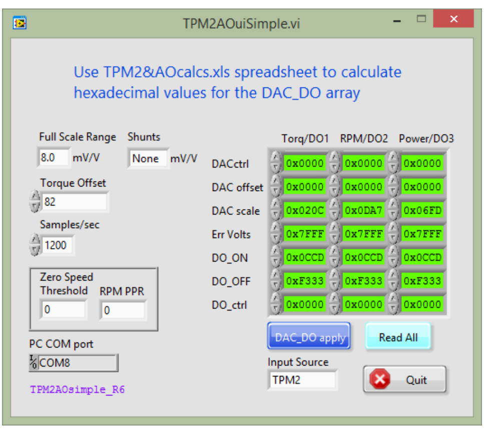
Find and run (double-click) the `tpm2aoSimple_Rx.exe` file. Normally it is found in the
`c:\Program Files (x86)\TPM2AOsimple`
folder but it depends on the folder specified during installation. The following window will open. If the TPM2AO module is powered and the USB cable is connected, the module's serial number should be listed in the Serial Number list box. If it is, click the START button to begin. If it is not, check the USB connection and the system power.



After START is clicked, the Start window will close and the Main program window will open.

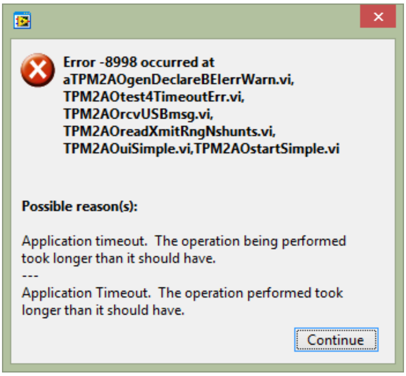
3.4 Main Screen

The Main screen is the only screen in the simplified version of the TPM2AO configuration and monitoring program. All necessary parameters can be configured from this screen.



When the main window opens, the program displays the present parameter values.

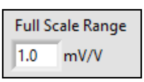
Note: If the TPM2 is not communicating with the AO module when attempting to run the program, an error will occur because the AO cannot read parameters from the TPM2.



If this occurs, check the TPM2 connections to the AO module.

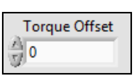
After parameter values have been configured, all parameters are permanently retained in either the TPM2 or the AO module and the PC can be disconnected. The PC program is only needed to change parameters.

3.4.1 Full Scale Range



The Full Scale Range control is used to set the transmitter gain. Changing the value causes a command to be sent to the transmitter.

3.4.2 Torque Offset

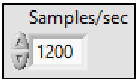


Use the Torque Offset to zero out the zero torque offset by adjusting the value up or down as needed. **This is not the DAC Offset!** The DAC Offset (see 3.4.5.2) is used to configure an Analog Output to a desired reference voltage (typically mid range analog output voltage).

The Torque Offset is used to compensate mainly for strain gage offset error. The Torque Offset is gain dependent but is normalized to the highest gain then adjusted internally by the AO module for the present gain setting.

The simplest way to adjust the Torque Offset is to monitor the torque analog output voltage with zero torque load applied to the shaft. Adjust the Torque Offset value as necessary to produce the desired zero torque output voltage.

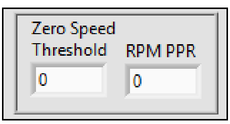
3.4.3 Samples / sec control



The *Samples/sec* control sets the TPM2 sampling rate which is directly related to the frequency response. The lower the sampling rate, the lower the frequency response.

3.4.4 Zero Speed controls

There are two speed control parameters; Zero Threshold and Pulses Per Revolution.



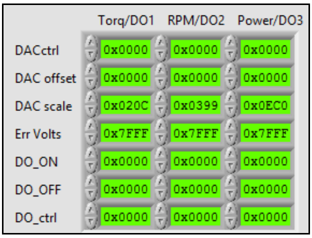
3.4.4.1 Zero Speed Threshold

The zero threshold parameter adjusts the RPM value below which the RPM is reported as zero even though the shaft may still be turning. Values from 0 to 250 are valid. 0 sets the value to about 0.4 RPM. Generally it is best to set the value no lower than necessary because speed can only be measured once per shaft revolution and low values can add many seconds of delay to the recognition of zero speed. For example a value of 1 RPM creates a delay of one minute.

