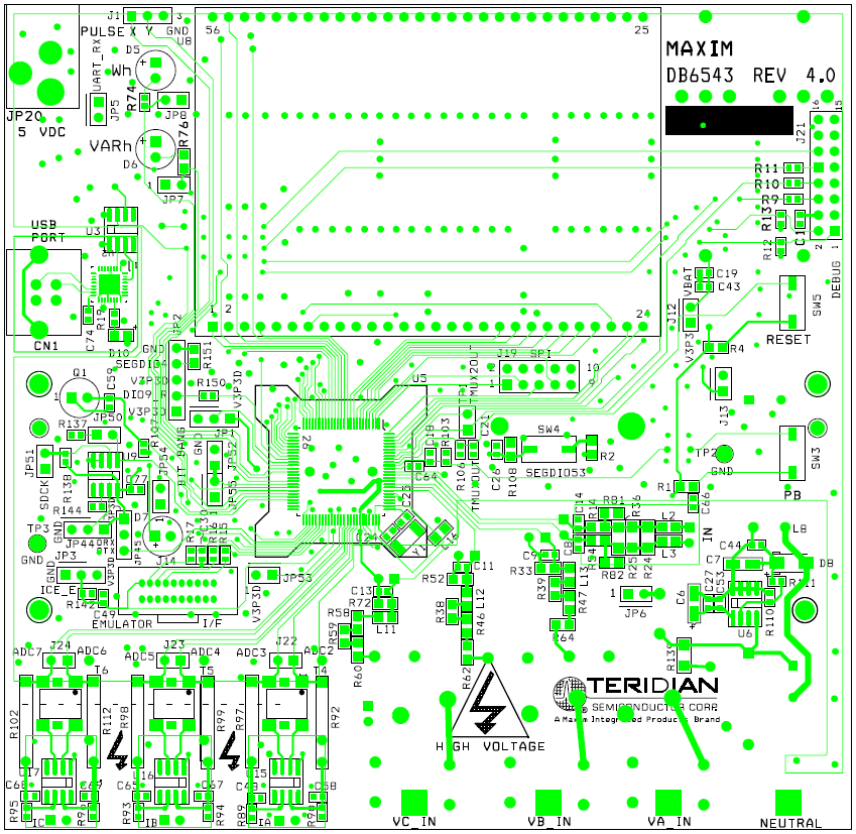
Teridian Smart Grid Solutions

71M6543 Demo Board

USER'S MANUAL



Teridian Smart Grid Solutions

71M6543

Polyphase Energy Meter IC

DEMO BOARD REV 4.0 and 5.0

USER'S MANUAL

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1 GETTING STARTED

1.1 GENERAL

The Teridian™ 71M6543 REV 4.0 and REV 5.0 Demo Boards are demonstration boards for evaluating the 71M6543F device for polyphase electronic power metering applications in conjunction with the Remote Sensor Interface or CT sensors. The Demo Boards allow the evaluation of the 71M6543F energy meter chip for measurement accuracy and overall system use.

The 71M6543 REV 4.0 Demo Board incorporates a 71M6543F integrated circuit, three 71M6103 or 71M6203 Remote Interface ICs, peripheral circuitry such as a serial EEPROM, emulator port, and on-board power supply, as well as a USB interface for serial communication with a PC.

The 71M6543 REV 5.0 Demo Board is optimized and prepared for the connection of external CTs and is otherwise identical to the REV 4.0 Demo Board.

All Demo Boards are pre-programmed with a Demo Program (Demo Code) in the FLASH memory of the 71M6543F IC. This embedded application is developed to exercise all low-level function calls to directly manage the peripherals, flash programming, and CPU (clock, timing, power savings, etc.).

The 71M6543F IC on the REV 4.0 Demo Board is pre-programmed and pre-calibrated for the 50 µΩ or 120 µΩ shunts shipped with the board. The Demo Board may also be used for operation with a CT after hardware modifications that can be performed by the user. This configuration will require a different version of the Demo Code and different settings. It should be noted that the 71M6543 performs better with CTs when used with the 71M6543 REV 5.0 Demo Board.

1.2 SAFETY AND ESD NOTES

Connecting live voltages to the demo board system will result in potentially hazardous voltages on the demo board.

THE DEMO SYSTEM IS ESD SENSITIVE! ESD PRECAUTIONS SHOULD BE TAKEN WHEN HANDLING THE DEMO BOARD!

EXTREME CAUTION SHOULD BE TAKEN WHEN HANDLING THE DEMO BOARD ONCE IT IS CONNECTED TO LIVE VOLTAGES! BOARD GROUND IS CLOSE TO LIVE VOLTAGE!

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1.3 DEMO KIT CONTENTS

- 71M6543 Demo Board REV 4.0 with three 71M6203 or 71M6103 ICs and one 71M6543F IC with pre-loaded demo program, or 71M6543 Demo Board REV 5.0 with inputs configured for CTs.
- 5VDC/1,000mA universal wall transformer with 2.5mm plug (Switchcraft 712A compatible)
- USB Interface Module (USB/Serial Adapter)
- USB cable
- ANSI base with three 50 µΩ shunt resistors, Oswell P/N EBSB20050H-92-19-73-6.4-V1 (optional, for ANSI kits only)
- Three 120 µΩ shunt resistors, Oswell P/N EBSA15120-32-14.8-21-6.2-V1 (optional, for IEC kits)

1.4 DEMO BOARD VERSIONS

The following versions of the Demo Board are or have been available:

- 71M6543 Demo Board Rev 1.0 (CTs only) - **discontinued**
- 71M6543 Demo Board Rev 2.0 (CTs or 71M6103 Remote Sensor Interface ICs on daughter boards) - **discontinued**
- 71M6543 Demo Board Rev 3.0 (71M6103 Remote Sensor Interface ICs) - **discontinued**
- 71M6543 Demo Board Rev 4.0 (71M6103 Remote Sensor Interface ICs)
- 71M6543 Demo Board Rev 5.0 (CTs or 71M6103 Remote Sensor Interface ICs

This manual applies to **71M6543 Rev 4.0 and Rev 5.0** only. For the earlier Demo Board revisions please see their respective manuals.

1.5 COMPATIBILITY

This manual applies to the following hardware and software revisions:

- 71M6543F IC revision B02.
- Demo Code revision 5.4F or later
- 71M6543 Demo Board Rev 4.0 or Rev. 5.0

1.6 SUGGESTED EQUIPMENT NOT INCLUDED

For functional demonstration:

PC with Microsoft Windows® versions Windows XP®, ME, or 2000, equipped with RS-232 port (COM port) via DB9 connector

For software development (MPU code):

Signum ICE (In Circuit Emulator): ADM-51

www.signum.com

Signum WEMU51 version 3.11.09 or later should be used. Using a USB isolator between PC and the Signum ADM-51 is strongly recommended

Keil 8051 "C" Compiler kit: CA51

www.keil.com/c51/ca51kit.htm, www.keil.com/product/sales.htm

Windows and Windows XP are registered trademarks of Microsoft Corp.

1.7 DEMO BOARD TEST SETUP

Figure 1-1 shows the basic connections of the Demo Board REV 4.0 plus optional Debug Board with the external equipment. The PC should be connected via the USB Interface (CN1). Communication can also be established via the optional Debug Board, but this board is not part of the Demo Kit.

For stand-alone testing (without AC voltage) the Demo Board maybe powered via the 5.0 VDC input (J20). The optional Debug Board must be powered with its own 5 VDC power supply.

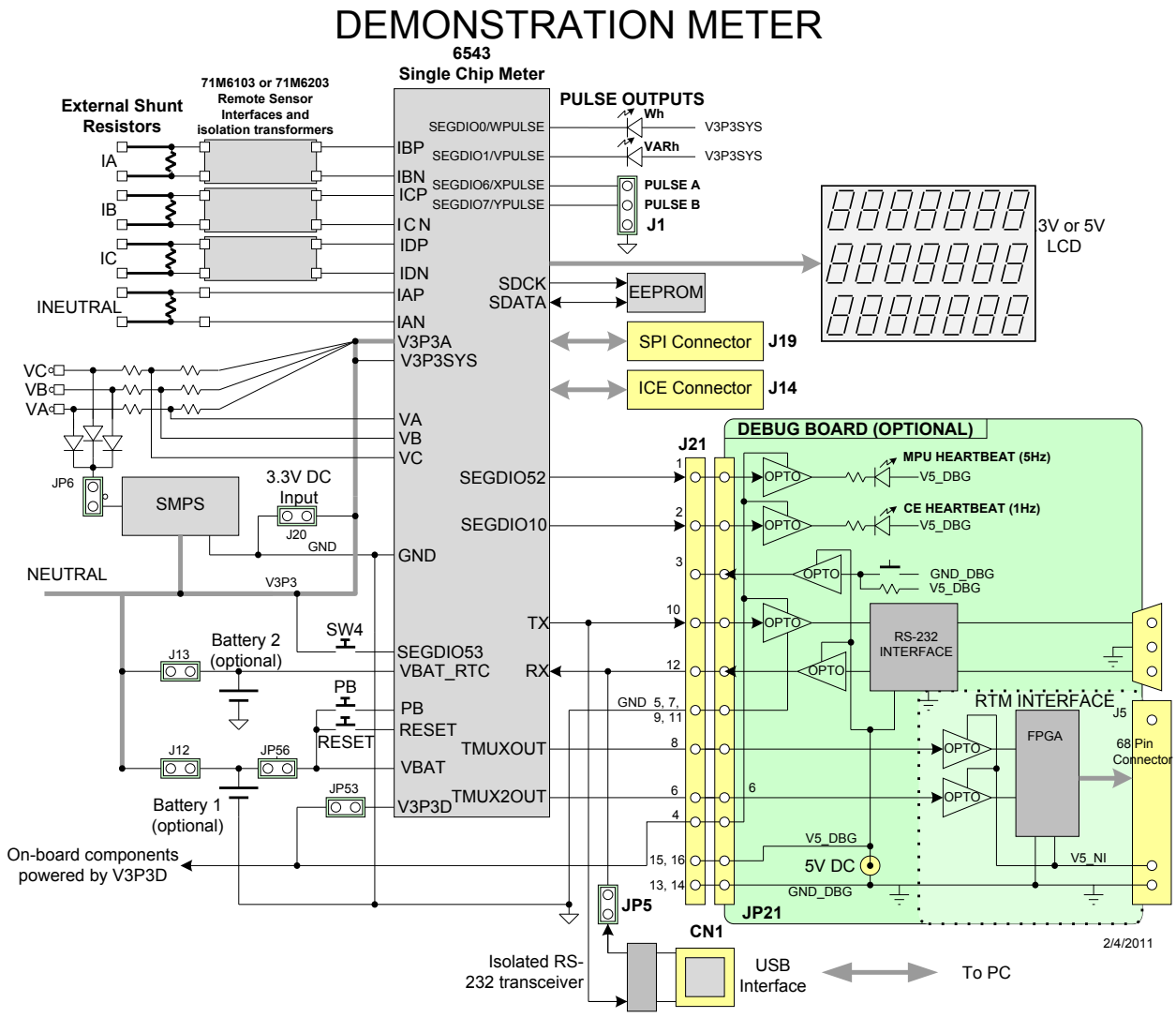

Figure 1-1: Teridian 71M6543 REV4.0 Demo Board with Debug Board: Basic Connections

The Demo Board contains all circuits necessary for operation as a meter, including display, calibration LEDs, and internal power supply. The optional Debug Board uses a separate power supply, and is optically isolated from the Demo Board. It interfaces to a PC through a 9 pin serial port connector.

It is recommended to set up the demo board with no live AC voltage connected, and to connect live AC voltages only after the user is familiar with the demo system.

All input signals are referenced to the V3P3A (3.3V power supply to the chip).

1.7.1 POWER SUPPLY SETUP

There are several choices for the meter power supply:

- Internal (using the AC line voltage). The internal power supply is only suitable when the voltage exceeds 100V RMS. To enable the internal supply, a jumper needs to be installed across JP6 on the top of the board.
- External 5.0 VDC connector (JP20) on the Demo Board.

1.7.2 CABLES FOR SERIAL COMMUNICATION

It is recommended to use the USB connection to communicate with the Demo Code. The optional Debug Board is not normally shipped with the Demo Kit and requires a serial port (DB9) on the PC along with a separate power supply.

1.7.2.1 USB Connection

A standard USB cable can be used to connect the Demo Board to a PC running HyperTerminal or a similar serial interface program. A suitable driver, e.g. the FTDI CDM Driver Package, must be installed on the PC to enable the USB port to be mapped as a virtual COM port. The driver can be found on the FTDI web site (http://www.ftdichip.com/Drivers/D2XX.htm).

See Table 3-1 for correct placement of jumper JP5 depending on whether the USB connection or the serial connection via the optional Debug Board is used.

1.7.2.2 Serial Connection (Optional)

For connection of the DB9 serial port of the Debug Board to a PC serial port (COM port), either a straight or a so-called "null-modem" cable may be used. JP1 and JP2 are plugged in for the straight cable, and JP3/JP4 are empty. The jumper configuration is reversed for the null-modem cable, as shown in Table 1-1.

Cable Configuration	Mode	Jumpers on Debug Board			
		JP1	JP2	JP3	JP4
Straight Cable	**Default**	Installed	Installed	--	--
Null-Modem Cable	Alternative	--	--	Installed	Installed

Table 1-1: Jumper Settings on Debug Board

JP1 through JP4 can also be used to alter the connection when the PC is not configured as a DCE device. Table 1-2 shows the connections necessary for the straight DB9 cable and the pin definitions.

PC Pin	Function	Demo Board Pin
2	TX	2
3	RX	3
5	Signal Ground	5

Table 1-2: Straight Cable Connections

Table 1-3 shows the connections necessary for the null-modem DB9 cable and the pin definitions.

PC Pin	Function	Demo Board Pin
2	TX	3
3	RX	2
5	Signal Ground	5

Table 1-3: Null-modem Cable Connections

See Table 3-1 for correct placement of jumper JP5 on the Demo Board depending on whether the USB connection or the serial connection via the Debug Board is used.

1.7.3 CHECKING OPERATION

A few seconds after power up, the LCD display on the Demo Board should display a brief greeting in the top row and the demo code revision in the bottom row:

H	**E**	**L**	**L**	**O**			
5.	**4**	**F**					

The "HELLO" message should be followed by the display of accumulated energy:

					0.	**0**	**0**	**Wh SYS**
	0	**3**						

The "SYS" symbol will be blinking, indicating activity of the MPU inside the 71M6543.

In general, the fields of the LCD are used as shown below:

			Measured value					Unit
	Command number							
					(Phase)			

1.7.4 SERIAL CONNECTION SETUP

After connecting the USB cable from the Demo Board to the PC, or after connecting the serial cable from the optional Debug Board to the PC, start the HyperTerminal application and create a session using the following parameters:

Port Speed: 9600 bd

Data Bits: 8

Parity: None

Stop Bits: 1

Flow Control: XON/XOFF

When using the USB connection, you may have to define a new port in HyperTerminal after selecting File → Properties and then clicking on the "Connect Using" dialog box. If the USB-to-serial driver is installed (see section 1.7.2.1) a port with a number not corresponding to an actual serial port, e.g. COM27, will appear in the dialog box. This port should be selected for the USB connection.

HyperTerminal can be found by selecting Programs →Accessories → Communications from the Windows© start menu. The connection parameters are configured by selecting File → Properties and then by pressing the Configure button. Port speed and flow control are configured under the General tab (Figure 1-3, left), bit settings are configured by pressing the Configure button (Figure 1-3, right), as shown below. A setup file (file name "Demo Board Connection.ht") for HyperTerminal that can be loaded with File → Open is also provided with the tools and utilities.

In Windows 7© , HyperTerminal is not available, but can be installed from various resources on the Internet.

Port parameters can only be adjusted when the connection is not active. The disconnect button, as shown in Figure 1-2 must be clicked in order to disconnect the port.

