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Calibrating the MTA11200 System

INTRODUCTION

This application note analyzes the calibration algorithm from theoretical and numerical approaches. It includes two calibration procedures, including information on setting up lab equipment, board modifications and additional hardware for the TrueGauge calibration. Lastly, it includes the methodology for re-biasing the comparators for different voltage, current and temperature ranges.

This calibration procedure can be modified to perform calibration in an automated manufacturing/test environment.

This procedure assumes the user is familiar with the TrueGauge demo kit P/N DV114001, documentation, hardware, and TrueGauge assemblies. Also that the TrueGauge demo software programs "TG Demo" and "Calibration" have been installed in Windows™ and the hardware has been functionally tested.

Required Equipment:

1. TrueGauge demo software 2.0 or higher. TG Demo and Calibration programs
2. TrueGauge demo kit P/N DV114001, or equivalent assemblies
3. DMM 4 1/2 digit (a second DMM is preferred)
4. Power Supply 14V, 1A minimum
5. Precise resistance source such as a Decade Resistance Box, Temperature Calibration Block (described in this procedure) or user designed resistance network
6. Assorted test leads, banana and clip styles

References:

1. MTA11200 Intelligent Battery Management IC Data Sheet DS40104
2. TrueGauge MTA11200 Introduction Kit User's Guide DS40108

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Windows is a registered trademark of Microsoft Corporation.

Notes and Precautions:

1. This calibration procedure requires slight modification of the TrueGauge and Charger/Discharger board assemblies to simulate ideal battery and thermistor operation. The modifications should only be made by qualified personnel. Individual assemblies should not be interconnected during modification or prior to beginning the calibration procedure.
2. **When a power supply is used in place of a battery, the charger/discharger board must be kept in the discharge mode. If not, damage may occur to the power supplies and/or the charger/discharger board.**
3. The calibration accuracy is determined by tolerances determined by the users allowable limits with consideration of the test equipment tolerances, and deviation from the optimum values given.
4. The Temperature Calibration Block shown in the Appendix, is used in this description when performing thermistor calibration.
5. To enhance familiarization with the TrueGauge system it is recommended that the manual calibration be done before attempting the automated calibration.
6. Please read this application note entirely, from beginning to end, **before** attempting to calibrate a TrueGauge.

THE CALIBRATION SOFTWARE

The calibration source code is provided on the diskette in the TrueGauge demo kit P/N DV114001 and is also available on the Microchip BBS. Instructions for logging on to the BBS can be found in the *Microchip Data Book*, or the *Embedded Control Handbook*.

The TrueGauge installation procedure installs the Windows software and the calibration program which provides a more automated method of calibrating the modules. The calibration source code is written in QBASIC.

The manual calibration is performed using the TrueGauge demo Windows software. For purposes of explanation of the calibration process, the TrueGauge demo software is used to record the voltage, current and temperature readings corresponding to the known values. These known values were taken from the calibration source code, and represent optimum values.

The calibration program software is invoked by double-clicking on the "Calibration" icon in the TrueGauge program group. Upon doing so, a full DOS screen will appear. The user works in the bottom half of the screen to set up the appropriate calibration parameters.

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THEORY OF OPERATION

TrueGauge digitally integrates battery charge and discharge current to provide an accurate state of charge indication. The state of charge indicator depends on relative accuracy from one discharge cycle to the next. However, there are several parameters such as End of Discharge Voltage (EODV), and Maximum Fast Charge Temperature (MAXTFC) that are referenced to absolute voltage and temperature limits. TrueGauge's absolute accuracy is achieved via calibration of the comparators and their respective external components.

Each of the four comparators on the TrueGauge module uses a timed ramp for A/D conversion. Ideally, the ramps would have a slope of one and an offset, or y-intercept, of zero. However, because of component tolerances and drift, the ramp is not ideal. The calibration software uses the fundamental slope equation to calculate the calibration factors for each A/D.

$$y = mx + b$$

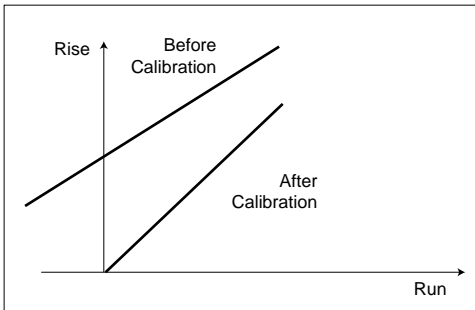
Slope "m" is first calculated by finding the difference between two points on the y-axis and dividing that value by the difference of two points on the x-axis.

$$m = (y_2 - y_1) / (x_2 - x_1)$$

Offset "b" is then calculated by rearranging the fundamental slope equation, where "y" is the known upper value and "x" is the corresponding value read and reported by TrueGauge.

$$b = y - mx$$

FIGURE 1 - SLOPE DIAGRAMS



The fundamental slope equation is expanded for voltage, current and temperature in the next section. Notice that the slope and y-intercept values are all scaled by 256₁₀ or 0100₁₆ or with an implied decimal point. This decimal point makes 256 equal to a slope of one. The hex values are stored in the EEPROM and used by the TrueGauge. However, the values are scaled by 256 in the demo software that runs in the Windows environment.

THE CALIBRATION HARDWARE

Charger/ Discharger Board

For a diagram of modifications to the Charger/Discharger Board, refer to drawing, "Charger/Discharger Board Calibration Modifications," in the Appendix section. To measure current, remove the resistor R7, 0.1 ohm from the charger/discharger board. R7 is physically located between the red and black banana jack connectors provided for ammeter connection. Retain the resistor for reinstallation after calibration.