3.4.4.2 RPM Pulses Per Revolution

Setting RPM PPR to 0 disables speed measurement so speed and power analog outputs will always be the zero voltage (not necessarily zero volts). Setting RPM PPR to 1 enables speed measurement.

3.4.5 DAC_DO



The DAC_DO control is an array of 21 parameter values associated with the three channels of Digital to Analog Conversion (Torque, Speed, and Power) and the three Discrete Outputs. The top four rows are DAC parameters. The bottom three rows are Discrete Output parameters.

All DAC_DO values are represented and entered as 16 bit hexadecimal values. This is because some are signed, some are unsigned, and some are bit fields. Using hexadecimal values provides a simple way to represent all types in the array. The `TPM2&AOcalc.xls` spreadsheet calculates all of the DAC_DO hexadecimal values based on user entered parameters. The hexadecimal values are indicated on the *DAC_DO calcs* sheet in Green boxes.

To change an array value, click on a cell and modify its contents. After editing one or more cells is completed, the blue *DAC_DO apply* button must be clicked to send the changes to the AO module.

See *Appendix A*

3.4.5.1 DAC ctrl

Analog channel control bits (unsigned 16 bit integer bit field) used to configure the output voltage range of each analog output.

b15:b3 unused, leave as zeros

b2:b0 output range

b2:b0 - analog output voltage:

binary	range	hexadecimal
0b000	±10V	0x0000
0b001	0 to 10V	0x0001
0b010	±5V	0x0002
0b011	0 to 5V	0x0003
0b100	±3V	0x0004

3.4.5.2 DAC offset

Digital to Analog Converter value (signed 16 bit integer) that sets the analog output channel zero signal voltage level. The DAC offset is added to the scaled variable value, resulting in the final DAC output value.

Typically this value is set to 0x0000 and results in a zero signal voltage level that is half of the selected analog output voltage range.

For example, if the analog output voltage range is ±10V the zero signal voltage level will be 0V. If the range is 0 to 10V, the zero signal voltage level will be 5V.

The range of the DAC offset value is -32768 (0x8000) to +32767 (0x7FFF). To calculate DAC offset value use the transfer function

DAC offset = (65536 * $\%V_{range}$) - 32768

where $\%V_{range}$ is the desired offset output voltage expressed as a percentage of the selected output voltage range.

For example if the output voltage range is 0 to 10V and the desired zero signal voltage level is 4.0V, then 4.0/10 = 40% or 0.4.

DAC offset = (65536 * 0.4) - 32768 = -6553.6

Only integer values can be used so round it to -6554 and convert to hexadecimal to get 0xE666 (see Appendix A).

3.4.5.3 DAC scale

Digital to Analog Converter transfer function multiplication factor (signed 16 bit fixed point value with 8 fractional bits). This is the multiplied combination of the variable transfer function scaling (Torque, Speed, Power) and a user scale factor. The variable value multiplied by the scale factor results in the DAC output value before the DAC offset is added.

DAC scale simply increases or decreases the amplitude of the analog output signal proportional to its value.

The range of the DAC scale value is -32768 (0x8000) to +32767 (0x7FFF). To calculate DAC scale value use the transfer function

DAC scale = $(VTF_{scale} * U_{scale}) * 256$

Where VTF_{scale} is the variable transfer function scale factor and U_{scale} is the additional user scale factor.

Round the result to the nearest integer value and convert to hexadecimal (see Appendix AAppendix A).

3.4.5.4 Error Volts

Error Volts is the analog output DAC value (signed 16 bit) output during an error condition.

The range of the Error Volts value is -32768 (0x8000) to +32767 (0x7FFF). To calculate Error Volts value use the transfer function

Error Volts = $(65536 * \%V_{range}) - 32768$

where $\%V_{range}$ is the desired error output voltage expressed as a percentage of the selected output voltage range.

For example if the output voltage range is 0 to 10V and the desired error indication voltage level is 4.0V, then 4.0/10 = 40% or 0.4.

Error Volts = (65536 * 0.4) - 32768 = -6553.6

Only integer values can be used so round it to -6554 and convert to hexadecimal to get 0xE666 (see Appendix A).

3.4.5.5 DO_ON

Discrete Output channel ON threshold is the DAC value for the analog voltage level used to trigger the associated discrete digital output to turn ON.

If the ON polarity (see section 0) is configured as ON > OFF then the output turns ON when the analog voltage level is > the DO_ON threshold.