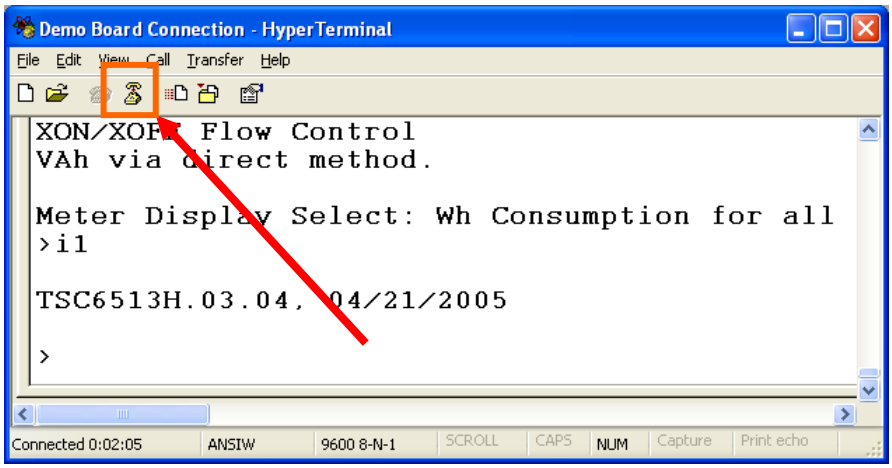

Figure 1-2: HyperTerminal Sample Window with Disconnect Button (Arrow)

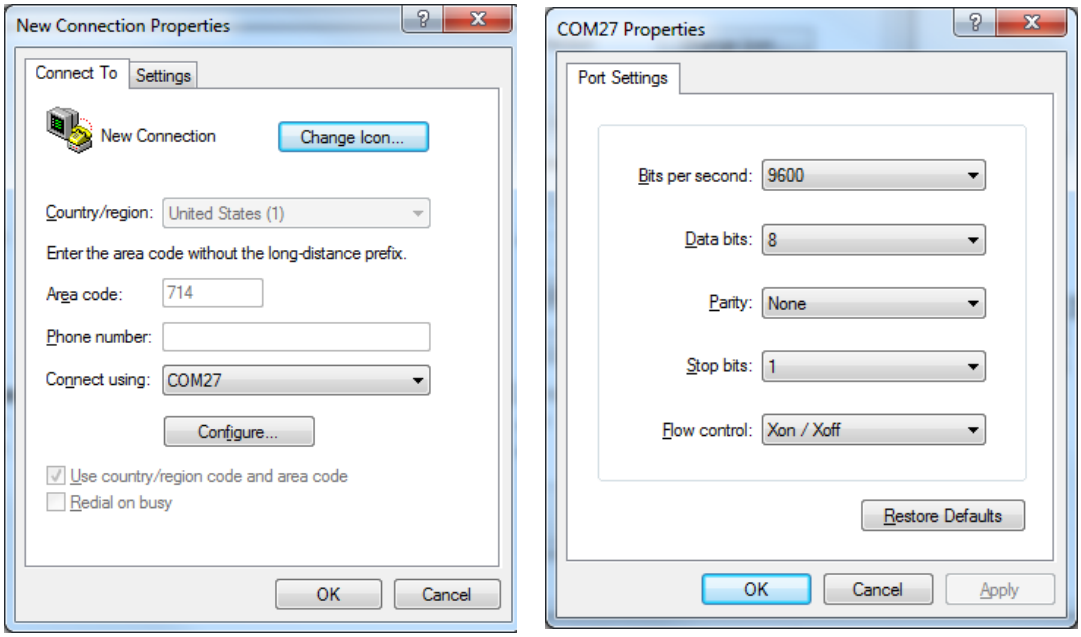

Figure 1-3: Port Setup (left) and Port Speed and Handshake Setup (right)

Once, the connection to the demo board is established, press <CR> and the command prompt, **>**, should appear. Type **>?** to see the **Demo Code** help menu. Type **>i** to verify the demo code revision.

1.8 USING THE DEMO BOARD

The 71M6543 Demo Board is a ready-to-use meter prepared for use with external shunt resistors.

Demo Code versions for polyphase operation (EQU 5) are available on the Maxim web site (www.maxim-ic.com) and the 71M6543F is pre-programmed with Demo Code that supports polyphase metering.

Using the Demo Board involves communicating with the Demo Code via the command line interface (CLI). The CLI allows all sorts of manipulations to the metering parameters, access to the EEPROM, selection of the displayed parameters, changing calibration factors and many more operations.

Before evaluating the 71M6543F on the Demo Board, users should get familiar with the commands and responses of the CLI. A complete description of the CLI is provided in section 1.8.1.

1.8.1 SERIAL COMMAND LANGUAGE

The Demo Code residing in the flash memory of the 71M6543F provides a convenient way of examining and modifying key meter parameters via its command line interface (CLI).

The tables in this chapter describe the commands in detail.

Commands for CE Data Access:

]	CE DATA ACCESS	Comment
Description:	Allows user to read from and write to CE data space.	
Usage:	] [Starting CE Data Address] [option]…[option]	
Command combinations:	]A???	Read consecutive 16-bit words in Decimal, starting at address A
	]A$$$	Read consecutive 16-bit words in Hex, starting at address A
	]A=n=n	Write consecutive memory values, starting at address A
	]U	Update default version of CE Data in flash memory
Example:	]40$$$	Reads CE data words 0x40, 0x41 and 0x42.
	]7E=12345678=9876ABCD	Writes two words starting @ 0x7E

All CE data words are in 4-byte (32-bit) format. Typing]A? will access the 32-bit word located at the byte address 0x0000 + 4 * A = 0x1028.

Commands for MPU/XDATA Access:

)	MPU DATA ACCESS	Comment
Description:	Allows user to read from and write to MPU data space.	
Usage:	) [Starting MPU Data Address] [option]…[option]	
Command combinations:	)A???	Read three consecutive 32-bit words in Decimal, starting at address A
	)A$$$	Read three consecutive 32-bit words in Hex, starting at address A
	)A=n=m	Write the values n and m to two consecutive addresses starting at address A
	?)	Display useful RAM addresses.
Example:	)08$$$$	Reads data words 0x08, 0x0C, 0x10, 0x14
	)04=12345678=9876ABCD	Writes two words starting @ 0x04

MPU or XDATA space is the address range for the MPU XRAM (0x0000 to 0xFFF). All MPU data words are in 4-byte (32-bit) format. Typing]A? will access the 32-bit word located at the byte address 4 * A = 0x28. The energy accumulation registers of the Demo Code can be accessed by typing two Dollar signs ("$$"), typing question marks will display negative decimal values if the most significant bit is set.

Commands for DIO RAM (Configuration RAM) and SFR Control:

R	DIO AND SFR CONTROL	Comment
Description:	Allows the user to read from and write to DIO RAM and special function registers (SFRs).	
Usage:	R [option] [register] … [option]	
Command combinations:	RIx…	Select I/O RAM location x (0x2000 offset is automatically added)
	Rx…	Select internal SFR at address x
	Ra???...	Read consecutive SFR registers in Decimal, starting at address a
	Ra$$$...	Read consecutive registers in Hex, starting at address a
	Ra=n=m…	Set values of consecutive registers to n and m starting at address a
Example:	RI2$$$	Read DIO RAM registers 2, 3, and 4 in Hex.

The SFRs (special function registers) are located in internal RAM of the 80515 core, starting at address 0x80.

Commands for EEPROM Control:

EE	EEPROM CONTROL	Comment
Description:	Allows user to enable read from and write to EEPROM.	
Usage:	EE [option] [arguments]	
Command combinations:	EECn	EEPROM Access (1 → Enable, 0 → Disable)
	EERa.b	Read EEPROM at address 'a' for 'b' bytes.
	EESabc..xyz	Write characters to buffer (sets Write length)
	EETa	Transmit buffer to EEPROM at address 'a'.
	EEWa.b...z	Write values to buffer
	CLS	Saves calibration to EEPROM
Example:	EEShello EET$0210	Writes 'hello' to buffer, then transmits buffer to EEPROM starting at address 0x210.

Due to buffer size restrictions, the maximum number of bytes handled by the EEPROM command is 0x40.

Commands for Flash Memory Control:

F	FLASH CONTROL	Comment
Description:	Allows user to enable read from and write to Flash memory.	
Usage:	F [option] [arguments]	
Command combinations:	FRa.b	Read Flash at address 'a' for 'b' bytes.
	FSabc..xyz	Write characters to buffer (sets Write length)
	FTa	Transmit buffer to Flash memory at address 'a'.
	FWa.b...z	Write string of bytes to buffer
Example:	FShello FT$FE10	Writes 'hello' to buffer, then transmits buffer to EEPROM starting at address 0xFE10.

Auxiliary Commands:

Typing a comma (",") repeats the command issued from the previous command line. This is very helpful when examining the value at a certain address over time, such as the CE DRAM address for the temperature (0x40).

The slash ("/") is useful to separate comments from commands when sending macro text files via the serial interface. All characters in a line after the slash are ignored.

Commands controlling the CE, TMUX and the RTM:

C	**COMPUTE ENGINE, MEMORY, AND CALIBRATION CONTROL**	**Comment**
Description:	Allows the user to enable and configure the compute engine, store and recall configurations, and initiate calibration.	
Usage:	C [option] [argument]	
Command combinations:	CEn	Compute Engine Enable (1 → Enable, 0 → Disable)
	CTn.m	Selects the signal for the TMUX output pins (n = 1 for TMUXOUT, n = 2 for TMUX2OUT). M is interpreted as a hex number.
	CREn	RTM output control (1 → Enable, 0 → Disable)
	CRSa.b.c.d	Selects CE addresses for RTM output
	CLS	Stores calibration and other settings to EEPROM.
	CLR	Restores calibration and other settings from EEPROM.
	CLD	Restores calibration and other settings to defaults.
	CLB	Start auto-calibration based on voltage (MPU address 0x0C, current (MPU 0x0D), and duration (MPU 0x0E) in seconds.
	CLC	Apply machine-readable calibration control (Intel Hex-Records).
	CPA	Start the accumulating periodic pulse counters.
	CPC	Clear the pulse counters
	CPDn	Activate pulse counters for n seconds
Example:	CE0	Disables CE, ("SYS will stop blinking on the LCD).
	CT1.12	Selects the VBIAS signal for the TMUXOUT pin

Commands for Identification and Information:

I	**INFORMATION MESSAGES**	**Comment**
Description:	Allows the user to read information messages.	
Usage:	I	Sends complete demo code version information on serial interface.
	M0	Displays meter ID on LCD.

The I command is mainly used to identify the revisions of Demo Code and the contained CE code.

Commands for Battery Mode Control and Battery Test:

B	INFORMATION MESSAGES	Comment
Description:	Allows the user to control battery modes and to test the battery.	
Usage:	BL	Enters LCD mode when in brownout mode (B> prompt).
	BS	Enters sleep mode when in brownout mode (B> prompt).
	BT	Starts a battery test – when in mission mode (> prompt).
	BWSn	Set wake timer to n seconds for automatic return to brownout mode.
	BWMn	Set wake timer to n minutes for automatic return to brownout mode.

Commands for Controlling the RTC:

RT	REAL TIME CLOCK CONTROL	Comment
Description:	Allows the user to read and set the real time clock.	
Usage:	RT [option] [value] … [value]	
Command combinations:	RTDy.m.d.w: Day of week	(Year, month, day, weekday [1 = Sunday]). If the weekday is omitted it is set automatically.
	RTR	Read Real Time Clock.
	RTTh.m.s	Time of day: (hr, min, sec).
	RTAs.t	Real Time Adjust: (start, trim). Allows trimming of the RTC. If s > 0, the speed of the clock will be adjusted by 't' parts per billion (PPB). If the CE is on, the value entered with 't' will be changing with temperature, based on Y_CAL, Y_CALC and Y_CALC2.
	>	Access look-up table for RTC compensation.
Example:	RTD05.03.17.5	Programs the RTC to Thursday, 3/17/2005
	RTA1.+1234	Speeds up the RTC by 1234 PPB.
	>0????	Read the first four bytes in the look-up table.

The "Military Time Format" is used for the RTC, i.e. 15:00 is 3:00 PM.

Commands for Accessing the Trim Control Registers:

T	TRIM CONTROL	Comment
Description:	Allows user to read trim and fuse values.	
Usage:	T [option]	
Command combinations:	T4	Read fuse 4 (TRIMM).
	T5	Read fuse 5 (TRIMBGA)
	T6	Read fuse 6 (TRIMBGB).
Example:	T4	Reads the TRIMM fuse.

These commands are only accessible for the 71M6543H (0.1%) parts. When used on a 71M6543F (0.5%) part, the results will be displayed as zero.

Reset Commands:

W	RESET	Comment
Description:	Watchdog control	
Usage:	W	Halts the Demo Code program, thus suppressing the triggering of the hardware watchdog timer. This will cause a reset, if the watchdog timer is enabled.

Commands for the 71M6x0x Remote Sensor Interface:

6	71M6x0x Interface	Comment
Description:	Commands for control of the Remote Sensor Interface IC.	
Usage:	6En	Remote sensor Enable (1 → Enable, 0 → Disable)
	6Ra.b	Read Remote Sensor IC number a with command b.
	6Ca.b	Write command b to Remote Sensor IC number a.
	6Ta.b	Send command b to Remote Sensor IC number a in a loop forever.
	6T	Send temp command to 6000 number 2 in a loop forever.
	6R1.20	Reads the temperature from Remote Sensor IC number 1. See section 1.10.7 for information on how to interpret the temperature data.

Commands for Controlling the Metering Values Shown on the LCD Display:

Step	Text or Numerical Display	CLI command	Displayed Parameter(s)
0	**10000 00**	**M0**	Meter ID
1	**24.5 °C 01**	**M1**	Temperature difference from calibration temperature. Displayed in 0.1°C
2	**59.9 02**	**M2**	Frequency at the VA_IN input [Hz]
3	**3.27 Wh 03**	**M3**	Accumulated imported real energy [Wh]. The default display setting after power-up or reset.
4	**1.04 Wh 04**	**M4**	Accumulated exported real energy [Wh].
5	**2.21 VARh 05**	**M5**	Accumulated reactive energy [VARh].
6	**0.95 VARh 06**	**M6**	Accumulated exported reactive energy [VARh].
7	**4.11 VAh 07**	**M7**	Accumulated apparent energy [VAh].
8	**0.7 h 08**	**M8**	Elapsed time since last reset or power up.
9	**01:43:59 09**	**M9**	Time of day (hh.mm.ss)
10	**01.01.01 10**	**M10**	Date (yy.mm.dd)
11	**0.62 11 1**	**M11.P**	Power factor (P = phase)
12	**0**	**M12**	Not used in the 71M6543
13	**120 13**	**M13**	Zero crossings of the mains voltage
14	**48 14**	**M14**	Duration of sag or neutral current [s]
15	**29.98 A 29.91 A 30.02 A**	**M15**	RMS current (P = phase). "M15.4" displays the neutral current.
16	**240.27 V 239.43 V 240.04 V**	**M16**	RMS voltage
17	**3.34 V 17**	**M17**	Battery voltage
18	**241.34 W 240.92 W 241.01 W**	**M18**	Momentary power in W (P = phase)
19	**50400 W 19**	**M19**	Demand
20	**88.88.88 88.88.88 88.88.88**	**M20**	LCD Test

Displays for total consumption wrap around at 999.999Wh (or VARh, VAh) due to the limited number of available display digits. Internal registers (counters) of the Demo Code are 64 bits wide and do not wrap around.

1.8.2 USING THE DEMO BOARD FOR ENERGY MEASUREMENTS

The 71M6543 Demo Board was designed for use with shunt resistors connected via the Remote Sensor Interfaces and it is shipped in this configuration.

The Demo Board may immediately be used with 50 μΩ shunt resistors (ANSI version) or 120 μΩ shunt resistors (IEC version). It is programmed for a kh factor of 3.2 (see Section 1.8.4 for adjusting the Demo Board for shunts with different resistance).

Once, voltage is applied and load current is flowing, the red LED D5 will flash each time an energy sum of 3.2 Wh is collected. The LCD display will show the accumulated energy in Wh when set to display mode 3 (command >**M3** via the serial interface).

Similarly, the red LED D6 will flash each time an energy sum of 3.2 VARh is collected. The LCD display will show the accumulated energy in VARh when set to display mode 5 (command >**M5** via the serial interface).

1.8.3 ADJUSTING THE KH FACTOR FOR THE DEMO BOARD

The 71M6543 Demo Board is shipped with a pre-programmed scaling factor Kh of 3.2, i.e. 3.2 Wh per pulse. In order to be used with a calibrated load or a meter calibration system, the board should be connected to the AC power source using the spade terminals on the bottom of the board. On the revision REV 4.0 of the Demo Board, the shunt resistor wires are terminated directly to the dual-pin headers J22, J23, and J24 on the board.

The Kh value can be derived by reading the values for $IMAX$ and $VMAX$ (i.e. the RMS current and voltage values that correspond to the 250mV maximum input signal to the IC), and inserting them in the following equation for Kh:

$$Kh = 54.5793 * VMAX * IMAX / (SUM_SAMPS * WRATE * X),$$

See the explanation in section 1.10.5 for an exact definition of the constants and variables involved in the equation above.

1.8.4 ADJUSTING THE DEMO BOARDS TO DIFFERENT SHUNT RESISTORS

The Demo Board REV 4.0 is prepared for use with 120 μΩ or 50 μOhm (ANSI option) shunt resistors in all current channels. A certain current flowing through the 120 μΩ shunt resistors will result in the maximum voltage drop at the ADC of the 71M6103 Remote Sensor ICs. This current is defined as $IMAX$ and can be adjusted at MPU location 0x03 (see section 1.10.3).

$IMAX$ will need to be changed when different values are used for the shunt resistor(s) which will require that $WRATE$ has to be updated as shown in section 1.10.5.

The scaling of the neutral current measurement is controlled by the i_max2 variable at MPU location 0x01C.

1.8.5 USING THE PRE-AMPLIFIER

In its default setting, the 71M6543F applies a gain of 1 to the current input for the neutral current inputs (IAP/IAN pins). This gain is controlled with the PRE_E bit in I/O RAM (see the Data Sheet). The command line interface (RI command) can be used to set or reset this bit. It is recommended to maintain the gain of setting of 1 (RI2704=0x90).

1.8.6 USING CURRENT TRANSFORMERS (CTS)

All phases of the 71M6543 REV 5.0 Demo Board are equipped with connectors for external CTs. CTs should be connected to the headers J5, J7, and J10. A burden resistor of 1.7 Ω is installed at the R26, R27, and R31 (and corresponding resistors for phases B and C) locations. With a 2000:1 ratio CT, the maximum current will be 208 A.