Temperature Calibration Block

To perform thermistor calibration, it is recommended that the Temperature Calibration Block be constructed. Refer to the drawing, "Charger/Discharger Board Calibration Modifications". Before connecting the calibration block to the TrueGauge module the calibration resistance values must be set. The accuracy of the thermistor calibration is determined by the deviation from optimum values when adjusting the calibration block resistance's.

Adjusting the Calibration Resistance Values

Set the DMM to measure resistance and connect the test leads to the Temperature Calibration Block, at the TG T2 and the TG LD-/T1 connections. Select the resistance value to be adjusted using S1, and adjust R2 or R4 the 10 turn rheostat for 207807 ohms or 51058 ohms respectively.

TrueGauge Module

For a diagram of modifications to the TrueGauge Module for calibration, refer to drawing, "Diagram for TrueGauge Calibration," in the Appendix section. If the TrueGauge module has a battery attached, it must be disconnected and the power supply (V1) connected in its place. The power supply should initially be set to 0.0VDC, and connected to TrueGauge module. Connect the Positive lead to terminal LD+ and the negative lead to terminal LD-/T1, at the TrueGauge module or the calibration block.

MANUAL CALIBRATION OF THE TRUEGAUGE MODULE

This calibration procedure is performed using the TrueGauge demo software and is intended for familiarization of the concepts involved in calibrating a TrueGauge. This procedure does not calibrate the REFVAL parameter. As a precaution retain all initial calibration factors by updating them from the TrueGauge module and storing them to a hard disk in an .h8m file.

Calibrating the MTA11200 System

Calibration Setup

Review the manual calibration procedure and refer to the diagram for TrueGauge calibration setup drawing in the Appendix.

Connect the charger/discharger board to the +6.0VDC power supply and the RS232 cable between the charger/discharger board and the host computer.

Connect the TrueGauge module IDC connector and modular plug to the charger/discharger board, and verify that the mode switch on the charger/discharger board is in the discharge position.

Set the power supply to 0.0VDC, and connect the TrueGauge Module LD+ and LD-/T1 to power supply (V1) + and - then LD-/T1 and T2 to the Temperature Calibration Block.

Connect the ammeter to the banana jacks on the charger/discharger board. Note that because R7 has been removed, the current reading in the run window will be 0mA if the ammeter is not connected.

Set the power supply V1 voltage to +6.0VDC and start the TrueGauge demo program. Use setup and select the appropriate COM port, upload the EEPROM data from the TrueGauge module then select parameters and move to the advanced factors screen (refer to the User's Guide).

Calibration Procedure

Consider the following manual calibration as an example, which was performed on an uncalibrated TrueGauge module. The values uploaded or these example values may be used. When the values in the demo program advanced factors screen are changed, the EEPROM data will need to be unlocked and the new values downloaded to the TrueGauge module before they effect the displayed readings in the run mode window.

The uncalibrated slope and offset values displayed in the advanced factors screen of the demonstration software were as follows: (Note: slopes = 1 and offsets = 0).

ISC:	Current Slope	=	256	(1.0)
VOC:	Voltage Offset	=	0	(0.0)
VSC:	Voltage Slope	=	256	(1.0)
TOC:	Temp. Offset	=	0	(0.0)
TSC:	Temp. Slope	=	256	(1.0)
REFVAL:	A/D Refer.	=	32767	

The data table which corresponds to the Windows values is shown below. From the TrueGauge data sheet, the calibration value addresses are shown in Table 2.

As explained above, a slope value of 256 in this window is equivalent to a slope of one. This slope of one and y-intercept of zero are ideal values.

Using these addresses and the data in Table 1, the correspondence between the EEPROM data and the Windows values can be verified. This table may be viewed by using Windows Notepad. Invoke Notepad and open *Filename.h8m*.

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TABLE 1 - BREAK-OUT OF .H8M FILE CALIBRATION DATA

byte count	address	record type	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	check sum
10	0030	00	FF	7F	00	01	00	00	00	01	00	01	00	00	00	00	E0	2E	71
			REFVAL		VSC		VOC		ISC		TSC		TOC						

TABLE 2 - CALIBRATION PARAMETER ADDRESSES

ISC _{hh}	37 ₁₆	VOC _{hh}	35 ₁₆	VSC _{hh}	33 ₁₆	TOC _{hh}	3B ₁₆	TSC _{hh}	39 ₁₆	REFVAL _{hh}	31 ₁₆
ISC _{lh}	36 ₁₆	VOC _{lh}	34 ₁₆	VSC _{lh}	32 ₁₆	TOC _{lh}	3A ₁₆	TSC _{lh}	38 ₁₆	REFVAL _{lh}	30 ₁₆

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TABLE 3 - .H8M FILE PRIOR TO CALIBRATION

byte count	address	record type	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	check sum
10	0000	00	01	10	DB	AA	25	00	00	00	28	0A	28	0A	00	2F	00	00	B2
10	0010	00	5F	00	00	00	00	00	1A	10	0E	16	05	05	03	01	00	00	45
10	0020	00	04	00	01	01	00	00	00	00	00	10	80	00	49	A5	04	00	78
10	0030	00	FF	7F	00	01	00	00	00	01	00	01	00	00	00	00	E0	2E	71
10	0040	00	9A	DA	F3	FB	FD	FD	FD	FD	FD	FD	FD	FD	F1	CA	80	43	38
10	0050	00	FF	FF	FF	FF	FF	FF	FF	F5	EB	E1	D7	CC	B2	B8	AE	A3	D8
10	0060	00	06	00	0B	00	13	00	21	00	3B	00	68	00	C9	00	48	01	16
10	0070	00	42	02	03	04	1B	07	95	0C	48	16	74	27	DE	45	B8	76	A6
00	0000	01	FF																

Once the advanced factors values are selected, enter the Run mode, after each setting read and record the resulting values that the TrueGauge Module reports via the Windows demo software.