If the ON polarity is configured as ON < OFF then the output turns ON when the analog voltage level is < the DO_ON threshold.

The range of the DO_ON value is -32768 (0x8000) to +32767 (0x7FFF). To calculate DO_ON value use the transfer function

DO_ON = (65536 * $\%V_{range}$) - 32768

where $\%V_{range}$ is the desired DO_ON output voltage threshold expressed as a percentage of the selected output voltage range.

For example if the output voltage range is 0 to 10V and the desired DO_ON voltage level is 4.0V, then 4.0/10 = 40% or 0.4.

DO_ON = (65536 * 0.4) - 32768 = -6553.6

Only integer values can be used so round it to -6554 and convert to hexadecimal to get 0xE666 (see Appendix A).

3.4.5.6 DO_OFF

Discrete Output channel OFF threshold is the DAC value for the analog voltage level used to trigger the associated discrete digital output to turn OFF.

If the ON polarity (see section 0) is configured as ON > OFF then the output turns OFF when the analog voltage level is < the DO_OFF threshold.

If the ON polarity is configured as ON < OFF then the output turns OFF when the analog voltage level is > the DO_ OFF threshold.

The range of the DO_ OFF value is -32768 (0x8000) to +32767 (0x7FFF). To calculate DO_ OFF value use the transfer function

DO_ OFF = (65536 * $\%V_{range}$) - 32768

where $\%V_{range}$ is the desired DO_ OFF output voltage threshold expressed as a percentage of the selected output voltage range.

For example if the output voltage range is 0 to 10V and the desired DO_ OFF voltage level is 4.0V, then 4.0/10 = 40% or 0.4.

DO_ OFF = (65536 * 0.4) - 32768 = -6553.6

Only integer values can be used so round it to -6554 and convert to hexadecimal to get 0xE666 (see Appendix A).

3.4.5.7 DO_ctrl

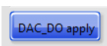
Discrete Output channel configuration bits (unsigned 16 bit integer bit field)

b15:b3 unused, leave as zeros

b2, On polarity, ON > OFF (0), ON < OFF (1)

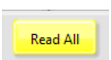
b1:b0 Signal Source, Disabled (0), Torque(1), RPM (2), Power(3)

3.4.6 DAC_DO Apply



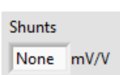
All DAC_DO parameter changes are buffered by the AO module and do not take effect until the DAC_DO apply button is clicked.

3.4.7 Read All



Clicking the Read All button causes all AO module parameters to be read and displayed. This can be used to verify that changes were accepted and implemented.

3.4.8 Shunts

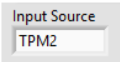


The transmitter has precision internal shunt resistors to simulate strain gage loads. The shunts are normally OFF and are only used to test the expected voltage output of the system.

There are two shunts; 0.2mV/V and 1.0mV/V that can be turned ON separately or together. The shunt value should always be less than the Full Scale Range or the transmitter may indicate an over-range condition.

The effect of the shunt on the torque output voltage is simply the ratio of the shunt to the Full Scale Range. For example, if the Shunt is set to 0.2mV/V and the Full Scale Range is 1.0mV/V, the ratio is 20% and the torque output voltage will be 20% of full scale.

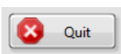
3.4.9 Input Source



Input Source is the signal used to generate the analog output voltages. Normally TPM2 is selected meaning that the input signal source is data from the TPM2.

Mid Scale, +Full Scale, and -Full Scale are the other input signal source options available for troubleshooting purposes. When selected these input signal sources generate analog voltages as described by their names on all three analog outputs.

3.4.10 Quit



Use the Quit button to close the program.

4 Specifications

4.1 Physical

Enclosure	DIN rail mount 22.5w x 107 h x 119mm dp (0.89 w x 4.21 h x 4.70” dp)
Operating temperature	0~70°C non-condensing Note: install with at least 20mm (0.8”) above and below the enclosure for proper ventilation
PC Connection	USB mini-B female connector located on top of enclosure
Power and TPM2 RS-422	8 position pluggable screw terminal connector, 5.08mm (0.2”) spacing located on top of enclosure
Analog and discrete digital output signals	12 position pluggable screw terminal connector, 5.08mm (0.2”) spacing located on bottom of enclosure