For the CT configuration, a shunt resistor of 50 μΩ should be installed to measure the neutral current. Different values can be accommodated by changing the value of i_max2 at MPU location 0x1C (see section 1.10.3).

Note: The CT configuration requires a different version of the Demo Code than is used for the shunt configuration.

1.8.7 ADJUSTING THE DEMO BOARDS TO DIFFERENT VOLTAGE DIVIDERS

The 71M6543 Demo Board comes equipped with its own network of resistor dividers for voltage measurement mounted on the PCB. The resistor values (for the 71M6543 REV 2.0 Demo Board) are 2.5477MΩ (R66, R64, R47, R39 combined) and 750Ω (R32, R52, R72), resulting in a ratio of 1:3,393.933. This means that $VMAX$ equals 176.78mV*3,393.933 = 600V. A large value for $VMAX$ has been selected in order to have headroom for

over-voltages. This choice need not be of concern, since the ADC in the 71M6543F has enough resolution, even when operating at 120 Vrms or 240 Vrms.

If a **different set of voltage dividers** or an external voltage transformer (potential transformer) is to be used, scaling techniques should be used.

In the following example we assume that the line voltage is not applied to the resistor divider for VA formed by R66, R64, R47, R39, and R32, but to a voltage transformer with a ratio N of 20:1, followed by a simple resistor divider. We also assume that we want to maintain the value for $VMAX$ at 600V to provide headroom for large voltage excursions.

When applying $VMAX$ at the primary side of the transformer, the secondary voltage V_s is:

$V_s = VMAX / N$

V_s is scaled by the resistor divider ratio R_R. When the input voltage to the voltage channel of the 71M6543 is the desired 177mV, V_s is then given by:

$V_s = R_R * 176.8\ mV$

Resolving for R_R, we get:

$R_R = (VMAX / N) / 176.8\ mV = (600V / 30) / 176.8\ mV = 170.45$

This divider ratio can be implemented, for example, with a combination of one 16.95 kΩ and one 100 Ω resistor.

If potential transformers (PTs) are used instead of resistor dividers, phase shifts will be introduced that will require negative phase angle compensation. Teridian Demo Code accepts negative calibration factors for phase.

1.9 CALIBRATION PARAMETERS

1.9.1 GENERAL CALIBRATION PROCEDURE

Any calibration method can be used with the 71M6543F ICs. This Demo Board User's Manual presents calibration methods with three or five measurements as recommended methods, because they work with most manual calibration systems based on counting "pulses" (emitted by LEDs on the meter).

Naturally, a meter in mass production will be equipped with special calibration code offering capabilities beyond those of the 71M6543 Demo Code. It is basically possible to calibrate using voltage and current readings, with or without pulses involved. For this purpose, the MPU Demo Code should be modified to display averaged voltage and current values (as opposed to momentary values). Also, automated calibration equipment can communicate with the Demo Boards via the serial interface and extract voltage and current readings. This is possible even with the unmodified Demo Code.

Complete calibration procedures are given in section 2.2 of this manual.

Regardless of the calibration procedure used, parameters (calibration factors) will result that will have to be applied to the 71M6543F IC in order to make the chip apply the modified gains and phase shifts necessary for accurate operation. Table 1-4 shows the names of the calibration factors, their function, and their location in the CE RAM.

Again, the command line interface can be used to store the calibration factors in their respective CE RAM addresses. For example, the command

>]10=+16302

stores the decimal value 16302 in the CE RAM location controlling the gain of the current channel (CAL_IA).

The command

>]11=4005

stores the hexadecimal value 0x4005 (decimal 16389) in the CE RAM location controlling the gain of the voltage channel (CAL_VA).

Table 1-4: CE RAM Locations for Calibration Constants

Coefficient	CE Address (hex)	Description
CAL_VA *CAL_VB* *CAL_VC*	0x11 0x14 0x17	Adjusts the gain of the voltage channels. +16384 is the typical value. The gain is directly proportional to the CAL parameter. Allowed range is 0 to 32767. If the gain is 1% slow, CAL should be increased by 1%.
CAL_IA *CAL_IB* *CAL_IC*	0x10 0x13 0x16	Adjusts the gain of the current channels. +16384 is the typical value. The gain is directly proportional to the CAL parameter. Allowed range is 0 to 32767. If the gain is 1% slow, CAL should be increased by 1%.
LCOMP2_A *LCOMP2_B* *LCOMP2_C*	0x12 0x15 0x18	This constant controls the phase compensation. No compensation occurs when *LCOMP2_n*=16384. As *LCOMP2_n* is increased, more compensation is introduced. CE codes for CT configuration do not use delay adjustment. These codes use phase adjustment (*PHADJ_n*).

1.9.2 CALIBRATION MACRO FILE

The macro file in Figure 1-4 contains a sequence of the serial interface commands. It is a simple text file and can be created with Notepad or an equivalent ASCII editor program. The file is executed with HyperTerminal's *Transfer->Send Text File* command.

```
CE0          /disable CE
]10=+16022   /CAL_IA (gain=CAL_IA/16384)
]11=+16381   /CAL_VA (gain=CAL_VA/16384)
]12=+17229   /LCOMP2_A (default 16384)
CE1          /enable CE
```

Figure 1-4: Typical Calibration Macro File

It is possible to send the calibration macro file to the 71M6543F for "temporary" calibration. This will temporarily change the CE data values. Upon power up, these values are refreshed back to the default values stored in flash memory. Thus, until the flash memory is updated, the macro file must be loaded each time the part is powered up. The macro file is run by sending it with the *transfer → send text file* procedure of HyperTerminal.

Use the *Transfer → Send Text File* command!

1.9.3 UPDATING THE DEMO CODE (HEX FILE)

The d_merge program updates the hex file (for example 6543eq5_6103_5p3c_01nov10.hex, or similar) with the values contained in the macro file. This program is executed from a DOS command line window. Executing the d_merge program with no arguments will display the syntax description. To merge macro.txt and old_6543_demo.hex into new_6543_demo.hex, use the command:

```
d_merge old_6543_demo.hex macro.txt new_6543_demo.hex
```

The new hex file can be written to the 71M6543F/71M6543H through the ICE port using the ADM51 in-circuit emulator or the TFP-2 flash programmer.

1.9.4 UPDATING CALIBRATION DATA IN FLASH OR EEPROM

It is possible to make data permanent that had been entered temporarily into the CE RAM. The transfer to EEPROM memory is done using the following serial interface command:

```
>]CLS
```

Thus, after transferring calibration data with manual serial interface commands or with a macro file, all that has to be done is invoking the U command.

Similarly, calibration data can be restored to default values using the CLD command.

After reset, calibration data is copied from the EEPROM, if present. Otherwise, calibration data is copied from the flash memory. Writing 0xFF into the first few bytes of the EEPROM deactivates any calibration data previously stored to the EEPROM.

1.9.5 LOADING THE CODE FOR THE 71M6543F INTO THE DEMO BOARD

Hardware Interface for Programming: The 71M6543F IC provides an interface for loading code into the internal flash memory. This interface consists of the following signals:

E_RXTX (data), E_TCLK (clock), E_RST (reset), ICE_E (ICE enable)

These signals, along with V3P3D and GND are available on the emulator headers J14.

Programming of the flash memory requires a specific in-circuit emulator, the ADM51 by Signum Systems or the Flash Programmer (TFP-2) provided by Maxim.

Chips may also be programmed before they are soldered to the board. Gang programmers suitable for high-volume production are available from BPM Microsystems.

In-Circuit Emulator: If firmware exists in the 71M6543F flash memory; it has to be erased before loading a new file into memory. Figure 1-5 and Figure 1-6 show the emulator software active. In order to erase the flash memory, the RESET button of the emulator software has to be clicked followed by the ERASE button.

To successfully erase the flash memory, the following steps have to be taken:

1) Disable the CE by writing 0x00 to address 0x2000
2) Write 0x20 to address 0x2702 (*FLSH_UNLOCK[ ]* register in I/O RAM)
3) Reset the demo board (RESET button or power cycle)
4) Activate the ERASE button in the WEMU51 user interface
5) Now, new code can be loaded into the flash memory

Once the flash memory is erased, the new file can be loaded using the commands File followed by Load. The dialog box shown in Figure 1-6 will then appear making it possible to select the file to be loaded by clicking the Browse button. Once the file is selected, pressing the OK button will load the file into the flash memory of the 71M6543F IC. At this point, the emulator probe (cable) can be removed. Once the 71M6543F IC is reset using the reset button on the Demo Board, the new code starts executing.

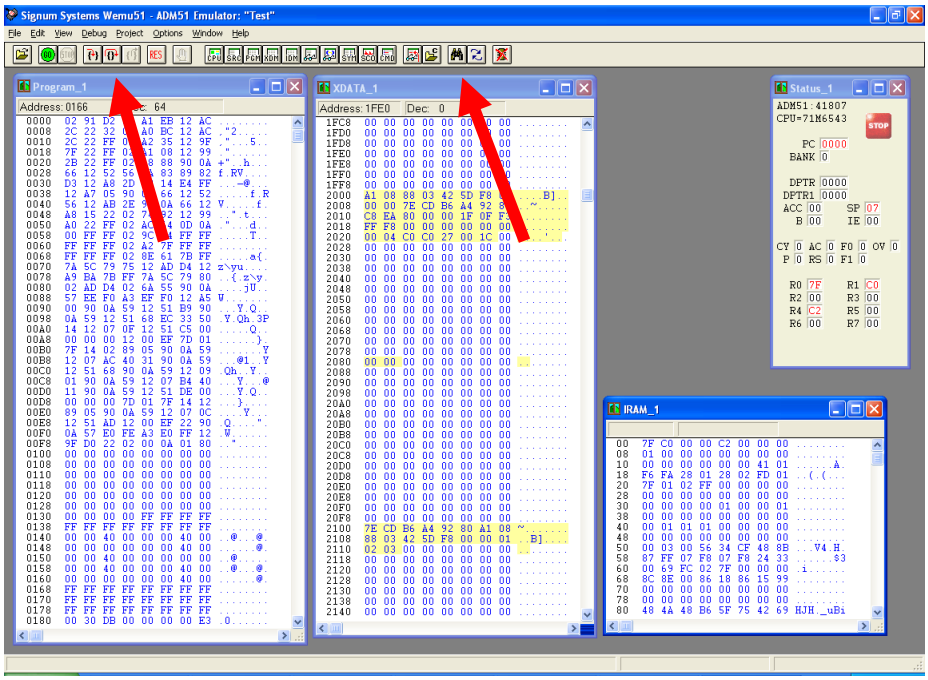

Figure 1-5: Emulator Window Showing Reset and Erase Buttons (see Arrows)

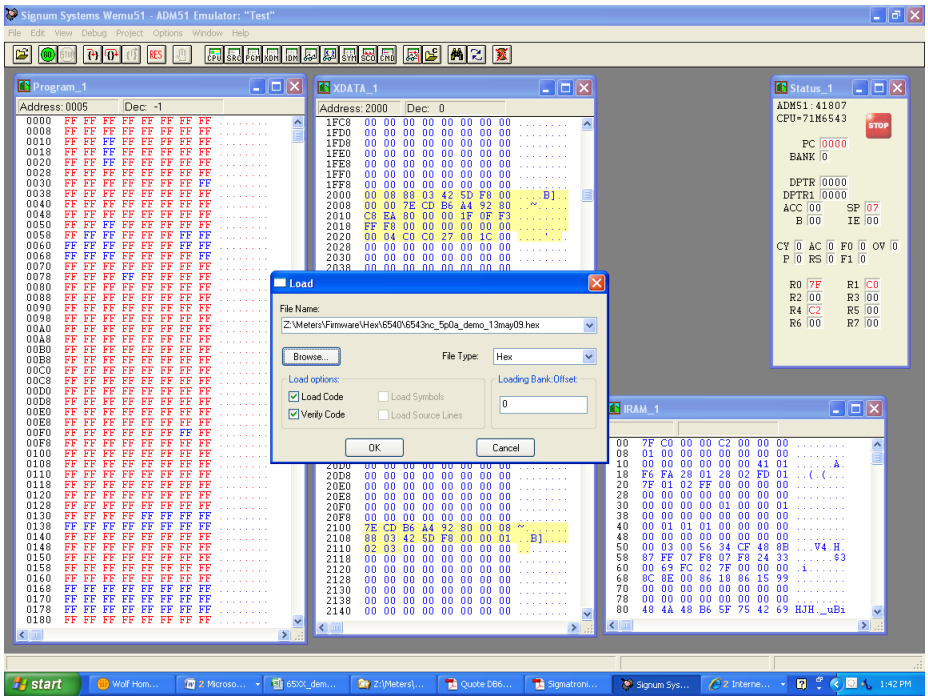

Figure 1-6: Emulator Window Showing Erased Flash Memory and File Load Menu

Flash Programmer Module (TFP-2): The operational firmware of the TFP2 will have to be upgraded to revision 1.53. Follow the instructions given in the User Manual for the TFP-2.

1.9.6 THE PROGRAMMING INTERFACE OF THE 71M6543F

Flash Downloader/ICE Interface Signals

The signals listed in Table 1-5 are necessary for communication between the TFP2 Flash Downloader or ICE and the 71M6543F.

Signal	Direction	Function
ICE_E	Input to the 71M6543F	ICE interface is enabled when ICE_E is pulled high
E_TCLK	Output from 71M6543F	Data clock
E_RXTX	Bi-directional	Data input/output
E_RST	Bi-directional	Flash Downloader Reset (active low)

Table 1-5: Flash Programming Interface Signals

The E_RST signal should only be driven by the Flash Downloader when enabling these interface signals. The Flash Downloader must release E_RST at all other times.

1.10 DEMO CODE

1.10.1 DEMO CODE DESCRIPTION

The Demo Board is shipped preloaded with Demo Code in the 71M6543F chip. The code revision can easily be verified by entering the command **>i** via the serial interface (see section 1.8.1). Check with your local Maxim representative/FAE or for the latest revision, or obtain the latest revision from the Maxim web site.

The Demo Code offers the following features:

- It provides basic metering functions such as pulse generation, display of accumulated energy, frequency, date/time, and enables the user to evaluate the parameters of the metering IC such as accuracy, harmonic performance, etc.
- It maintains and provides access to basic household functions such as the real-time clock (RTC).
- It provides access to control and display functions via the serial interface, enabling the user to view and modify a variety of meter parameters such as Kh, calibration coefficients, temperature compensation etc.
- It provides libraries for access of low-level IC functions to serve as building blocks for code development.

A detailed description of the Demo Code can be found in the Software User's Guide (SUG). In addition, the comments contained in the library provided with the Demo Kit can serve as useful documentation.

The Software User's Guide contains the following information:

- Design guide
- Design reference for routines
- Tool Installation Guide
- List of library functions
- 80515 MPU Reference (hardware, instruction set, memory, registers)

1.10.2 DEMO CODE VERSIONS

Each sensor configuration has its own Demo Codes version. Using the wrong type of Demo Code will result in malfunction. Table 1-6 shows the available Demo Code versions and their application.

Table 1-6: Demo Code Versions

File Name	Supported Configuration	Supported Demo Board
6543equ5_6103_5p3d_14feb11.hex	3 x 71M6103 with shunts	71M6543 DB REV4-0
6543equ5_6113_5p3d_14feb11.hex	3 x 71M6113 with shunts	71M6543 DB REV4-0
6543equ5_6203_5p3d_14feb11.hex	3 x 71M6203 with shunts	71M6543 DB REV4-0
6543equ5_6603_5p3d_14feb11.hex	3 x 71M6603 with shunts	71M6543 DB REV4-0
6543equ5_ct_5p3d_14feb11.hex	CT	71M6543 DB REV5-0

1.10.3 IMPORTANT MPU ADDRESSES

In the Demo Code, certain MPU XRAM parameters have been given addresses in order to permit easy external access. These variables can be read via the command line interface (if available), with the **)n$** command and written with the **)n=xx** command where n is the word address. Note that accumulation variables are 64 bits long and are accessed with **)n$$** (read) and **)n=hh=ll** (write) in the case of accumulation variables.

The first part of the table, the addresses)00..)1F, contains adjustments, i.e. numbers that may need adjustment in a demonstration meter, and so are part of the calibration for demo code. In a reference meter, these may be in an unchanging table in code space.

The second part,)20..)2F, pertains to calibration, i.e. variables that are likely to need individual adjustments for quality production meters.

The third part,)30…, pertains to measurements, i.e. variables and registers that may need to be read in a demonstration meter.