Disconnect the ammeter from the charger/discharger board. Note that because R7 has been removed, the Current reading in the Run window will be 0mA if the ammeter is not connected. Set the DMM to read DC volts.

Set the power supply to +6.0VDC and record the voltage reported by the TrueGauge as v_1' . Refer to the flowchart in the Appendix.

Next set the power supply to +14.0VDC and record the voltage reported by the TrueGauge as v_2' . Return the power supply V1 voltage to +6.0VDC, and disconnect the DMM.

Reset the DMM to read current and reconnect the ammeter to the banana jacks on the charger/discharger board. Note that the current reading in the Run window will indicate some value when the ammeter is connected.

Adjust the discharge potentiometer on the charger/discharger board, set the current to 0mA and -900mA reading on the ammeter and record the values for current reported by the TrueGauge as i_2' and i_1' , respectively. (Note: a typical current reading in the discharge mode with current set for minimum is -15mA, if this occurs set both charger/discharger potentiometers to minimum then switch the mode switch to charge and adjust for 0mA reading on the ammeter. Return to the discharge mode as soon as an accurate reading is recorded).

Simulate the thermistor by selecting the resistor network using the Temperature Calibration Block S1, to known values of 51058 ohms and 207807 ohms for 40°C and 10°C respectively. Read the resulting values that the TrueGauge reports via the Windows demo software and record as t_1' and t_2' .

The values from the readings noted are applied to mathematical formulas. These formulas are extracted directly from the calibration source code. These calculations become the new slope and offset values.

VOLTAGE: VSC AND VOC

Note: The known upper and lower ramp voltage values were found in the "Calibrate Voltage" function of the calibration source code. The corresponding voltage values as reported by the TrueGauge module were read from the display screen of the Windows demo software.

v_2 = Applied known upper ramp voltage = 14.00 volts

v_1 = Applied known lower ramp voltage = 6.00 volts

v_2' = Reported voltage reading when 14.00 volts is applied

v_1' = Reported voltage reading when 6.00 volts is applied

$$m = ((v_2 - v_1) / (v_2' - v_1')) * 256$$

$$m = ((14000\text{mV} - 6000\text{mV}) / (14972\text{mV} - 6391\text{mV})) * 256$$

$$m = ((8000\text{mV}) / (8581\text{mV})) * 256$$

$$\text{VSC} = m_v = 238.67 = 239$$

$$b = v_2 - (m * v_2') / 256$$

$$b = 14000\text{mV} - (238.67 * 14972\text{mV}) / 256$$

$$b = 14000\text{mV} - 13958.28\text{mV}$$

$$\text{VOC} = b_v = 41.72 = 42$$

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CURRENT : ISC

Note: The known upper and lower ramp current values were found in the "Calibrate Current" function of the calibration source code. The corresponding current values were read from the display screen of the Windows demo software.

i_2 = Applied known upper ramp current = -900mA

i_1 = Applied known lower ramp current = 0mA

i_2' = Reported current reading corresponding to i_2 = -1088mA

i_1' = Reported current reading corresponding to i_1 = 0mA

$$m = ((i_2 - i_1) / (i_2' - i_1')) * 256$$

$$m = ((-900\text{mA} - 0\text{mA}) / (-1088\text{mA} - 0\text{mA})) * 256$$

$$m = ((-900\text{mA}) / (-1088\text{mA})) * 256$$

$$\text{ISC} = m_i = 211.76 = 212$$

TEMPERATURE: TSC AND TOC

Note: The known upper and lower ramp temperature/resistance values were found in the "Calibrate Temperature" function of the calibration source code. The two resistance values were used in place of the thermistor to simulate the thermistor at 10°C and 40°C. The corresponding temperature values were read from the display screen of the Windows demo software.

t_2 = Applied known upper ramp temperature = 10°C

t_1 = Applied known lower ramp temperature = 40°C

t_2' = Reported temperature reading corresponding to t_2 = 182°C-256°C = -74°C

t_1' = Reported temperature reading corresponding to t_1 = 218°C-256°C = -38°C

$$m = ((t_2 - t_1) / (t_2' - t_1')) * 256$$

$$m = ((10^\circ\text{C} - 40^\circ\text{C}) / (-74^\circ\text{C} - (-38^\circ\text{C}))) * 256$$

$$m = ((-30^\circ\text{C}) / (-36^\circ\text{C})) * 256$$

$$\text{TSC} = m_t = 213.33 = 213$$

$$b = ((t_2 - ((m/256) * t_2')) * 256$$

$$b = (10^\circ\text{C} - ((.833) * (-74^\circ\text{C}))) * 256$$

$$b = (10^\circ\text{C} - (-61.6^\circ\text{C})) * 256$$

$$\text{TOC} = b_t = 18329.6 = 18330$$

The newly calibrated slope and offset values should then be input in the advanced factors screen (refer to the User's Guide) of the demonstration software running in Windows.