4.2 Electrical

Power Supply	10~30Vdc @250mA(max) Note: an external fuse rated at 500mA is recommended
Voltage Outputs	
	Selectable ranges ±10V, 0 to 10V, ±5V, 0 to 5V, ±3V
	Offset Error: ±0.05%FS(max) ±20ppm/°C
	Scale Error: ±0.10%R(max) ±20ppm/°C
	Output Impedance: 150Ω
Digital NPN Outputs	
	Voltage C-E (OFF): 40Vdc(max)
	Voltage C-E (ON): 1.5Vdc(max) @100mA
	Current: 100mAdc(max)

4.2.1 Electrical Isolation

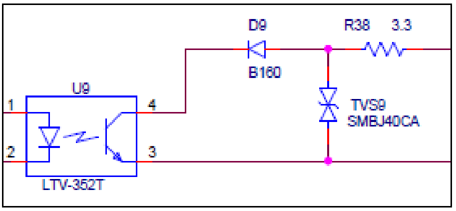
The TPM2-AO employs electrical isolation to reduce the chance of ground loop problems causing erratic operation, noise or damage to the unit or other connected electrical equipment.

The power input, EMC ground, RS422, USB and analog outputs are all electrically isolated from each other up to 1000V.

The torque, speed, and power analog outputs all share a common analog ground.

The three discrete digital outputs are all electrically isolated from each other and all other external connections.

Typical Discrete Output circuit. VceOff max = 40V, Ic max = 100mA, VceOn max = 1.5V (including 3.3 ohm resistor @100mA).



4.2.2 Recommended RS-422 Cable

Belden Type	**Config/ gauge**	**OD (inches)**	**capacitance (pF/ft)**	**Impedance (ohms)**
9842	2 pair 24awg	0.34"	12.8	120

Capacitance of the cable affects the maximum data rate and maximum length of the cable. Generally a low capacitance cable with a characteristic impedance of 120 ohms is best for RS-422 communications. Regardless of the sample rate selected, the TPM2-AO module communicates with the TPM2 at a baud rate of 460.8K baud. This cable should allow cable lengths up to approximately 750ft. For shorter cable lengths higher capacitance can be tolerated.

4.3 Timing

Analog output signal delay is due to a combination of digital filtering and buffering.

Sample Rate (samples/second)	Bandwidth[1] (Hz)	Delay[2] (ms)
9.375	3	1860
18.75	6	912
37.5	12	464
75	25	226
150	50	111
300	100	54.4
600	200	26.4
1200	380	12.3
2400	740	5.2
4800	1000	1.8

[1] Bandwidth is the frequency at which the signal is -3dB (70.8%) relative to the DC (0Hz) level.

[2] Signal delay is measured from analog (gage) input of the TPM2 transmitter to the analog output waveform.

These values are valid for all input range (gain) settings.

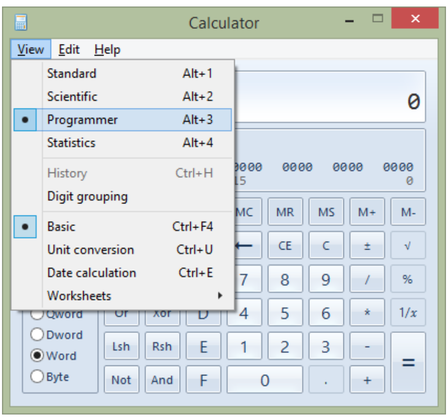
The Speed and Power voltage outputs are updated once per revolution of the shaft. There are no user selectable filters on these outputs.

The discrete digital NPN outputs are updated every 60msec.

Appendix A: Decimal to Hexadecimal conversion

Hexadecimal values are base 16 where decimal values are base 10. Computers use hexadecimal because they don't have 10 fingers. Computers have virtually 16 fingers so they count 0 thru 9 then add 6 more values, A thru F, to count using base 16.

Converting a decimal (base 10) number to hexadecimal (base 16) is not easy to do in your head so it's best to use a calculator. The *Calculator* that is part of Windows has a *Programmer* mode that can be used to easily convert between decimal and hexadecimal. Open the *Calculator* program and select *View* > *Programmer*.



For our purposes here, select the *Word* data size. While *Dec* is selected, enter a decimal value. Then select *Hex* to convert the value to hexadecimal. To enter a negative decimal value, enter the value then click ±.

For example, enter 555 followed by ± for a -555 decimal. Select *Hex* and the display will change to FDD5. When writing hexadecimal values, the convention is to add a 0x prefix to the value so the example result would be written as 0xFDD5.