Table 1-7: MPU XRAM Locations

Name	Purpose	LSB	Default	)?	Signed?	Bits
i_min	Metering element enters creep mode if current is below this value. If 0, creep logic is disabled. In creep mode, on each metering element, Wh, VARh, i0sqsum, and other items are zeroed.	Same units as CE's i0sqsum.	0.08A	)0	signed	32
cfg	Configure meter operation on the fly.	bit0: 1=Display KWh. bit1: 1=clear accumulators, errors, etc. (e.g. ")1=2") bit2: 1=Reset demand. (e.g. ")1=4") bit3: 1=CE Raw mode. MPU does not change CE values with creep or small current calculations. bit5: 1= Send a message once per second for IEC 62056-217 Mode D on UART 1, at 2400 BAUD, even parity. The meter's serial number and current Wh display are sent as data. UART 1 is routed to an IR LED if possible. Mode D data fields are prefaced with OBIS codes in legacy format. [7,1] bit6: 1=Auto calibration mode [1] bit7: 1=Enable Tamper Detect [2,1]	0 Do nothing special.	)1	N/A	8
v_min	error if below. Also creep.* Below this, low voltage seconds are counted. Voltage, Wh, VARh, Frequency, and other voltage-dependent items are zeroed.	Same units as CE's v0sqsum.	40V	)2	signed	32
i_max	Scaling Maximum Amps for standard sensor.	0.1A	110.5 for 200 µOhm shunt with 8x preamp. 884.0 A for 200 µOhm shunt, 442.0A for 400 µOhm shunt.	)3	signed	16
v_max	Scaling Maximum Volts for PCB	0.1V	600 V, for the Demo Board.	)4	signed	16
i_limit	Error if exceeded.	Same units as CE's i0sqsum.	50.9A = 30A*sqrt(2) *120%	)5	signed	32
v_limit	Error if exceeded.*	Same units as CE's v0sqsum.	407.3V = 240V*sqrt(2) *120%	)6	signed	32

wrate_mpu	Convert from CE counts to pulses.	CE's w0sum units per pulse, rounded up to next largest CE count so Wh accumulation and display is always rounded down.	3.2 Wh	)7	signed	32
interval	The number of minutes of a demand interval.	Count of minutes. (60/interval)*interval = 60.	2 minutes	)8	unsigned	8
mains_hz	Expected number of cycles per second of mains. 0 disables the software RTC run from mains.	Hz	0	)9	unsigned	8
temp_cal1	Machine-readable units per 0.1C	See data sheet. Temperature is calculated as temp = (measured_temp – temp_datum) /temp_cal1 + temp_cal0	See data sheet.	)A	signed	32
mtr_cal1 [0..3] [9]	Linear temperature calibration for meter elements A..D.	ppm*(T - mtr_datum), in 0.1˚C	150	)B..E	signed	16
mtr_cal2 [0..3] [9]	Squared temperature calibration for meter elements A..D.	ppm2*(T - mtr_datum)^2, in 0.1˚C	-392	)F..12	signed	16
y_datum	Center temperature of the crystal.	0.1 C	25C	)13	signed	16
y_cal1 [5]	RTC adjust, linear by temp.	10 ppb*(T - y_datum), in 0.1˚C	0	)14	signed	16
y_cal2 [5]	RTC adjust, squared by temp.	1 ppb*(T - y_datum)2, in 0.1˚C	38	)15	signed	16
s_cal [1]	Accumulation intervals of Autocalibration	Count of accumulation intervals of calibration.	accumulation intervals cover both chop polarities.	)C	signed	16
v_cal [1]	Volts of Autocalibration	0.1 V rms of AC signal applied to all elements during calibration.	2400 240 V is the default full-scale for meter test.	)D	signed	16
i_cal [1]	Amps of Autocalibration	0.1 A rms of AC signal applied to all elements during calibration. Power factor of calibration signal must be 1.	300 30 A is the default full-scale for meter test.	)E	signed	16

lcd_idx	Selects LCD's current display.	0: Meter identification. ("#") 1: Display variation from calibration temperature, 0.1C 2: Display mains Hz, 0.1 Hz 3: mWh, total 4: mWh total exported. 5: mVARh, total. 6: mVARh, total exported. 7:mVAh, total 8: Operating hours. 9: Time of day 10: Calendar date 11: Power factor, total 12: Angle between phase 0 & 1 13: Main edge count, last accumulation. 14: KW, instantaneous total 15: V, instantaneous max of all phases. 16: A, total 17: V, Battery ("VB") 18: Seconds, bad power ("BPS") 19: Seconds, tamper (- = tamper in progress) ("TS") 20: LCD Test Scrolling not standard for these: 111: PF, phase 0 112: Angle, phase 0 & 1 114: KW, phase 0 115: V, phase 0 116: A, phase 0 211: PF, phase 1 212: Angle, phase 0 & 2 214: KW, phase 1 215: V, phase 1 216: A, phase 1 311: PF, phase 2 312: Angle, phase 2.0 314: KW, phase 2 315: V, phase 2 316: A, phase 2 416: A, neutral (measured)	3	)19	signed	16
lcd_bit	Defines sequence of LCD displays.	The value is a bit mask that describes a scrolling display sequence. Each set bit permits a display with an lcd_idx value from 0..31. Each is displayed for 7 seconds. Ordered by increasing bit number. If value is zero, display does not change.	0	)1A	unsigned	32
mfr_id [6]	Manufacturer's ID text string of the meter	3 ASCII bytes, in MSB of 32-bit number. Least significant byte should be zero. For AMR demonstrations, sent as the manufacturer's ID of the meter.	"TSC", 0x54534300	)1B	unsigned	32

i_max2 [4]	Like i_max, except for the 2nd current sensor. Currents, Wh etc. using currents from the second sensor are rescaled into the same units as the first current sensor.	0.1 Amps	208 A (2080)	)1C	signed	16
in_limit [3]	Maximum valid neutral current.	Same units as CE's i3sqsum.	0.1A	)1D	signed	32
in_wait [3]	The time that neutral current can exceed n_max before the neutral error is asserted.	Count of accumulation intervals.	10 secs.	)1E	signed	16
Reserved				)1F		
meter_id [8]	Identification number of meter.	32 bit unsigned number. For AMR demonstrations, this is sent in decimal as the identification number of the meter.	100000000	)20	signed	32
temp_datum [8]	Count of temperature sensor at calibration.	See data sheet. Temperature is calculated as temp = (measured_temp – temp_datum)/temp_cal1 + temp_cal0	n/a	)21	signed	32
mtr_datum[0..3] [8]	Center temperature of a meter element's temperature curve.	0.1C	22C	)22..25	signed	16
rtca_adj [8]	Default value for RTCA_ADJ, the crystal's capacitor adjustment.	See data sheet. Set from hardware value when hardware is changed.	Hardware default (see data sheet).	)26	unsigned	8
y_cal0 5, [8]	RTC offset rate adjust	100ppb	0	)27	signed	16
v_bat_min [8]	Minimum valid battery voltage.	Units of hardware's battery measurement register.	2V on a real PCB; should be adjusted for battery and chip.	)28	signed	32
cal_cnt	Count of calibrations. In demo code, it also checks adjustments.	Counts number of times calibration is saved, to a maximum of 255.	0	)29	unsigned	8
ver_hash	Checked to prevent old calibration data from being used by new code. Value that changes with the banner text, and therefore with the version, date and time.	Uses data_ok() to calculate a value from the string.	n/a	)2A	unsigned	8
data_ok_cal	Checks calibrations. In demo code, it also checks adjustments.	Checked by data_ok() of calibration value.	n/a	)2B	unsigned	16
Reserved				)2C.)2F		

state_bit_array	Status of meter. Nonvolatile.	Bits: See table below.	0 = no errors	)30	unsigned	32
wh_im	Wh energy register. Nonvolatile.	First 32-bit number is a count of pulses, =3.2 Wh in 3-phase meters, or 1 in 1-phase. A fractional pulse is present in the CE data, but not preserved.	n/a	)31		64
wh_ex	Wh exported energy register. Nonvolatile.	Like wh_im	n/a	)32		64
varh_im	VARh register. Nonvolatile.	Like wh_im	n/a	)33		64
varh_ex	VARh exported register. Nonvolatile.	Like wh_im	n/a	)34		64
dmd_max	Maximum demand, W	Units of w0sum	n/a	)35	signed	32
dmd_max_rtc	Time of maximum demand.	Standard time and date structure.	year, month, date, hour, min	)36..3A	unsigned	7x8
v_bat	Battery voltage at last measurement. Volatile; not saved on power failure.	0.1V	n/a	)3B	signed	8
acc_cnt	Count of accumulation intervals since reset, or last clear. Cleared with)1=2 or meter read. Volatile; not saved on power failure.	count	n/a	)3C	signed	32
tamper_sec	Counts seconds that tamper errors were asserted. Cleared with)1=2 or meter read. Nonvolatile.	This is a tamper measurement.	n/a	)3D	signed	32
sag_sec	Counts seconds that voltage low error occurred. or meter read. Nonvolatile.	This is a power quality measurement.	n/a	)3E	signed	32
in_sec [3]	Counts seconds that neutral current error was asserted. Cleared with)1=2 or meter read. Nonvolatile.	This is a power quality measurement.	n/a	)3F	signed	32
rtc_copy	Clock time and date when data was last read from the RTC.	Standard time and date structure. year, month, date, hour, min, sec	n/a	)40..45	unsigned	8*7
save_cnt	Number of power register saves.	n/a	n/a	)46	unsigned	16
data_ok_reg	Checks data.	n/a	n/a	)47	unsigned	16

[1] Valid only when autocalibration is integrated. Meters with metering equations with differential currents or voltages do not normally support autocalibration.

[2] Requires features not in some demo PCBs.

[3] Three-phase ICs only. Some CE codes calculate neutral current rather than measuring it. Consult the CE documentation.

[4] Only in systems with two current sensors.

[5] High accuracy use of this feature may require a calibrated clock.

[6] IEC 62056 Manufacturers' IDs are allocated by the FLAG association. Maxim does not own or profit from the FLAG association. Maxim's default id may not conform, and is for demonstration purposes only.

[7] Nothing in the document should be interpreted as a guarantee of conformance to a 3rd party software specification. Conformance testing is the responsibility of a meter manufacturer.

[8] May require calibration for best accuracy.

[9] Calibration item in high-precision "H" series meters (71M6543H only).

Table 1-8: Bits in the MPU Status Word

Name	Bit No.	Explanation
MINIA	0	IA is below IThrshld. Current for this phase is in creep.
MINIB	1	IB is below IThrshld. Current for this phase is in creep.
MINIC	2	IC is below IThrshld. Current for this phase is in creep.
MINVA	3	VA is below VThrshld. Voltage for this phase is in creep.
MINVB	4	VB is below VThrshld. Voltage for this phase is in creep.
MINVC	5	VC is below VThrshld. Voltage for this phase is in creep.
CREEPV	6	All voltages are below VThrshld.
CREEP	7	There is no combination of current and voltage on any phase.
SOFTWARE	8	A software defect was detected. error_software() was called. E.g.: An impossible value occurred in a selection, or the timers ran out.
NEUTRAL	9	Neutral current was above in_limit for more than in_wait seconds.
SPURIOUS	10	An unexpected interrupt was detected.
SAG	11	Voltage was below VThrshld for more than in_wait seconds
DEMAND	12	Demand was too big (too many watts) to be credible.
CALIBRATION	13	Set after reset if the read of the calibration data has a bad checksum, or is from an earlier version of software. The default values should be present.
RTC_UNSET	14	Set when the clock's current reading is A) Obtained after a cold start, indicating that there was no battery power, and therefore the clock has to be invalid. B) More than a year after the previously saved reading, or C) Earlier than the previously saved reading. In this case, the clock's time is preserved, but the clock can't be trusted.
HARDWARE	15	An impossible hardware condition was detected. For example, the woftware times out waiting for RTC_RD to become zero.
BATTERY_BAD	16	Just after midnight, the demo code sets this bit if VBat < VBatMin. The read is infrequent to reduce battery loading to very low values. When the battery voltage is being displayed, the read occurs every second, for up to 20 seconds.
REGISTER_BAD	17	Set after reset when the read of the power register data has a bad longitudinal redundancy check or bad software version in all 5 copies. Unlikely to be an accident.
RTC_TAMPER	18	Clock set to a new value more than two hours from the previous value.
TAMPER	19	Tamper was detected. Normally this is a power tamper detected in the creep logic. For example, current detected with no voltage.

Table 1-9 contains LSB values for the CE registers. All values are based on the following settings:

- Gain in amplifier for IAP/IAN pins selected to 1.
- 71M6103, 71M6113, or 71M6203 Remote Sensor Interface is used.

Note that some of the register contents can be zeroed out by the MPU when it applies functions contained in its creep logic.

1.10.4 LSB VALUES IN CE REGISTERS

Table 1-9: CE Registers and Associated LSB Values

Register Name	LSB Value	Comment
W0SUM_X *W1SUM_X* *W2SUM_X*	$1.55124*10^{-12}*IMAX*VMAX$	The real energy for elements A, B, and C, measured in Wh per accumulation interval
VAR0SUM_X *VAR1SUM_X* *VAR2SUM_X*	$1.55124*10^{-12}*IMAX*VMAX$	The reactive energy for elements A, B, and C, measured in VARh per accumulation interval
I0SQSUM_X *I1SQSUM_X* *I2SQSUM_X* *INSQSUM_X*	$2.55872*10^{-12}*IMAX*VMAX$	The sum of squared current samples in elements A, B, C, and neutral. This value is the basis for the I_{RMS} calculation performed in the MPU.
V0SQSUM_X *V1SQSUM_X* *V1SQSUM_X*	$9.40448*10^{-13}*IMAX*VMAX$	The sum of squared voltage samples in elements A, B, and C.

1.10.5 CALCULATING IMAX AND KH

The relationship between the resistance of the shunt resistors and the system variable *IMAX* is determined by the type of Remote Sensor Interface used, and is as follows:

IMAX = 0.044194 / R_S for the 71M6603

IMAX = 0.019642 / R_S for the 71M61X1

IMAX = 0.012627 / R_S for the 71M6203

Where:

R_S = Shunt resistance in Ω

Table 1-10 shows *IMAX* values resulting from possible combinations of the shunt resistance value and the type of 71M6x0x Remote Sensor Interface used for the application.

Table 1-10: IMAX for Various Shunt Resistance Values and Remote Sensor Types

Remote Sensor Interface	Rated Current [A]	Max. RMS Voltage at IAP/IAN [mV]	Shunt Resistor Value [µΩ]	IMAX [A]	*IMAX* Entry at MPU 0x03	*WRATE* for kH = 3.2, VMAX = 600 V, X = 0.09375
71M6603	60	44.2	500	88.39	+884	3829
			400	110.49	+1105	4786
			300	147.31	+1473	6381
			250	176.78	+1768	7657
			200	220.97	+2209	9572
			160	276.21	+2762	11965
			120	368.28	+3683	15953
71M6103, 71M6113	100	19.64	250	78.57	786	3403
			200	98.21	982	4254
			160	122.76	1228	5318
			120	163.68	1637	7090
			100	196.42	1964	8508
71M6203, 71M6203	200	12.63	75	168.36	1684	7293
			50	252.54	2525	10939
			25	505.08	5050	21878

The meter constant kh (Wh per pulse) is calculated as follows:

Kh = 54.5793*$VMAX$*$IMAX$ / (SUM_SAMPS*$WRATE$*X),

where

$VMAX$ = RMS voltage at the meter input corresponding to 176.8 mV RMS at the VA pin of the 71M6543. This value is determines by the divider ratio of the voltage divider resistors. For the 71M6543 Demo Board, this value is 600.
$IMAX$*I* = RMS current through one current sensor corresponding to the maximum RMS voltage at the input pins of the 71M6103, as determined by the formula above.
SUM_SAMPS = The value in the SUM_SAMPS register in I/O RAM (2520 for this version of the Demo Code).
$WRATE$ = The value in the pulse rate adjustment register of the CE.
X = The pulse rate adjustment modifier, determined by the $PULSE_FAST$ and $PULSE_SLOW$ bits in the $CECONFIG$ register.

For the 71M6103, a kh of 3.2 (3.2 Wh per pulse) is achieved by the following combination of system settings:

$VMAX$ = 600 V
$IMAX$*I* = 163.7 A, based on R_S = 120 µΩ
SUM_SAMPS = 2520
$WRATE$ = 7090
X = 0.09375, based on $PULSE_FAST$ =0 and $PULSE_SLOW$ = 1

The calculations shown above are simplified if the calibration spreadsheet provided with each Demo Kit is used. Figure 1-7 shows an example: The user enters data in the yellow fields, and the results will show in the green fields.

System Settings for 71M6541 and 71M6543 REV 6.0

TERIDIAN SEMICONDUCTOR CORP

Poly-Phase Operation

71M6X0X Part No.	I nom [A]	VMAX [V]	PULSE _FAST/ PULSE_SLOW	X	Shunt Voltage [mV] RMS	V max [mV]	Shunt Resistance [µΩ]	Power [W]	kH	IMAX [A]	WRATE
71M6603	60	600	01	0.09375	30	44.2	500	1.8	3.2	88.39	3829
71M6103/6113	100	600	01	0.09375	12	19.6	120	1.2	3.2	163.68	7091
71M6203	200	600	01	0.09375	10	12.6	50	2	3.2	252.54	10940

Single-Phase Operation

71M6X0X Part No.	I nom [A]	VMAX [V]			71M6541 Gain	CE 0x30	Shunt Voltage [mV] RMS	V max [mV]	Shunt Resistance [µΩ]	Power [W]	kH	IMAX [A]	WRATE
71M6601	60	600	00	6	1	2483	30	44.2	500	1.8	1.0	88.39	383
71M6201	200	600	00	6	1	8691	10	12.6	50	2	1.0	252.54	1094

Figure 1-7: Worksheet from Calibration Spreadsheets REV 6.0

1.10.6 DETERMINING THE TYPE OF 71M6X0X

Sometimes it is useful to be able to determine the type of 71M6x0x Remote Sensor Interface that is mounted on the Demo Board. The CLI can be used to find out which Remote Sensor Interface is present, using the following steps:

1) Type 6R1.14, 6R2.14, or 6R3.14, depending on which phase is tested.
2) The CLI will respond with a two-byte hex value, e.g. E9DB.
3) Write the hex value out as binary sequence, e.g. 1110 1001 11**01** 1011. Bits 4 and 5 determine the type of the 71M6x0x Remote Sensor Interface, as shown in Table 1-11.