ISC: Current Slope = 212

VOC: Voltage Offset = 42

VSC: Voltage Slope = 239

TOC: Temp. Offset = 18330

TSC: Temp. Slope = 213

REFVAL: A/D Refer. = 32589

Upon performing a download with these new calibration factors to the EEPROM, the values would be reflected in the data table (Table 2).

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TABLE 4 - .H8M FILE AFTER CALIBRATION AND DOWNLOADING TO EEPROM

byte count	address	record type	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	check sum
10	0000	00	01	10	DB	AA	25	00	00	00	28	0A	28	0A	00	2F	00	00	B2
10	0010	00	5F	00	00	00	00	00	1A	10	0E	16	05	05	03	01	00	00	45
10	0020	00	04	00	01	01	00	00	00	00	10	80	00	49	A5	04	00	78	
10	0030	00	4D	7F	EF	00	2A	00	D4	00	D5	00	9A	47	00	00	E0	2E	71
10	0040	00	9A	DA	F3	FB	FD	FD	FD	FD	FD	FD	FD	FD	F1	CA	80	43	38
10	0050	00	FF	FF	FF	FF	FF	FF	FF	F5	EB	E1	D7	CC	C2	B8	AE	A3	D8
10	0060	00	06	00	0B	00	13	00	21	00	3B	00	68	00	B9	00	48	01	16
10	0070	00	42	02	03	04	1B	07	95	0C	48	16	74	27	DE	45	B8	76	A6
00	0000	01	FF																

Verify the TrueGauge readings in the run mode using the method described earlier. Confirm that the voltage, current, and temperature readings are within the users tolerances. If needed, the slope and offset calculations may be calculated.

When calibration is complete, use the Lock EEPROM command to protect the values, then exit out of the demo program. The test equipment, TrueGauge module and charger/discharger board may be de-energized and disconnected. Reconnect the battery and a thermistor to the TrueGauge module, reinstall R7 into the charger/discharger board.

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THE AUTOMATED CALIBRATION

The calibration exercise in the previous section was performed manually using the TrueGauge demo Windows software. However, the installation procedure also installs a calibration program which provides a more automated method of calibrating the modules.

Calibration Setup

Review this procedure and refer to the diagrams in the Appendix.

Connect the charger/discharger board to the wall power supply, and the RS232 cable between the charger/discharger board and the host computer.

Connect the TrueGauge module IDC connector and modular plug to the charger/discharger board, and verify that the mode switch on the charger/discharger board is in the discharge position.

Set the power supply to 0.0VDC, and connect the TrueGauge module LD+ and LD-/T1 to power supply (V1) + and - then LD-/T1 and T2 to the Temperature Calibration Block.

Connect the ammeter to the banana jacks on the charger/discharger board. Note that because R7 has been removed, the current reading in the run window will be 0mA if the ammeter is not connected.

Set the power supply V1 voltage to +6.0VDC and start the calibration program.

The calibration software is invoked by double-clicking on the "Calibration" icon in the TrueGauge program group. Upon doing so, a full DOS screen will appear. A reproduction of the bottom halves of the screens appear below. The user works in the bottom half of the screen to set up the appropriate calibration parameters.

```
Setup  Begin  Set NP  Voltage  Current  Temp  End  Restore  Quit
Initialize Calibration Options
    1.  Open calibration result log file (optional).
    2.  Select comm port.
    3.  Open EEPROM data file (optional).
    4.  Specify load for current calibration (optional).
<Enter=Initialize>      <Tab=skip to Next>      <Back Tab=skip to Previous>
```

Initialization is started when the user presses the <ENTER> key.

Upon pressing <ENTER>, the screen will read:

```
Setup  Begin  Set NP  Voltage  Current  Temp  End  Restore  Quit
  
Open a calibration result log file.
  

<Enter=Open>      <Tab=skip to Next>      <Back Tab=skip to Previous>
```

Press the <ENTER> key again, the screen will read:

```
Setup  Begin  Set NP  Voltage  Current  Temp  End  Restore  Quit
  
Open a calibration result log file.
Enter results log filename:
  

<Enter=Open>      <Tab=skip to Next>      <Back Tab=skip to Previous>
```

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In this screen, the software is prompting the user to set up a file to store the results of calibration. This file stores the part serial number and the calibration values in a single file which is appended with new values from each separate calibration sequence.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Enter COM port number (1, 2, 3 or 4).								
<1, 2, 3 or 4=Port Number>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

In this screen, the calibration software is asking to be referred to the COM port which the charger/discharger board is attached to. This is so that communication may be established with the TrueGauge module.

TYPE : The COM port number to which the TrueGauge is attached. Upon doing so, the screen will then read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Open an EEPROM initialization data file.								
<Enter=Open>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

Press the <ENTER> key again, the screen will read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Open an EEPROM initialization data file.								
Enter EEPROM DATA filename:								
<Enter=Open>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

In this screen, the software is prompting the user to specify a default file for TrueGauge module(s) to be calibrated.

TYPE: *Filename* (this is an optional filename) If filename is not specified the screen will display an alarm message.

Press the <ENTER> key the screen will read:

(If the alarm message occurs press <ENTER> a second time).

This default file will initialize the entire EEPROM with the data contained in the file. The A/D calibration factors contained in this file will set all of the A/D gain values to one and offsets to zero, thus facilitating the simple mathematical formulas shown in the Manual Calibration section in this document.