Table 1-11: Identification of 71M6x0x Remote Sensor Types

Bit 5/Bit 4	71M6x0x Remote Interface	Current [A]	For Accuracy Class (%)
00	71M6601 or 71M6603	60	1
01	71M6103 (Polyphase) or	100	1
	71M6113 (Polyphase)		0.5
10	71M6201 or 71M6203	200	0.2
11	Invalid	--	--

1.10.7 COMMUNICATING WITH THE 71M6X0X

Some commands are useful to communicate with the 71M6x0x Remote Sensor Interface for the purpose of test and diagnosis. Some useful commands are:

1) 6C1.42 – this command causes the 71M6x0x Remote Sensor Interface to output its reference voltage on the TMUX pin (pin 5).

2) 6R1.20 – this command returns the reading from the temperature sensor (STEMP) of the 71M6x0x Remote Sensor Interface in a two-byte hexadecimal format (e.g. FFDF). Negative readings are signaled by the MSB being 1.
   $T = 22°C + (STEMP*0.33 - (STEMP^2)*0.00003)°C$
   Example: For STEMP = 0xFFDF the decimal equivalent is -32. The temperature calculates to 22°C – 10.59°C = 11.4°C.
   Note that the IC temperature is averaged and displayed more accurately with the M1 command.

1.10.8 BOOTLOADER FEATURE

Demo Codes 5.4F and later are equipped with a bootloader feature. This feature allows the loading of code via the serial interface (USB connector CN1) when a Signum ADM51 emulator or Maxim TFP2 Flash Loader is not available.

The bootloader functions as follows:

1) Meter code must be modified in order to be loaded by the bootloader. The meter code must start at address 0x0400, and its interrupt vector table must also start at 0x400. The bootloader itself is located at address 0x0000 and must be loaded into the IC by some method if the flash memory of the 71M6543 is empty or if code of a previous revision is loaded. The bootloader is part of Demo Code 5.4F.

2) The bootloader loads Intel hex-86 files at 38,400 baud 8 bits, no parity. It will only accept record types 0, 4 and 1, which are the types produced by Maxim's Teridian bank_merge program or checksum program, and the Keil compiler (PK51). No records may overlap. (Keil, bank_merge and checksum produce this style of hex file by default.)
   The records from 0x00000 to 0x00400 are ignored, so that the bootloader can't overwrite itself.

3) If the bootloader load process is not invoked, the bootloader jumps to address 0x0400 and executes the code found there.

4) A detailed description of the bootloader can be found in the _readme.txt file contained in the source code ZIP package (folder 6543_5p4f_14dec11\Config\Series6540\BtLd).

For a 71M6543 Demo Board containing code with the bootloader, instructions for loading new code are as follows:

1) Connect a PC running HyperTerminal or a similar terminal program to the 71M6543 Demo Board. Set the program to 38,400 baud 8 bits, no parity, XON/XOFF flow control.

2) Turn off the power to the 71M6543 Demo Board.

3) Install a jumper from board ground to the VARh pulse output (JP7, right pin), which is also SEGDIO2. A low voltage on this pin signals to the bootloader that new code should be loaded via the UART.

4) Apply power to the meter.

5) After a brief delay, the Wh pulse LED (D5) will light up (SEGDIO1). The bootloader should send a ":" on the UART to the PC. If this occurs, the flash is erased, and the 71M6543 Demo Board is ready to load code.
   - If this does not occur, check the jumper, and reset or repower the unit
   - If the Wh LED still does not light up, then the boot code is not installed.

- If the Wh LED lights up, but the ":" does not appear, debug the RS-232 wiring. Possible issues are that the baud rate is not 38400 baud, or that the wiring is wrong, (debug using a known-good meter), or that the terminal program in the PC is not working.

6) Send the Intel hex file built for operation with the bootloader (e.g. 6543eq5_6103_5p4f_14dec11.hex) using the 'Send Text File' command of HyperTerminal.

7) During the load procedure, the Wh LED will blink. Once the load process is completed it stops blinking. The Wh LED should remain on solidly at the completion of the load procedure, which indicates an error-free load. If the LED turns off at the end, an error must have occurred. In this case the load should be repeated. The bootloader sends a "1" on the UART if the load succeeded, and "0" if it failed.

8) Check the display of terminal program (e.g. the PC running Hyperterminal). If no checksum error has occurred, the bootloader sends a 1 on the UART. In case of an error, reset the 71M6543 Demo Board, or turn it off and on, and reload the code.

9) Remove the jumper on JP7. This will cause the loaded Demo Code to start.

2

2 APPLICATION INFORMATION

2.1 CALIBRATION THEORY

A typical meter has phase and gain errors as shown by ϕ_S, A_{XI}, and A_{XV} in Figure 2-1. Following the typical meter convention of current phase being in the lag direction, the small amount of phase lead in a typical current sensor is represented as $-\phi_S$. The errors shown in Figure 2-1 represent the sum of all gain and phase errors. They include errors in voltage attenuators, current sensors, and in ADC gains. In other words, no errors are made in the 'input' or 'meter' boxes.

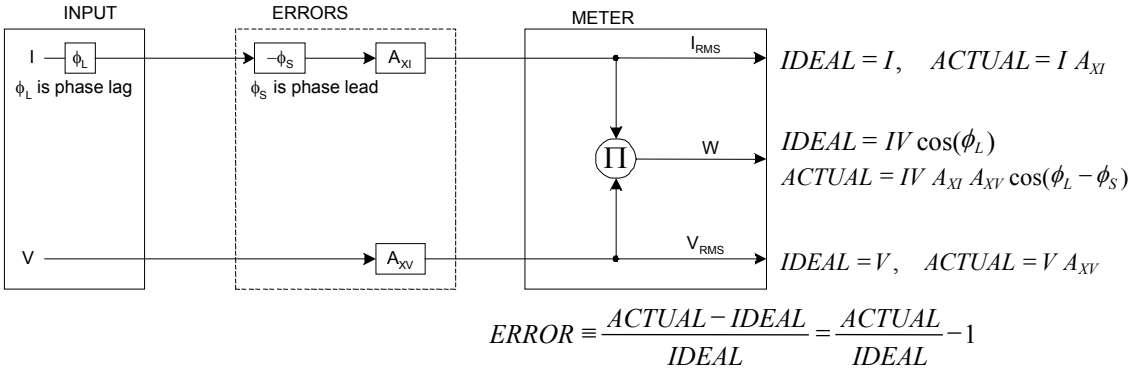

Figure 2-1: Watt Meter with Gain and Phase Errors.

During the calibration phase, we measure errors and then introduce correction factors to nullify their effect. With three unknowns to determine, we must make at least three measurements. If we make more measurements, we can average the results.

2.1.1 CALIBRATION WITH THREE MEASUREMENTS

The simplest calibration method is to make three measurements. Typically, a voltage measurement and two Watt-hour (Wh) measurements are made. A voltage display can be obtained for test purposes via the command >**MR2.1** in the serial interface.

Let's say the voltage measurement has the error E_V and the two Wh measurements have errors E_0 and E_{60}, where E_0 is measured with $\phi_L = 0$ and E_{60} is measured with $\phi_L = 60$. These values should be simple ratios—not percentage values. They should be zero when the meter is accurate and negative when the meter runs slow. The fundamental frequency is f_0. T is equal to $1/f_S$, where f_S is the sample frequency (2560.62Hz). Set all calibration factors to nominal: CAL_IA = 16384, CAL_VA = 16384, $LCOMP2_A$ = 16384.

Note: The derivation of the calibration formulae is provided for CTs, where a phase adjustment is performed to compensate for the phase error of the CT. For operation with 71M6xxx Remote Sensor Interfaces, a delay compensation $LCOMP2_n$ is used. Spreadsheets are available to calculate the calibration coefficients for all hardware configurations.

From the voltage measurement, we determine that

1.➔ $$A_{XV} = E_V + 1$$

We use the other two measurements to determine ϕ_S and A_{XI}.

2. $$E_0 = \frac{IV\ A_{XV}\ A_{XI} \cos(0 - \phi_S)}{IV \cos(0)} - 1 = A_{XV}\ A_{XI} \cos(\phi_S) - 1$$

2a. $$A_{XV} A_{XI} = \frac{E_0 + 1}{\cos(\phi_S)}$$

3. $$E_{60} = \frac{IV\ A_{XV}\ A_{XI} \cos(60 - \phi_S)}{IV \cos(60)} - 1 = A_{XV}\ A_{XI}\ \frac{\cos(60 - \phi_S)}{\cos(60)} - 1$$

3a. $$E_{60} = \frac{A_{XV} A_{XI} \left[\cos(60)\cos(\phi_S) + \sin(60)\sin(\phi_S)\right]}{\cos(60)} - 1$$

$$= A_{XV} A_{XI} \cos(\phi_S) + A_{XV} A_{XI} \tan(60)\sin(\phi_S) - 1$$

Combining 2a and 3a:

4. $$E_{60} = E_0 + (E_0 + 1)\tan(60)\tan(\phi_S)$$

5. $$\tan(\phi_S) = \frac{E_{60} - E_0}{(E_0 + 1)\tan(60)}$$

6.➔ $$\phi_S = \tan^{-1}\left(\frac{E_{60} - E_0}{(E_0 + 1)\tan(60)}\right)$$

and from 2a:

7.➔ $$A_{XI} = \frac{E_0 + 1}{A_{XV} \cos(\phi_S)}$$

Now that we know the A_{XV}, A_{XI}, and ϕ_S errors, we calculate the new calibration voltage gain coefficient from the previous ones:

$$CAL_V_{NEW} = \frac{CAL_V}{A_{XV}}$$

We calculate PHADJ from ϕ_S, the desired phase lag:

$$PHADJ = 2^{20}\left[\frac{\tan(\phi_S)\left[1 + (1 - 2^{-9})^2 - 2(1 - 2^{-9})\cos(2\pi f_0 T)\right]}{(1 - 2^{-9})\sin(2\pi f_0 T) - \tan(\phi_S)\left[1 - (1 - 2^{-9})\cos(2\pi f_0 T)\right]}\right]$$

And we calculate the new calibration current gain coefficient, including compensation for a slight gain increase in the phase calibration circuit.

$$CAL_I_{NEW} = \frac{CAL_I}{A_{XI}} \frac{1}{\sqrt{1 + \frac{2^{-20} PHADJ(2 + 2^{-20} PHADJ - 2(1 - 2^{-9})\cos(2\pi f_0 T))}{1 - 2(1 - 2^{-9})\cos(2\pi f_0 T) + (1 - 2^{-9})^2}}}$$

2.1.2 CALIBRATION WITH FIVE MEASUREMENTS

The five measurement method provides more orthogonality between the gain and phase error derivations. This method involves measuring E_V, E_0, E_{180}, E_{60}, and E_{300}. Again, set all calibration factors to nominal, i.e. CAL_IA = 16384, CAL_VA = 16384, $PHADJ_A$ = 0.

Note: The derivation of the calibration formulae is provided for CTs, where a phase adjustment is performed to compensate for the phase error of the CT. For operation with 71M6xxx Remote Sensor Interfaces, a delay compensation $LCOMP2_n$ is used. Spreadsheets are available to calculate the calibration coefficients for all hardware configurations.

First, calculate A_{XV} from E_V:

1.➔ $$A_{XV} = E_V + 1$$

Calculate A_{XI} from E_0 and E_{180}:

2. $$E_0 = \frac{IV\ A_{XV}\ A_{XI}\cos(0-\phi_S)}{IV\cos(0)} - 1 = A_{XV}\ A_{XI}\cos(\phi_S) - 1$$

3. $$E_{180} = \frac{IV\ A_{XV}\ A_{XI}\cos(180-\phi_S)}{IV\cos(180)} - 1 = A_{XV}\ A_{XI}\cos(\phi_S) - 1$$

4. $$E_0 + E_{180} = 2A_{XV}A_{XI}\cos(\phi_S) - 2$$

5. $$A_{XV}A_{XI} = \frac{E_0 + E_{180} + 2}{2\cos(\phi_S)}$$

6.➔ $$A_{XI} = \frac{(E_0 + E_{180})/2 + 1}{A_{XV}\cos(\phi_S)}$$

Use above results along with E_{60} and E_{300} to calculate ϕ_S.

7. $$E_{60} = \frac{IV\ A_{XV}\ A_{XI}\cos(60-\phi_S)}{IV\cos(60)} - 1$$

$$= A_{XV}A_{XI}\cos(\phi_S) + A_{XV}A_{XI}\tan(60)\sin(\phi_S) - 1$$

8. $$E_{300} = \frac{IV\ A_{XV}\ A_{XI}\cos(-60-\phi_S)}{IV\cos(-60)} - 1$$

$$= A_{XV}A_{XI}\cos(\phi_S) - A_{XV}A_{XI}\tan(60)\sin(\phi_S) - 1$$

Subtract 8 from 7

9. $$E_{60} - E_{300} = 2A_{XV}A_{XI}\tan(60)\sin(\phi_S)$$

use equation 5:

10. $$E_{60} - E_{300} = \frac{E_0 + E_{180} + 2}{\cos(\phi_S)}\tan(60)\sin(\phi_S)$$

11. $$E_{60} - E_{300} = (E_0 + E_{180} + 2)\tan(60)\tan(\phi_S)$$

12.➔ $$\phi_S = \tan^{-1}\left(\frac{(E_{60} - E_{300})}{\tan(60)(E_0 + E_{180} + 2)}\right)$$

Now that we know the A_{XV}, A_{XI}, and ϕ_S errors, we calculate the new calibration voltage gain coefficient from the previous ones:

$$CAL_V_{NEW} = \frac{CAL_V}{A_{XV}}$$

We calculate PHADJ from ϕ_S, the desired phase lag:

$$PHADJ = 2^{20}\left[\frac{\tan(\phi_S)\left[1+(1-2^{-9})^2-2(1-2^{-9})\cos(2\pi f_0 T)\right]}{(1-2^{-9})\sin(2\pi f_0 T)-\tan(\phi_S)\left[1-(1-2^{-9})\cos(2\pi f_0 T)\right]}\right]$$

And we calculate the new calibration current gain coefficient, including compensation for a slight gain increase in the phase calibration circuit.

$$CAL_I_{NEW} = \frac{CAL_I}{A_{XI}}\frac{1}{\sqrt{1+\frac{2^{-20}PHADJ(2+2^{-20}PHADJ-2(1-2^{-9})\cos(2\pi f_0 T))}{1-2(1-2^{-9})\cos(2\pi f_0 T)+(1-2^{-9})^2}}}$$

2.2 CALIBRATION PROCEDURES

2.2.1 CALIBRATION EQUIPMENT

Calibration requires that a calibration system is used, i.e. equipment that applies accurate voltage, load current and load angle to the unit being calibrated, while measuring the response from the unit being calibrated in a repeatable way. By repeatable we mean that the calibration system is synchronized to the meter being calibrated. Best results are achieved when the first pulse from the meter opens the measurement window of the calibration system. This mode of operation is opposed to a calibrator that opens the measurement window at random time and that therefore may or may not catch certain pulses emitted by the meter.

It is essential for a valid meter calibration to have the voltage stabilized a few seconds before the current is applied. This enables the Demo Code to initialize the 71M6543F and to stabilize the PLLs and filters in the CE. This method of operation is consistent with meter applications in the field as well as with metering standards.

During calibration of any phase, a stable mains voltage has to be present on phase A. This enables the CE processing mechanism of the 71M6543F necessary to obtain a stable calibration.

2.2.2 DETAILED CALIBRATION PROCEDURES

The procedures below show how to calibrate a meter phase with either three or five measurements. The PHADJ equations apply only when a current transformer is used for the phase in question. Note that positive load angles correspond to lagging current (see Figure 2-2).

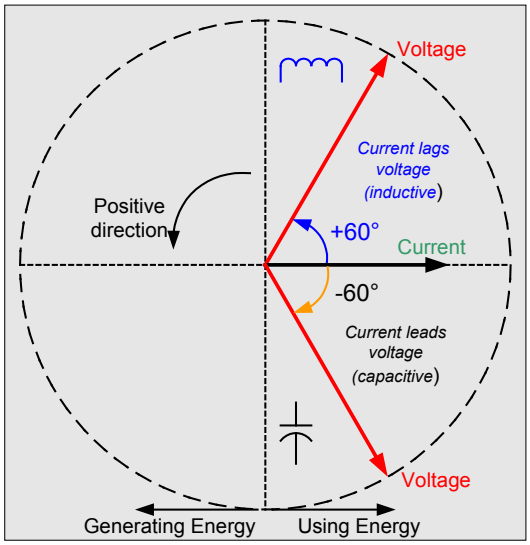

Figure 2-2: Phase Angle Definitions

The calibration procedures described below should be followed after interfacing the voltage and current sensors to the 71M6543F chip. When properly interfaced, the V3P3 power supply is connected to the meter neutral and is the DC reference for each input. Each voltage and current waveform, as seen by the 71M6543F, is scaled to be less than 250mV (peak).