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TYPE: *Filename.h8m*

Press the <ENTER> key.

If the file does not exist the screen will display an alarm message.

Press the <ENTER> key again, the screen will read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Open an EEPROM initialization data file.								
<Enter=Open> <Tab=skip to Next> <Back Tab=skip to Previous>								

Press the <TAB> key, the screen will read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Change reference load (1000 milliamps) for Current Calibration.								
<Enter=Change> <Tab=skip to Next> <Back Tab=skip to Previous>								

Press the <ENTER> key again, the screen will read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Change reference load (1000 milliamps) for Current Calibration.								
Enter new load in milliamps:								
<Enter=Change> <Tab=skip to Next> <Back Tab=skip to Previous>								

If the power supply used in the lab setup is incapable of outputting -1000 mA of current, the reference load should be changed.

If <TAB> is pressed, the reference load will default to -1000 mA, and the software will jump ahead to the "start calibration" screen. Otherwise, the user can lower this value to one that the power supply can deliver.

If <ENTER> is pressed, the screen will read:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Enter new load in milliamps:								
<Enter=Open> <Tab=skip to Next> <Back Tab=skip to Previous>								

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TYPE: the new value as a positive number, the program will change this to a negative value, to indicate *discharge* current.

Press: <ENTER>. The software will then proceed to the next screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Start Calibration Sequence								
1. Specify part number.								
2. Verify broadcast mode is off.								
3. Verify comm link to TrueGauge is operational.								
4. Load current calibration factors.								
<Enter=Start> <Tab=skip to Next> <Back Tab=skip to Previous>								

In this screen, the software is waiting for the user to begin calibration, which starts when the user presses the <ENTER> key. Upon pressing the <ENTER> key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Enter part/serial number:								

The user must enter a number to identify the module being calibrated.

The length may vary from one to eight characters.

After entering the number,

Press: <ENTER>. The screen will begin a routine which will display this information:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Checking for broadcast enabled. Broadcasting is disabled.								
Unlocking EEPROM. EEPROM Unlocked.								
Reading battery data.								
Uploading original calibration factors: [*****]								

In this screen, the software is informing the user of the status for different operations which are being performed in preparation for calibration. The software will always disable broadcast. If it is not disabled, the software will proceed to disable it. EEPROM unlocking will then take place so that new calibration factors can be

written to the EEPROM. Finally, the software reads and uploads the original calibration values which are currently in the EEPROM. Upon completed uploading of these calibration factors, the software will proceed to the next screen.

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Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	---------------	---------	---------	------	-----	---------	------

Set Normalization Point.

<Enter=Set NP> <Tab=skip to Next> <Back Tab=skip to Previous>

In this screen, the software is prompting the user to set the normalization point. This is an A/D reference point, and is typically set once, at the beginning of a calibration. It is reflected as the numerical value stored in REFVAL of the Windows demo software, and is a representation of the time value for REFC input to TrueGauge. Once set, the normalization point compensates for any changes

in TrueGauge module components over time and temperature. During normal operation, the present measured value for REFC is compared with the stored value in the EEPROM, and the ISENC, BATVC and TEMPC TrueGauge inputs are each compensated by the difference in the measured versus stored REFC values. Press : The <ENTER> key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	---------------	---------	---------	------	-----	---------	------

Setting normalization point. One moment, please.
Resetting TrueGauge. One moment, please.
Reset successful.
Unlocking EEPROM. EEPROM Unlocked.

The normalization point should be set immediately before calibrating. Calibration should not be done without first setting the normalization point. This is because the REFC input is used to compensate for changes in components over time and temperature. If new calibra-

tion values are being offset by a REFC delta which was established at a different time in the life of the TrueGauge module, optimal accuracy will not be achieved. The software will then proceed to the next screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	----------------	---------	------	-----	---------	------

Calibrate voltage.

<Enter=Calibrate> <Tab=skip to Next> <Back Tab=skip to Previous>

In this screen, the software is prompting the user to begin calibrating the voltage parameters. Upon pressing the <ENTER> key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	----------------	---------	------	-----	---------	------

Initializing correction factors. One moment, please: [**]**
Set voltage to 6.000 volts then hit any key.

Calibrating the MTA11200 System

In this screen, the software is prompting the user to adjust the power supply to +6.0VDC, which is the lower end of the voltage slope defined by the formulas in the program. Upon setting the power supply to six volts and pressing any key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	----------------	---------	------	-----	---------	------

Set voltage to 14.000 volts then hit any key.

Upon setting the power supply to +14.0VDC, which is the upper end of the voltage slope defined by the formulas in the program, and pressing any key. The

software takes the inputs and their corresponding reading applies slope and intercept formulas to the numbers, deriving new calibration factors. The screen then reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	----------------	---------	------	-----	---------	------

Storing new correction factors. One moment, please: [**]**
Read battery data.

In this screen, the software is informing the user that the new voltage calibration parameters are being loaded to the EEPROM. The software will then proceed to the next screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	---------	----------------	------	-----	---------	------

Calibrate Current.

<Enter=Calibrate> <Tab=skip to Next> <Back Tab=skip to Previous>

In this screen, the software is prompting the user to begin calibrating the current parameters. Upon pressing the <ENTER> key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	---------	----------------	------	-----	---------	------

Calibrate Current.
Initializing correction factors. One moment, please: []**
Set current to 0mA then hit any key (Hit Esc to Quit).