2.2.3 CALIBRATION PROCEDURE WITH THREE MEASUREMENTS

Each phase is calibrated individually. The calibration procedure is as follows:

1) The calibration factors for all phases are reset to their default values, i.e. CAL_In = CAL_Vn = 16384, and $LCOMP2_n$ = 16384.
2) An RMS voltage V_{ideal} consistent with the meter's nominal voltage is applied, and the RMS reading V_{actual} of the meter is recorded. The voltage reading error Axv is determined as

   $Axv = (V_{actual} - V_{ideal}) / V_{ideal}$
3) Apply the nominal load current at phase angles 0° and 60°, measure the Wh energy and record the errors E_0 AND E_{60}.
4) Calculate the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$, using the formulae presented in section 2.1.1 or using the spreadsheet presented in section 2.2.5.
5) Apply the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$ to the meter. The memory locations for these factors are given in section 1.9.1.
6) Test the meter at nominal current and, if desired, at lower and higher currents and various phase angles to confirm the desired accuracy.
7) Store the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$ in the EEPROM or FLASH memory of the meter. If the calibration is performed on a Teridian Demo Board, the methods involving the command line interface, as shown in sections 1.9.3 and 1.9.4, can be used.
8) Repeat the steps 1 through 7 for each phase.

Tip: Step 2 and the energy measurement at 0° of step 3 can be combined into one step.

2.2.4 CALIBRATION PROCEDURE WITH FIVE MEASUREMENTS

Each phase is calibrated individually. The calibration procedure is as follows:

1) The calibration factors for all phases are reset to their default values, i.e. CAL_In = CAL_Vn = 16384, and $LCOMP2_n$ = 0.
2) An RMS voltage V_{ideal} consistent with the meter's nominal voltage is applied, and the RMS reading V_{actual} of the meter is recorded. The voltage reading error Axv is determined as

   $Axv = (V_{actual} - V_{ideal}) / V_{ideal}$
3) Apply the nominal load current at phase angles 0°, 60°, 180° and –60° (-300°). Measure the Wh energy each time and record the errors E_0, E_{60}, E_{180}, and E_{300}.
4) Calculate the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$, using the formulae presented in section 2.1.2 or using the spreadsheet presented in section 2.2.5.
5) Apply the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$ to the meter. The memory locations for these factors are given in section 1.9.1.
6) Test the meter at nominal current and, if desired, at lower and higher currents and various phase angles to confirm the desired accuracy.
7) Store the new calibration factors CAL_In, CAL_Vn, and $LCOMP2_n$ in the EEPROM or FLASH memory of the meter. If a Demo Board is calibrated, the methods involving the command line interface shown in sections 1.9.3 and 1.9.4 can be used.
8) Repeat the steps 1 through 7 for each phase.

Tip: Step 2 and the energy measurement at 0° of step 3 can be combined into one step.

2.2.5 CALIBRATION SPREADSHEETS

Calibration spreadsheets are available on the Maxim web site (www.maxim-ic.com). Figure 2-3 shows the spreadsheet for three measurements. Figure 2-4 shows the spreadsheet for five measurements with three phases.

Use the standard calibration spreadsheets (for 71M651x, 71M652x, or 71M653x) when calibrating meters with CTs. These spreadsheets will provide results for the $PHADJ_n$ parameters instead of the $LCOMP2_n$ parameters.

For the calibration, data should be entered into the calibration spreadsheets as follows:

1. Calibration is performed one phase at a time.
2. Results from measurements are generally entered in the yellow fields. Intermediate results and calibration factors will show in the green fields.
3. The line frequency used (50 or 60Hz) is entered in the yellow field labeled AC frequency.
4. After the voltage measurement, measured (observed) and expected (actually applied) voltages are entered in the yellow fields labeled "Expected Voltage" and "Measured Voltage". The error for the voltage measurement will then show in the green field above the two voltage entries.
5. The relative error from the energy measurements at 0° and 60° are entered in the yellow fields labeled "Energy reading at 0°" and "Energy reading at 60°". The corresponding error, expressed as a fraction will then show in the two green fields to the right of the energy reading fields.
6. The spreadsheet will calculate the calibration factors CAL_IA, CAL_VA, and $LCOMP2_A$ from the information entered so far and display them in the green fields in the column underneath the label "new".
7. If the calibration was performed on a meter with non-default calibration factors, these factors can be entered in the yellow fields in the column underneath the label "old". For a meter with default calibration factors, the entries in the column underneath "old" should be at the default value (16384).

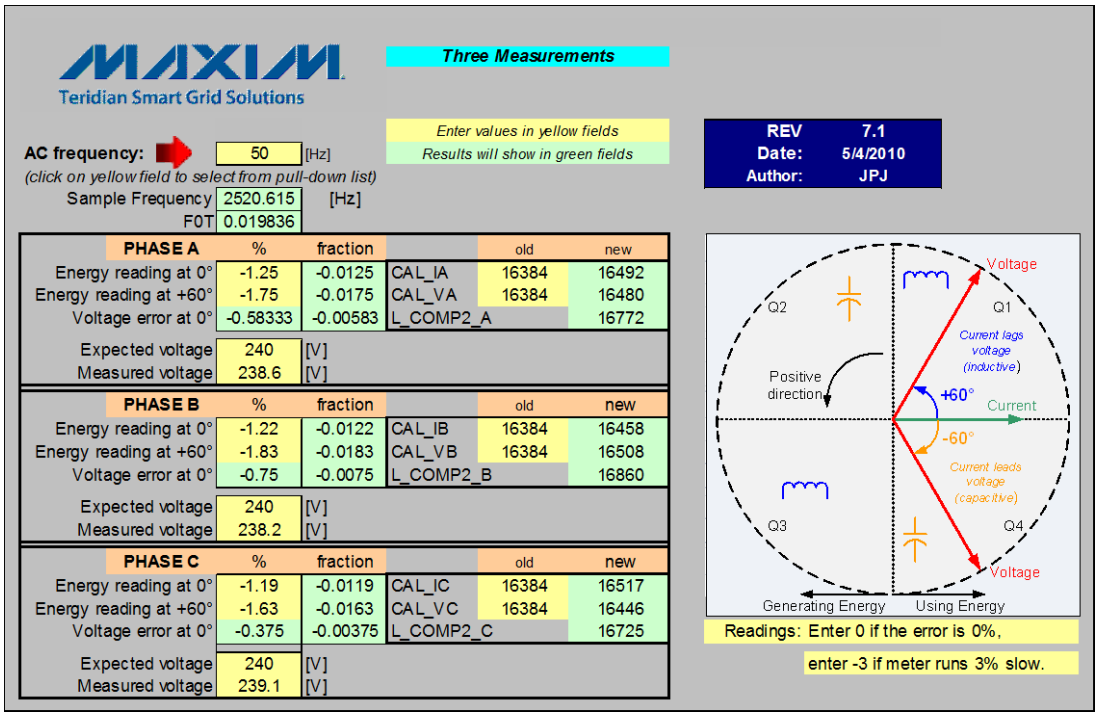

Figure 2-3: Calibration Spreadsheet for Three Measurements

Note: The values for $LCOMP2_n$ may have to be changed slightly depending on shunt sensor and cable inductance. The values from the spreadsheets provide starting points. For example, if after calibration the error or 0° load angle is 0.024%, but +1.25% at 60° and -1.18% at 300°, $LCOMP2_n$ should be increased to minimize the errors at 60° and at 300°.

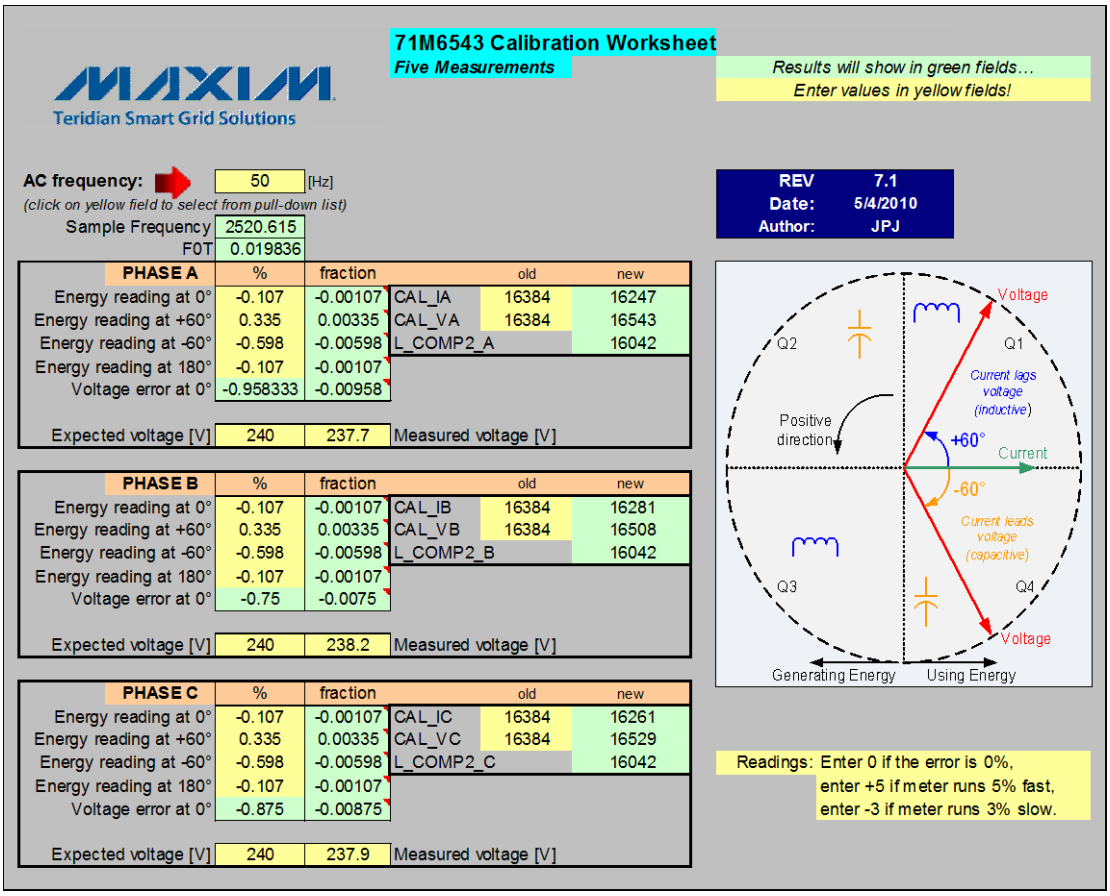

Figure 2-4: Calibration Spreadsheet for Five Measurements

Note: The spreadsheets shown above apply to calibration for systems with 71M6xxx Remote Sensor Interfaces. For CT-bases meters, the regular spreadsheets (also used for the 71M6513, 71M6533, and 71M6534) should be used.

2.2.6 COMPENSATING FOR NON-LINEARITIES

Nonlinearity is most noticeable at low currents, as shown in Figure 2-5, and can result from input noise and truncation. Nonlinearities can be eliminated using the *QUANTA, QUANTB,*and *QUANTC* variables.

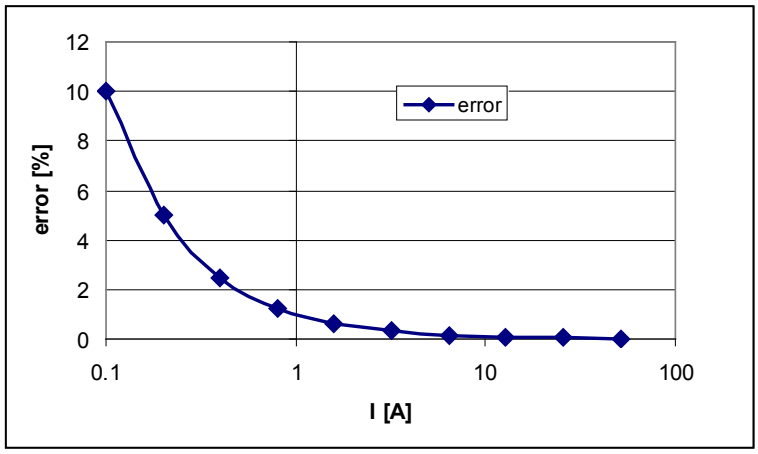

Figure 2-5: Non-Linearity Caused by Quantification Noise

The error can be seen as the presence of a virtual constant noise current. While 10mA hardly contribute any error at currents of 10A and above, the noise becomes dominant at small currents.

The value to be used for $QUANT$ can be determined by the following formula:

$$QUANT = -\frac{\frac{error}{100} V \cdot I}{VMAX \cdot IMAX \cdot LSB}$$

Where error = observed error at a given voltage (V) and current (I),
$VMAX$ = voltage scaling factor, as described in section 1.8.3,
$IMAX$ = current scaling factor, as described in section 1.8.3,
LSB = QUANT LSB value = $7.4162*10^{-10}$W

Example: Assuming an observed error as in Figure 2-5, we determine the error at 1A to be +1%. If $VMAX$ is 600V and $IMAX$ = 208A, and if the measurement was taken at 240V, we determine $QUANTn$ as follows:

$$QUANT = -\frac{\frac{1}{100} 240 \cdot 1}{600 \cdot 208 \cdot 7.4162 \cdot 10^{-10}} = -11339$$

There is a $QUANTn$ register for each phase, and the values are to be written to the CE locations 0x28, 0x2C, or 0x30. It does not matter which current value is chosen as long as the corresponding error value is significant (5% error at 0.2A used in the above equation will produce the same result for $QUANTn$).

Input noise and truncation can cause similar errors in the VAR calculation that can be eliminated using the $QUANT_VARn$ variables. $QUANT_VARn$ is determined mula as $QUANT$.

2.3 TEMPERATURE COMPENSATION

2.3.1 ERROR SOURCES

This section discussed the temperature compensation for meters equipped with 71M6xxx Remote Sensor Interfaces. Compensation for CT-based systems is much simpler, since the error sources are only the reference voltage, the burden resistor, and the voltage dividers.

For a meter to be accurate over temperature, the following major sources of error have to be addressed:

1) The resistance of the shunt sensor(s) over temperature. The temperature coefficient (TC) of a shunt resistor is typically positive (PTC) and can be far higher than the TC of the pure Manganin material used in the shunt. TCs of several hundred PPM/°C have been observed for certain shunt resistors. A shunt resistor with +100 PPM/°C will increase its resistance by 60°C * $100*10^{-6}$ PPM/°C, or +0.6% when heated up from room temperature to +85°C, causing a relative error of +0.6% in the current reading. This makes the shunt the most pronounced influence on the temperature characteristics of the meter.
   Typically, the TC of shunt resistors is mostly linear over the industrial temperature range and can be compensated, granted the shunt resistor is at the same temperature as the on-chip temperature sensors on the 71M6x0x Remote Sensor Interface IC or the 71M6543.
   Generally, the lower the TC of a shunt resistor, the better it can be compensated. Shunts with high TCs require more accurate temperature measurements than those with low TCs. For example, if a shunt with 200 PPM/°C is used, and the temperature sensor available to the 71M6543 is only accurate to ±3°C, the compensation can be inaccurate by as much as 3°C*200PPM/°C = 600 PPM, or 0.06%.

2) The reference voltage of the 71M6x03 Remote Sensor Interface IC. At the temperature extremes, this voltage can deviate by a few mV from the room temperature voltage and can therefore contribute to some temperature-related error. The TC of the reference voltage has both linear and quadratic components (TC_1 and TC_2). Since the 71M6X03 Remote Interface IC has an on-chip temperature sensor, and since the development of the reference voltage over temperature is predictable (to within ±10 PPM/°C for high-grade parts). For example, compensation of the current reading is possible for a part with ±80 PPM°C to within ±60°C *$80*10^{-6}$ PPM/°C, or ±0.48%.
   The reference voltage can be approached by the nominal reference voltage:

   $VNOM(T) = VNOM(22)+(T-22)*TC_1+(T-22)^2*TC_2$

   Actual values for TC_1 and TC_2 can be obtained using the formulae given in the data sheets for the 71M6543 and for the 71M6x03. Additionally, the Demo Code will automatically generate the compensation coefficients based on TC_1 and TC_2 using the fuse values in each device.

3) The reference voltage of the 71M6543F IC. At the temperature extremes, this voltage can deviate by a few mV from the room temperature voltage and can therefore contribute to some temperature-related error, both for the current measurement (pins IAP and IAN) of the neutral current sensor (if used) and for the voltage measurement (pin VA). As with the Remote Sensor Interface IC, the TC of the 71M6543F reference voltage has both linear and quadratic components. The reference voltage of the 71M6543F over temperature is predictable within ±40 PPM/°C, which means that compensation of the current and voltage reading is possible to within ±0.24%.
The 71M6543H has more predictable temperature coefficients that allow compensation to within ±10 PPM/°C, resulting in ±0.06% inaccuracy.

   The temperature coefficients of the reference voltage are published in the 71M6543F/H data sheet. The Demo Code will automatically generate the compensation coefficients based on TC_1 and TC_2 using the fuse values in each device.

4) The voltage divider network (resistor ladder) on the Demo Board will also have a TC. Ideally, all resistors of this network are of the same type so that temperature deviations are balanced out. However, even in the best circumstances, there will be a residual TC from these components.

The error sources for a meter are summed up in Table 2-1.

Table 2-1: Temperature-Related Error Sources

Measured Item	Error Sources for Current	Error Sources for Voltage	Pins on 71M6543
Energy Reading for phase A	VREF of 71M6xx3 for phase A	71M6543 VREF	VA, ADC2/ADC3 (IBP/IBN)
	Shunt resistor for phase A	Voltage divider for VA	
Energy Reading for phase B	VREF of 71M6xx3 for phase B	71M6543 VREF	VB, ADC4/ADC5) ICP/ICN
	Shunt resistor for phase B	Voltage divider for VB	
Energy Reading for phase C	VREF of 71M6xx3 for phase C	71M6543 VREF	VC, ADC6/ADC7 (IDP/IDN)
	Shunt resistor for phase C	Voltage divider for VC	
Neutral Current Reading	71M6543 VREF	--	ADC0/ADC1 (IAP/IAN)
	Sensor for neutral current	--	

When can summarize the thermal errors per phase n in the following equation:

$$P_n = V_n \cdot I_n \cdot (1 + C_{VD}) \cdot (1 + C_{4X}) \cdot (1 + C_{Sn}) \cdot (1 + C_{6X})$$

The terms used in the above equation are defined as follows:

- Vn = voltage applied to the meter in phase n
- In = current applied to the shunt in phase n
- C_{VD} = error contribution from the voltage divider
- C_{4X} = error contribution from the voltage reference of the 71M6543
- C_{Sn} = error from the shunt resistor that is connected via the Remote Interface IC
- C_{6X} = error contribution from the voltage reference of the Remote Interface IC

2.3.2 SOFTWARE FEATURES FOR TEMPERATURE COMPENSATION

In the default settings for the Demo Code, the *CECONFIG* register has its *EXT_TEMP* bit (bit 22) set, which means that temperature compensation is performed by the MPU by controlling the *GAIN_ADJ0* through *GAIN_ADJ,* registers of the CE. Generally, these four (and when using neutral current measurement, five) registers are used as follows:

- *GAIN_ADJ0* for VA, VB, VC – CE RAM 0x40
- *GAIN_ADJ1* – Current, phase A (via 71M6xx3) – CE RAM 0x41
- *GAIN_ADJ2* - Current, phase B (via 71M6xx3) – CE RAM 0x42
- *GAIN_ADJ3* - Current, phase C (via 71M6xx3) – CE RAM 0x43
- *GAIN_ADJ4* – Current from neutral current sensor (via 71M6543) – CE RAM 0x44

In general, the *GAIN_ADJn* registers offer a way of controlling the magnitude of the voltage and current signals in the data flow of the CE code. A value of 16385 means that no adjustment is performed (unity gain), which

means that the output of the gain adjust function is the same as the input. A value of 99% of 16385, or 16222, means that the signal is attenuated by 1%.

The Demo Code bases its adjustment on the deviation from calibration (room) temperature *DELTA_T* and the coefficients *PPMC* and *PPMC2* to implement the equation below:

$$GAIN_ADJ = 16385 + \frac{DELTA_T \cdot PPMC}{2^{14}} + \frac{DELTA_T^2 \cdot PPMC2}{2^{23}}$$

It can be seen easily that the gain will remain at 16385 (0x4001), or unity gain, when *DELTA_T* is zero. In the Demo Code, *DELTA_T* is scaled so 0.1°C corresponds to 1 LSB of *DELTA_T*.

For complete compensation, the error sources for each channel have to be combined and curve-fit to generate the *PPMC* and *PPMC2* coefficients, as will be shown in the following section.

For Demo Codes revision 5.3a and later, the *PPMC* and *PPMC2* coefficients are in the MPU RAM locations listed in Table 2-3:

Table 2-2: MPU Registers for Temperature-Compensation

CE Location	*PPMC* Register for	CE Location	*PPMC2* Register for
0x20	*GAIN_ADJ0*	0x25	*GAIN_ADJ0*
0x21	*GAIN_ADJ1*	0x26	*GAIN_ADJ1*
0x22	*GAIN_ADJ2*	0x27	*GAIN_ADJ2*
0x23	*GAIN_ADJ3*	0x28	*GAIN_ADJ3*
0x24	*GAIN_ADJ0*	0x29	*GAIN_ADJ0*

When the Demo Code starts up (after reset or power-up), it determines whether the meter has been calibrated. If this is not the case, the coefficients *PPMC* and *PPMC2* are automatically determined based on information found in the 71M6543 and in the 71M6x0x Remote Sensor Interface ICs. These coefficients are calculated to compensate for the reference voltage deviation in these devices, but can be enhanced to also compensate for the shunt resistors connected to each device.

2.3.3 CALCULATING PARAMETERS FOR COMPENSATION

2.3.3.1 Shunt Resistors

The TC of the shunt resistors can be characterized using a temperature chamber, a calibrated current, and a voltmeter with filtering capabilities. A few shunt resistors should be measured and their TC should be compared. This type of information can also be obtained from the manufacturer. For sufficient compensation, the TC of the shunt resistors must be repeatable. If the shunts are the only temperature-dependent components in a meter, and the accuracy is required to be within 0.5% over the industrial temperature range, the repeatability must be better than:

R = (5000 PPM) / (60°C) = 83.3 PPM/°C

This means that for a shunt resistor with +200 PPM/°C, the individual samples must be within +116.7 PPM/°C and 283.3 PPM/°C.

Let us assume a shunt resistor of 55 µΩ in phase A. This resistor is 10% above the nominal value of 50 µΩ, but this is of minor importance, since this deviation will be compensated by calibration. In a temperature chamber, this resistor generates a voltage drop of 5.4559 mV at -40°C and 5.541 mV at +85°C with a current of 100 A applied. This is equivalent to a resistance deviation of 0.851 µΩ, or 15,473 PPM. With a temperature difference between hottest and coldest measurement of 125°C, this results in +124 PPM/°C. At high temperatures, this resistor will read the current 60°C * 124 PPM/°C, or 0.744% too high. This means that the *GAIN_ADJ1* register has to be adjusted by -0.744% at the same temperature to compensate for the TC of the shunt resistor.

Let us assume that only linear components appear in the formula below, i.e. $PPMC2$ is zero.

$$GAIN_ADJ = 16385 + \frac{DELTA_T \cdot PPMC}{2^{14}} + \frac{DELTA_T^2 \cdot PPMC2}{2^{23}}$$

We must now find the $PPMC$ value that decreases $GAIN_ADJ$ by 0.744% when $DELTA_T$ is +600 ($DELTA_T$ is measured in tens of °C). We find $PPMC_S$ to be:

$PPMC_S = 2^{14} * (16263 – 16385) / 600 = -3331$

2.3.3.2 Remote Sensor Reference Voltage

The compensation coefficients for the reference voltage of the three 71M6103 are derived automatically by the Demo Code. Typical coefficients are in the range of +500 to -300 for $PPMC_{6X}$ and -200 to -400 for $PPMC2_{6X}$.

2.3.3.3 Reference Voltage of the 71M6543 or 71M6543H

The compensation coefficients for the reference voltage of the 71M6543 are derived automatically by the Demo Code. Typical coefficients are in the range of -200 to -400 for $PPMC_{4X}$ and -400 to -800 for $PPMC2_{4X}$.

2.3.3.4 Voltage Divider

In most cases, especially when identical resistor types are used for all resistors of the voltage divider ladder, the TC of the voltage divider will be of minor influence on the TC of the meter.

If desired, the voltage divider can be characterized similar to the shunt resistor as shown above. The difference is that there is no individual $GAIN_ADJ$ for each voltage channel. $GAIN_ADJ0$ is primarily intended to compensate for the temperature coefficients of the reference voltage. If the TC of the voltage dividers is to be considered, it has to be calculated based on the average error of each phase.

Let us assume, applying 240 Vrms to a meter and recording the RMS voltage displayed by the meter at -40°C, room temperature, +55°C, and at +85°C (when averaged over all phases), we obtain the values in the center column of Table 2-3.

Table 2-3: Temperature-Related Error Sources

Temperature [°C]	Displayed Voltage	Normalized Voltage
-40	246.48	240.458
25	246.01	240.0
55	245.78	239.78
85	245.56	239.57

After normalizing with the factor 240/246.01 to accommodate for the initial error, we obtain the values in the third column. We determine the voltage deviation between highest and lowest temperature to be -0.88 V, which is equivalent to -3671 PPM, or -29.4 PPM/°C.

For this, we obtain a $PPMC_{VD}$ value of 788.

2.3.3.5 Combining the Coefficients for Temperature Compensation

After characterizing all major contributors to the TC of the meter, we have all components at hand to design the overall compensation. If we examine only phase A for the moment, we find that we will need the following coefficients for the control of $GAIN_ADJn$:

C_{S1}: The $PPMC_S$ = -3331 determined for the shunt resistor. $PPMC2_S$ for the shunt resistor is 0.

C_{VD}: The $PPMC_{VD}$ value of 788 determined for the voltage divider.

C_{4X}: $PPMC_{4X}$ = -820 and $PPMC2_{4X}$ = -680

C_{6X}: $PPMC_{6X}$ = -620 and $PPMC2_{6X}$ = -510

We will find that coefficients can simply be added to combine the effects from several sources of temperature dependence.

Following this procedure, we obtain the coefficients for $GAIN_ADJ0$ (voltage measurement) as follows:

- $PPMC_A = PPMC_{4X} + PPMC_{VD}$ = – 820 + 788 = -32
- $PPMC2_A = PPMC2_{4X} + PPMC2_{VD}$ = -680 + 0 = -680

Next, we obtain the coefficients for $GAIN_ADJ1$ (current measurement) as follows:

- $PPMC_A = PPMC_S + PPMC_{6X}$ = -3331 - 620 = -3951
- $PPMC2_A = PPMC2_S + PPMC2_{6X}$ = 0 - 510 = -510

Similar calculations apply to the remaining current phases.

2.3.3.6 Test Results for Temperature Compensation

Temperature tests were conducted that exercised the fuse accuracy in the 71M6xxx and 71M6543 in conjunction with the capability of the 654x Code to accurately read and interpret the fuses and to compensate the gain in all measurement channels.

For these tests, three 50 µΩ shunts had been characterized, and coefficients combined from the shunt coefficients and the VREF coefficients for the 71M6543H and 71M6xxx had been generated and loaded into the 71M6543H. No compensation was used for the voltage divider in the 71M6543 Demo Board. The tests were conducted with a 71M6543 Demo Board REV 3.0 populated with a 71M6543H and 3 x 71M6203 (dual-trim).

Figure 2-6 shows the results for the VREF compensation only (original coefficients obtained from fuses).

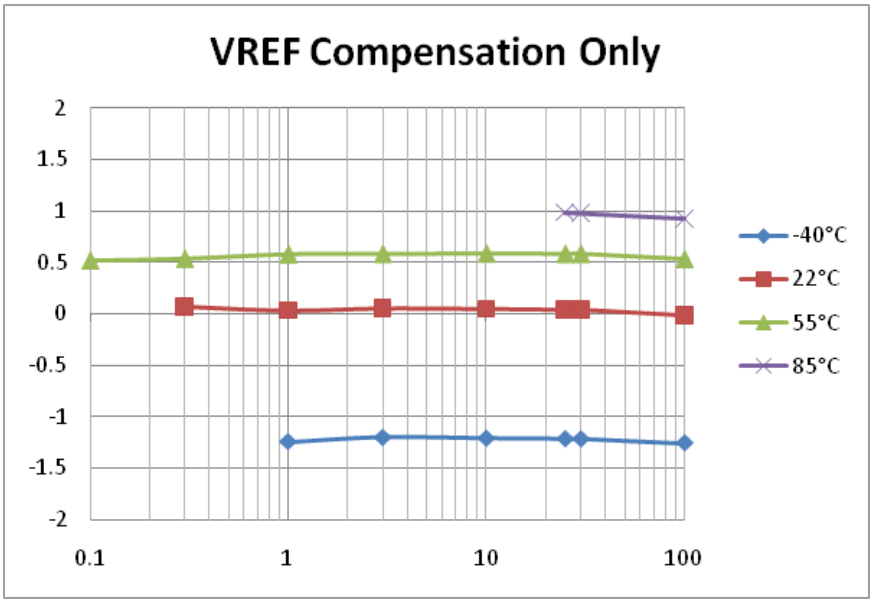

Figure 2-6: Wh Registration Error with VREF Compensation

Figure 2-7 shows the results for the combined compensation (original coefficients obtained from fuses combined with shunt coefficients).

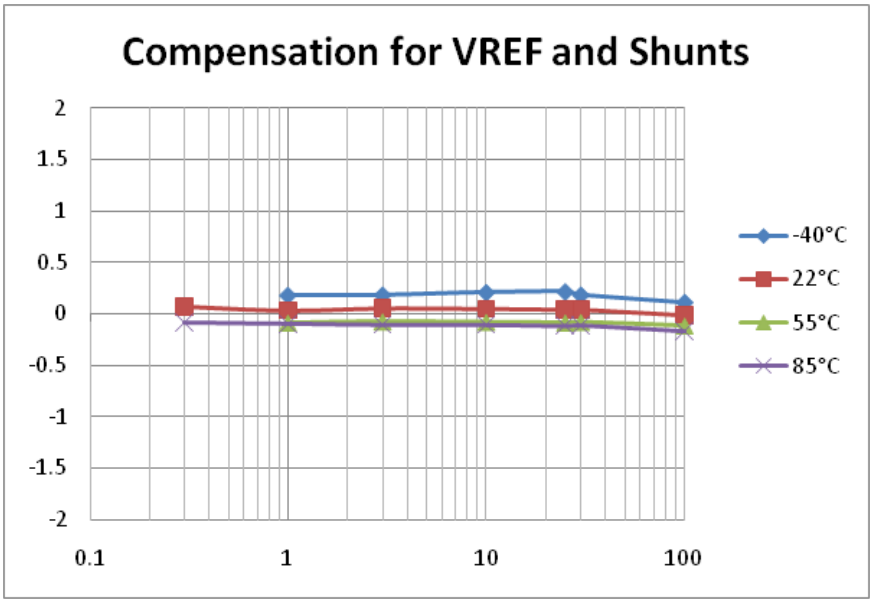

Figure 2-7: Wh Registration Error with Combined Compensation

2.4 TESTING THE DEMO BOARD

This section will explain how the 71M6543F IC and the peripherals can be tested. Hints given in this section will help evaluating the features of the Demo Board and understanding the IC and its peripherals.

Demo Board. It interfaces to a PC through a 9 pin serial port connector.

It is recommended to set up the demo board with no live AC voltage connected, and to connect live AC voltages only after the user is familiar with the demo system.

BEFORE CONNECTING THE DEMO BOARD TO A CALIBRATION SYSTEM OR OTHER HIGH-VOLTAGE SOURCE IT IS RECOMMENDED TO MEASURE THE RESISTANCE BETWEEN THE LINE AND THE NEUTRAL TERMINALS OF THE DEMO BOARD WITH A MULTIMETER. ANY RESISTANCE BELOW THE 1 MΩ RANGE INDICATES A AFAULTY CONNECTION RESULTING INDESTRUCTION OF THE 71M6543.

2.4.1 FUNCTIONAL METER TEST

This is the test that every Demo Board has to pass before being integrated into a Demo Kit. Before going into the functional meter test, the Demo Board has already passed a series of bench-top tests, but the functional meter test is the first test that applies realistic high voltages (and current signals from current transformers) to the Demo Board.

Figure 2-8 shows a meter connected to a typical calibration system. The calibrator supplies calibrated voltage and current signals to the meter. It should be noted that the current flows through the shunts or CTs that are not part of the Demo Board. The Demo Board rather receives the voltage output signals from the current sensor. An optical pickup senses the pulses emitted by the meter and reports them to the calibrator. Some calibration systems have electrical pickups. The calibrator measures the time between the pulses and compares it to the expected time, based on the meter Kh and the applied power.

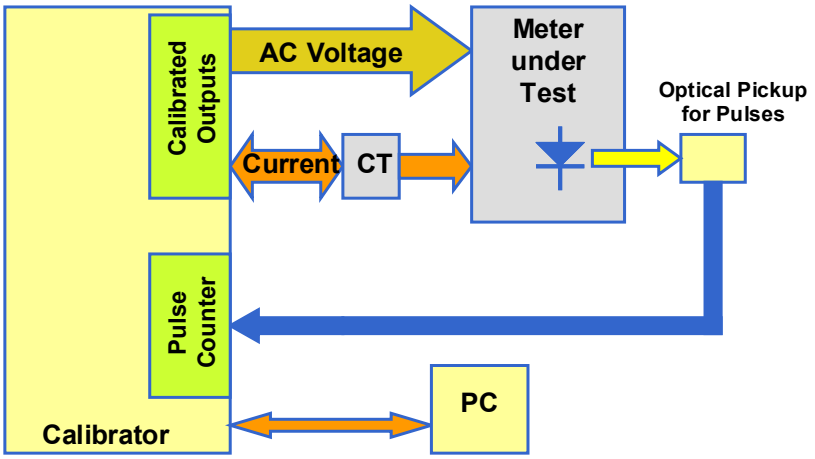

Figure 2-8: Meter with Calibration System

Figure 2-9 shows the screen on the controlling PC for a typical Demo Board. The error numbers are given in percent. This means that for the measured Demo Board, the sum of all errors resulting from tolerances of PCB components, current sensors, and 71M6543F tolerances was –3.41%, a range that can easily be compensated by calibration.

Figure 2-10 shows a load-line obtained with a 71M6543F. As can be seen, dynamic ranges of 200:0.25, or 1:800 for current can easily be achieved. Dynamic current ranges of 2,000:1 (0.1 A to 200 A) have been achieved with 50 µΩ shunts mounted in ANSI enclosures.