Calibrating the MTA11200 System

In this screen, the software is prompting the user to move the slide switch on the charger/discharger board to the "sleep" position for a moment to achieve a zero current reading. This switch must be returned to the discharge pin very quickly (before the next polling cycle).

If not, the software will report that it is unable to communicate with the TrueGauge, and calibration will have to be restarted. Upon doing so and pressing any key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Set current to - xxxx mA then hit any key.								

Note: (xxxx = value entered earlier)

Upon setting the discharge potentiometer on the charger/discharger board to obtain the specified current (observed on the DMM) and pressing any key, the software

takes the inputs and their corresponding reading and applies slope and intercept formulas to the numbers, deriving new calibration factors. The screen then reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Storing new correction factors. One moment, please: [**] Reading battery data.								

In this screen, the software is informing the user that the new current calibration parameters are being loaded to the EEPROM. The software will then proceed to the next screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
 Calibrate Temperature.								
<Enter=Calibrate>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

Calibrating the MTA11200 System

In this screen, the software is prompting the user to begin calibrating the temperature parameters.

Press the <ENTER> key , the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	---------	---------	-------------	-----	---------	------

Initializing correction factors. One moment, please: [**]**
Set thermistor to 51058 Ω then hit any key.

In this screen, the software is prompting the user to move the toggle switch shown on the Temperature Calibration Block to the position which selects the 51058 ohm resistor. Upon doing so and pressing any key, the screen reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	---------	---------	-------------	-----	---------	------

Initializing correction factors. One moment, please: [**]**
Set thermistor to 51058 Ω then hit any key.
Set thermistor to 207807 Ω then hit any key.

The software is now prompting the user to move the toggle switch to the position which selects the 207807 ohm resistor. Upon doing so the software takes the inputs and their corresponding readings and applies slope and intercept formulas to the numbers, deriving new calibration factors. These two resistance measurements were taken from the specification for the ther-

mistor which is included with the TrueGauge module in the development kit. 207807 ohms corresponds to a temperature of 10°C and 51058 ohms to a temperature of 40°C. Upon doing so the software takes the inputs and their corresponding readings and applies slope and intercept formulas to the numbers, deriving new calibration factors. The screen then reads:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
-------	-------	--------	---------	---------	-------------	-----	---------	------

Storing new correction factors. One moment, please: [**]**
Reading battery data.

Calibrating the MTA11200 System

In this screen, the software is informing the user that the new temperature calibration parameters are being loaded to the EEPROM. The software will then proceed to the next screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
End Calibration.								
<Enter=End Calibration>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

In this screen, the software is prompting the user to end calibration. Pressing the <Enter> key will end calibration. The screen then changes to:

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
End Calibration.								
Locking EEPROM.								
<Enter=End Calibration>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

This screen completes storage of the new calibration parameters to the TrueGauge EEPROM. The screen then changes to the "Start Calibration Sequence" screen.

Setup	Begin	Set NP	Voltage	Current	Temp	End	Restore	Quit
Start Calibration Sequence								
1. Specify part number.								
2. Verify broadcast mode is off.								
3. Verify comm link to TrueGauge is operational.								
4. Load current calibration factors.								
<Enter=Start>			<Tab=skip to Next>			<Back Tab=skip to Previous>		

Press the <TAB> key until the Quit option is highlighted and appears in the window then press the <ENTER> key. This ends this procedure.

Verify the TrueGauge readings in the run mode using the method described earlier. Confirm that the voltage, current, and temperature readings are within the users tolerances. If needed, the slope and offset calculations may be calculated.

When the actual readings are within tolerance, use the Lock EEPROM command to protect the values, then exit out of the demo program. The test equipment, TrueGauge Module and charger/discharger board may be de-energized and disconnected. Reconnect the battery and a thermistor to the TrueGauge module, reinstall R7 into the charger/discharger board.

COMPARATOR BIASING FOR UNIQUE A/D RANGING

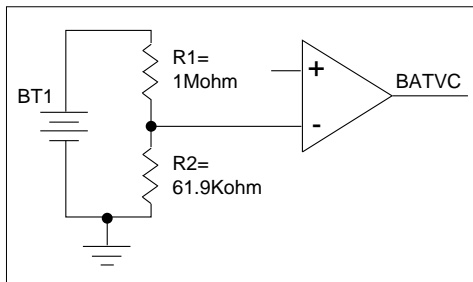
Minimum and maximum voltage biases configured in the present design at the comparator inputs are provided in Table 5. Individual explanations of these bias voltages will follow. Input common-mode voltage for the comparator used on the TrueGauge module is:

$$V_{DD}-1.5\text{volts}=3.5\text{volts}$$

This common mode voltage information was used to determine the bias voltage ranges for the comparators as shown in Table 5.

The TrueGauge module schematic included in the data sheet has been biased for a certain parameter range. Individual comparator biasing can be adjusted to accommodate special cases.

FIGURE 2 - VOLTAGE COMPARATOR SCHEMATIC



In Figure 2, the voltage divider of R1 and R2 was selected for a highest allowable battery voltage of 64 volts.

$$Voltage_{max} = (61.9K\Omega / (1M\Omega + 61.9K\Omega)) * 64 \text{ volts} = 3.7 \text{ volts}$$

$$Voltage_{min} = (61.9K\Omega / (1M\Omega + 61.9K\Omega)) * 2.7 \text{ volts} = .16 \text{ volts}$$

3.7 volts is on the high end of the linear comparator input curve. If a higher battery voltage is desired, this voltage divider must be recalculated to maintain proper comparator biasing.

In Figure 3, the bias voltage is calculated as shown below:

$$Voltage_{bias} = (572K\Omega / (1M\Omega + 572K\Omega)) * 5 \text{ volts} = 1.8 \text{ volts}$$

The .1ohm current sense resistor and battery can be modeled as a voltage source, such as the one shown in Figure 3. As current flows into the positive terminal of the battery during charge, a "c (charging)" voltage is developed across R6. Alternately, as current flows out of the battery during discharge, a "d (discharging)" voltage is developed. To maintain minimal power loss, the voltage drop across R6 was designed to equal plus/minus .5 volts. By applying the same voltage divider to this voltage as was applied to the SWVCC voltage, and applying Kirchoff's Voltage Law, it is shown that the input pin to the comparator is kept between 1.62 to 1.98 volts. This configuration facilitates 1mA A/D resolution.

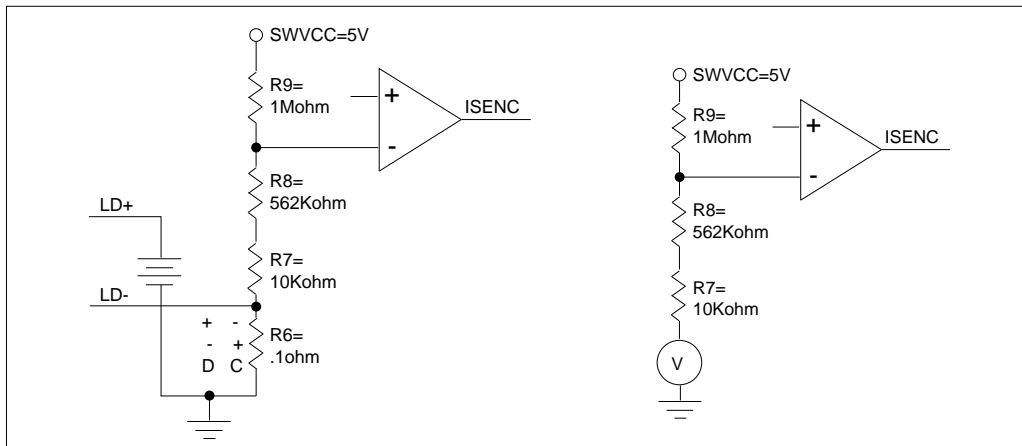
By applying Ohm's law:

$$I = .5\text{volts} / .1\Omega = 5A$$

TABLE 5 - BIAS LIMITS FOR COMPARATORS IN DEVELOPMENT KIT CONFIGURATION

	Voltage Comparator	Current Comparator	Temperature Comparator
Voltage _{Max}	3.7 Volts	1.98 Volts	1.5 Volts
Voltage _{Min}	.16 Volts	1.62 Volts	.022 Volts

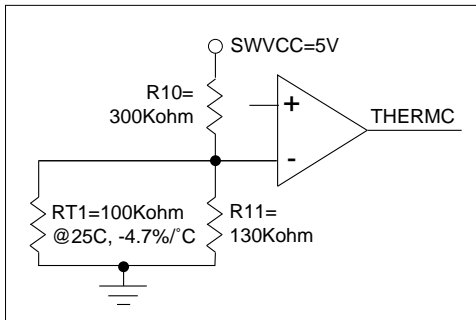
FIGURE 3 - CURRENT COMPARATOR SCHEMATIC



Calibrating the MTA11200 System

Therefore, to boost the current range for the TrueGauge, the current sense resistance must be reduced. For example, a current range of 10 amps could be achieved by setting $R6 = .05\text{ohm}$. However, this will only allow 2mA A/D resolution.

FIGURE 4 - TEMPERATURE COMPARATOR SCHEMATIC



Refer to Figure 4 for the following explanation.

Per the thermistor specification, the highest calculated temperature/resistance values are:

-55°C	12,162,871Ω
150°C	1358Ω

Calculating the equivalent parallel resistance of RT1 and R11 at these temperature limits, the following values were found:

$$R_{-55^{\circ}\text{C}} = 128,625\Omega$$
$$R_{150^{\circ}\text{C}} = 1,344\Omega$$

Finally, using these equivalent resistances, the upper and lower points on the input voltage curve can be calculated.

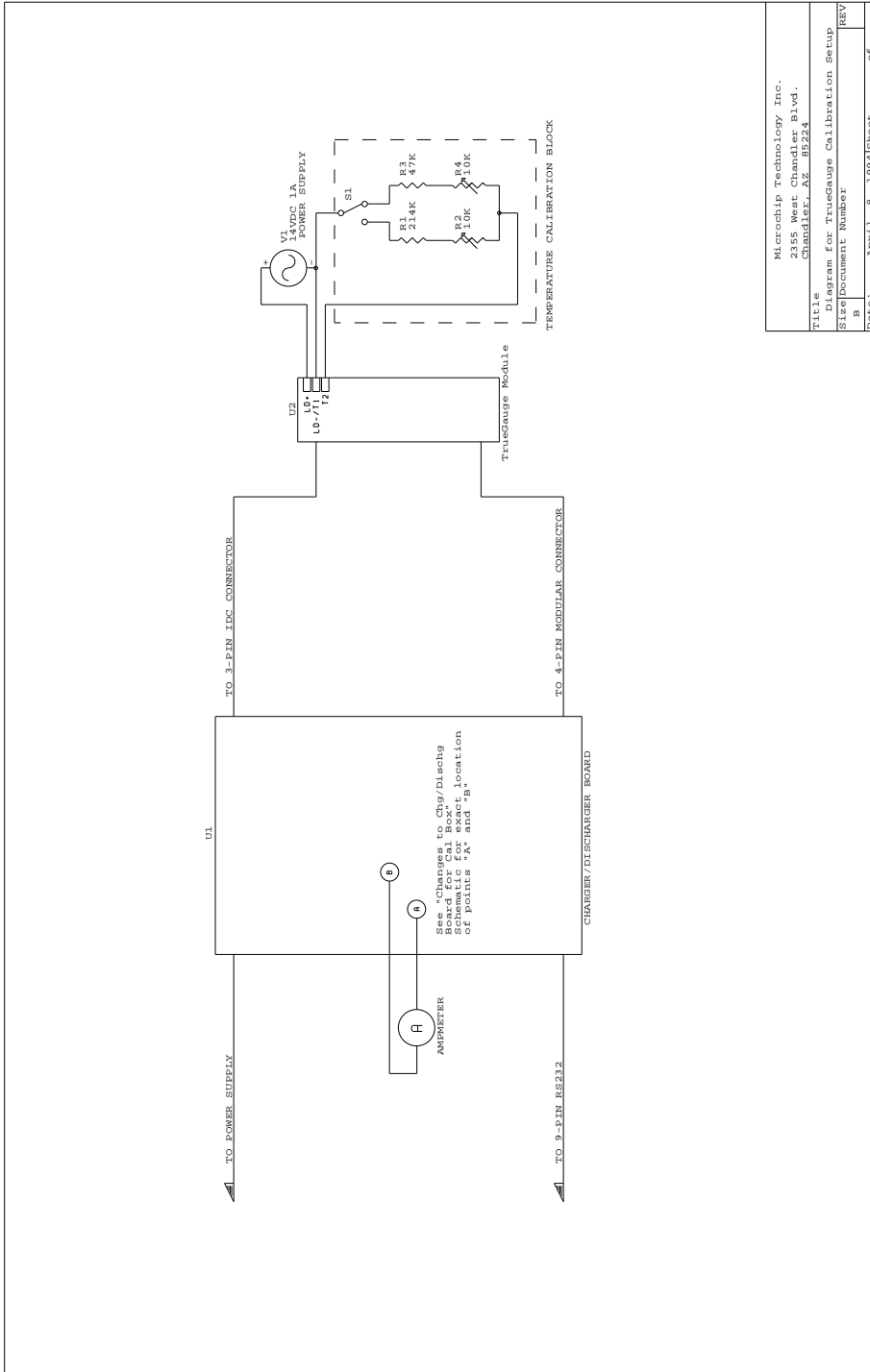
$$\text{Voltage}_{\text{max}} = (128,625\Omega / (300\text{K}\Omega + 128,625\Omega)) * 5 \text{ volts} = 1.5 \text{ volts}$$

$$\text{Voltage}_{\text{min}} = (1,344\Omega / (300\text{K}\Omega + 1,344\Omega)) * 5 \text{ volts} = .022 \text{ volts}$$

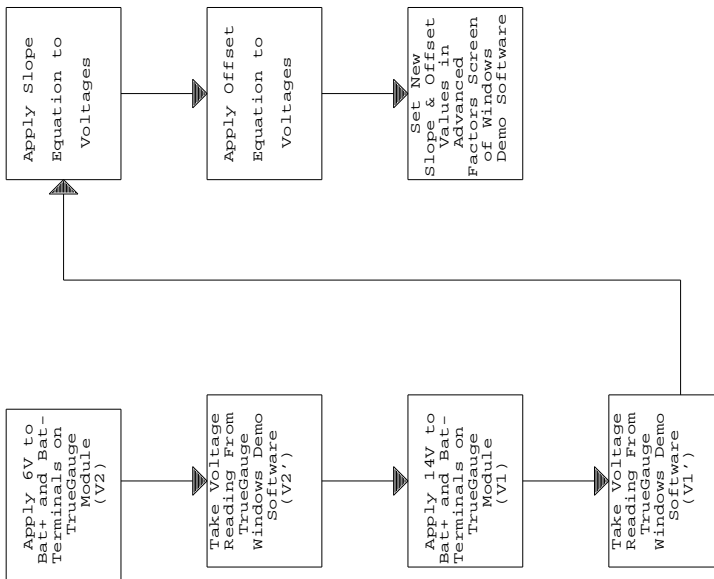
CONCLUSION

Calibration of the TrueGauge is very versatile. The operation is simple enough that it can be performed with a minimum amount of equipment in a lab environment. However it is also flexible enough to allow fully automated batch calibration in a manufacturing environment.

Calibrating the MTA11200 System



Microchip Technology Inc. 2355 West Chandler Blvd. Chandler, AZ 85224	
TITLE	Diagram for TrueGauge Calibration Setup
SIZE	Document Number
REV	B
DATE	April 8, 1994
SHEET	1 of 1



Microchip Technology Inc. 2355 W. Chandler Blvd. Chandler, AZ 85224	
Title TrueGauge Calibration Flowchart	
Size A	REV
Date: March 30, 1994	Sheet of

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