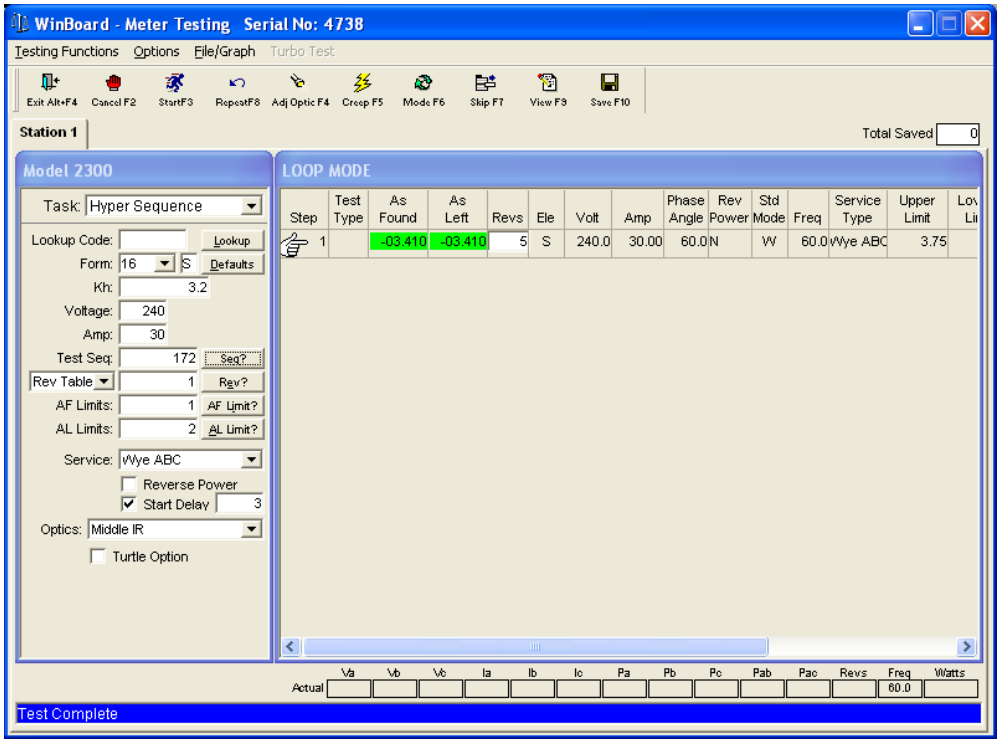

Figure 2-9: Calibration System Screen

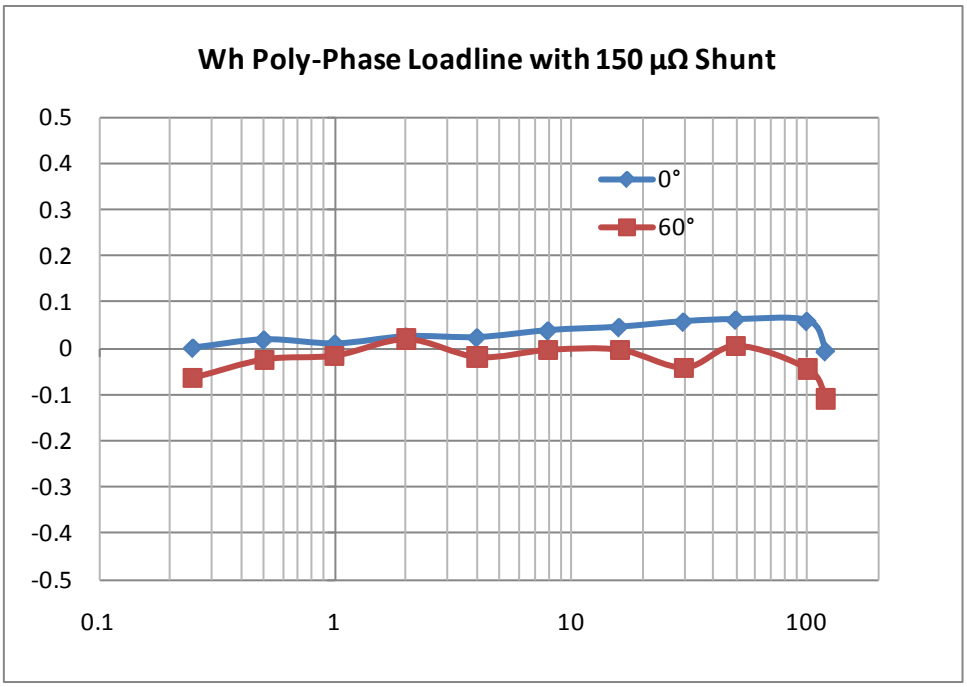

Figure 2-10: Wh Load Lines at Room Temperature with 150 µΩ Shunts

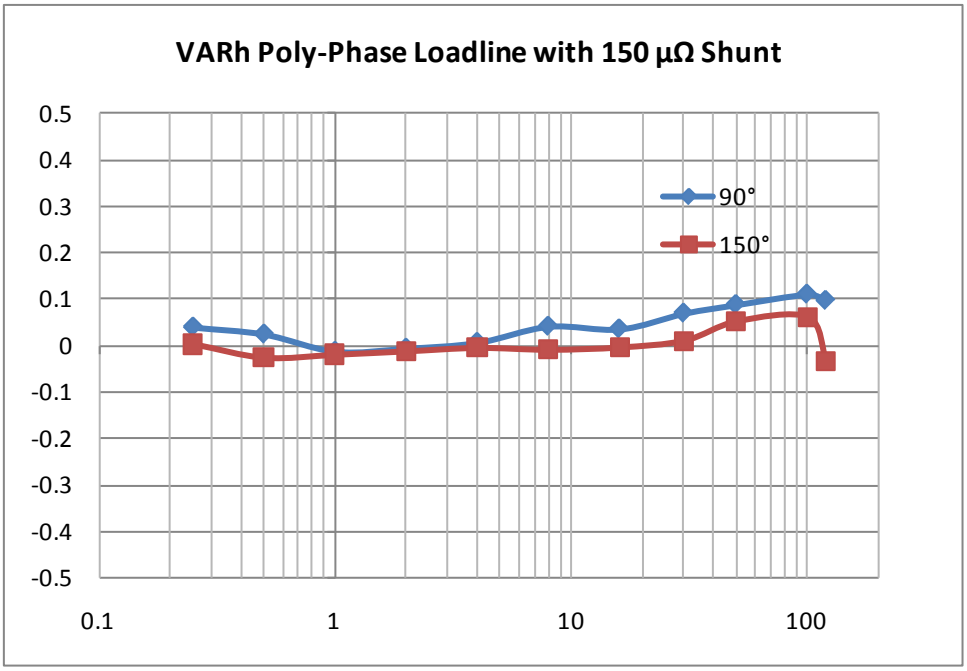

Figure 2-11: VARh Load Lines at Room Temperature with 150 µΩ Shunts

2.4.2 EMC TEST

This Demo Board is not optimized for EMC. Please contact your Maxim representative or FAE for questions regarding EMC.

2.5 SENSORS AND SENSOR PLACEMENT

Both sensor self-heating and sensor placement have to be considered in order to avoid side effects that can affect measurement accuracy. These considerations apply in general to both ANSI meters and IEC meters.

Both meter variations will be discussed below.

2.5.1 SELF-HEATING

The effect of self-heating will be most pronounced at maximum current and depends on the following parameters:

- Nominal shunt resistance
- Current through the shunt resistor
- Thermal mass
- Heat conduction away from the shunt (thermal resistance towards the environment)
- Temperature coefficient of copper and resistive material.

It is quite obvious that the nominal resistance of the shunt resistor should be kept as low as possible. Table 1-10 shows a few combinations of shunt resistance and 71M6x0x part number. The parts with part numbers corresponding to higher current capacity are designed to work with low shunt resistance. Lowering the shunt resistance below the recommended limits decreases accuracy and repeatability.

Good heat conduction can help to maintain the shunt temperature. Attaching the shunt to solid metallic structures such as meter terminal blocks helps decreasing the thermal resistance. This, of course, applies to meters where the terminals and other mechanical parts can be considered heat sinks, i.e. they do not heat up due to other effects.

The thermal mass will control how long it takes the sensor to reach its maximum temperature. Meters, for which only short-time maximum currents are applied, can benefit from a large thermal mass, since it will increase the time constant of the temperature rise.

The temperature coefficient (TC) of the shunt is a very important factor for the self-heating effect. Shunts with a TC of just a few PPM/°C can maintain good shunt accuracy even in the presence of significant self-heating.

There are several methods that can be applied in the meter design to minimize the effects of self-heating:

- Software algorithms emulating the thermal behavior of the shunt(s).
- Direct temperature measurement, ideally with the 71M6xx3 mounted directly on the shunt (collocation) or employing some other method of temperature sensing (PTC resistor, NTC resistor, discrete temperature sensor).

The effect of shunt self-heating can be described by the following formulae. First, the relative output of a shunt resistor is:

$$\Delta V/V = \Delta R/R$$

ΔR is a function of the change in temperature, the temperature coefficient (TC_R), the thermal resistance (R_{TH}), and, of course, the applied power, which is proportional to the square of the current:

$$\frac{\Delta V}{V} = \frac{\Delta R}{R} = \frac{R \cdot \Delta T \cdot TC_R}{R} = I^2 R \cdot R_{TH} \cdot TC_R$$

Ultimately, it is up to the meter designer to select the best combination of shunt resistance, TC, shunt geometry and potential software algorithms for the given application.

2.5.2 PLACEMENT OF SENSORS (ANSI)

The arrangement of the current terminals in an ANSI meter enclosure predetermines shunt orientation, but it also allows for ample space in between the sensors, which helps to minimize cross-talk between phases.

A good practice is to shape the shunts like blades and to place them upright so their surfaces are parallel. In an ANSI-type 16S meter, the distance between the phase A sensor and the phase B sensor is roughly 25 mm, which makes these two phases most critical for cross-talk. For the ANSI form 2S meter, which is a frequently used single-phase configuration, the distance between the sensors is in the range of 70 mm, which makes this configuration much less critical. However, even for this case, good sensor placement is essential to avoid cross-talk.

Sensor wires should be tightly twisted to avoid loops that can be penetrated by the magnetic fields of the sensors or conductors.

2.5.3 PLACEMENT OF SENSORS (IEC)

The arrangement of the current terminals in a typical IEC meter enclosure predetermines the spacing of the shunts, and usually allows for only for 20 to 22 mm center-to-center spacing between the shunts. This means that the clearance between adjacent shunts is typically only 10 mm or less. A typical arrangement is shown in

Figure 2-12, left side. This arrangement is not optimized for suppression of cross-talk, but it works well in most cases.

If magnetic cross-talk between shunt sensors has to be minimized, the shunts may be arranged slightly different from the standard configuration. An example with staggered shunt arrangement is shown in Figure 2-12, right side. This illustration shows the shunts as seen from inside the meter, looking towards the terminal blocks. The center shunt is lifted on spacers, which decouples the magnetic field lines.

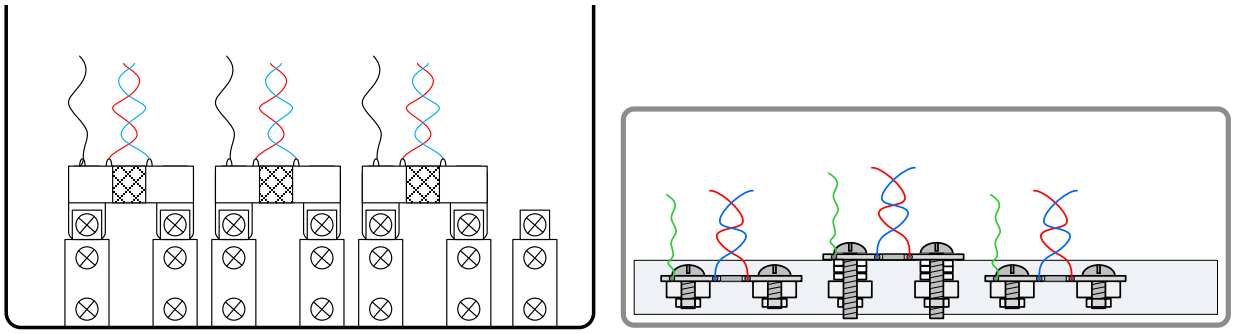

Figure 2-12: Typical Sensor Arrangement (left), Alternative Arrangement (right)

Another possible arrangement is to swivel the shunts by 90°, as shown in Figure 2-13. This method is most effective at suppressing magnetic cross-talk, but requires more space in the meter enclosure.

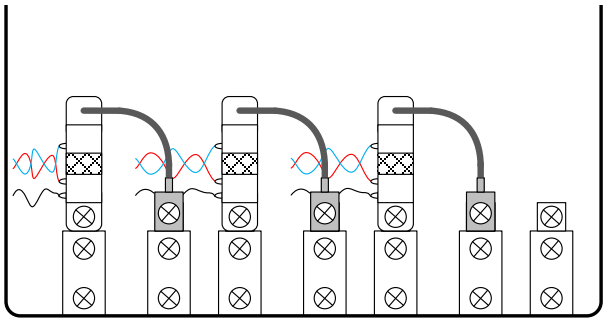

Figure 2-13: Swiveled Sensor Arrangement

It is useful to minimize the loop area formed by the Manganin zone of the shunts and the wires. As with the ANSI sensors, it is recommended that sensor wires are tightly twisted to avoid loops that can be penetrated by the magnetic fields of the sensors or conductors.

2.5.4 OTHER TECHNIQUES FOR AVOIDING MAGNETIC CROSSTALK

With very high currents or close distances between shunt sensors, magnetic pickup or cross-talk will sometimes occur even if good placement practices are followed.

One mechanism for cross-talk is shown in Figure 2-14, where the Manganin zone and the sensor wire act as a loop that will generate an output voltage similar to that generated by a Rogowski coil.

The effect of this loop can be compensated by adding a second loop on the opposite side of the shunt resistors, as shown in Figure 2-15.

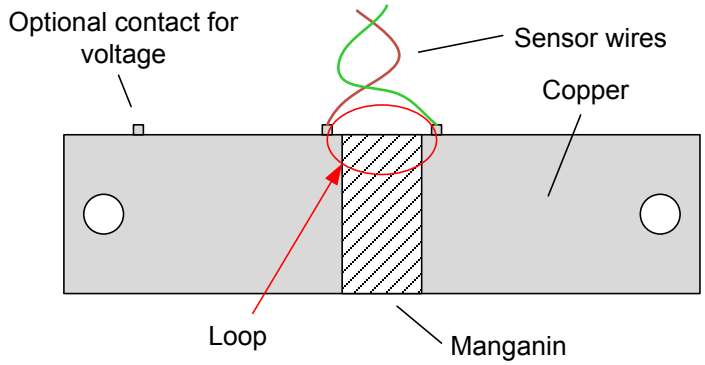

Figure 2-14: Loop Formed by Shunt and Sensor Wire

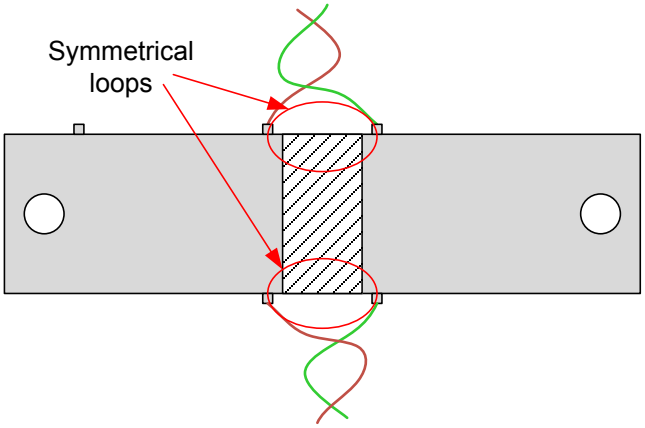

Figure 2-15: Shunt with Compensation Loop

Since the compensation loop is impractical, a similar compensation effect can be achieved by attaching the sensor wires in the center, as shown in Figure 2-16. An economical approach to this technique is to drill holes in the center of the shunt resistor for attachment of the sensor wires [1].

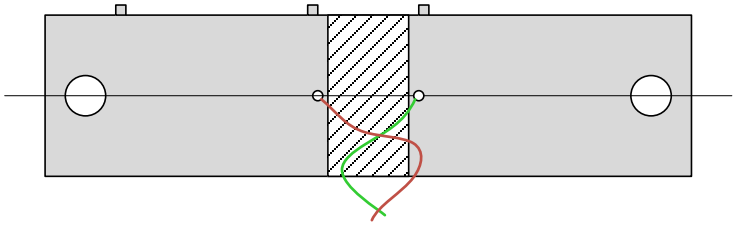

Figure 2-16: Shunt with Center Drill Holes

[1] U.S. Pat. Pending

3

3 HARDWARE DESCRIPTION

3.1 71M6543 REV 4.0 DEMO BOARD DESCRIPTION: JUMPERS, SWITCHES AND TEST POINTS

The items described in Table 3-1 refer to the flags in Figure 3-1.

Table 3-1: 71M6543 REV 4.0 Demo Board Description

Item #	Reference Designator	Name	Use
1	D5	Wh	Wh pulse LED.
2	J1	PULSE X Y	3-pin header for monitoring X and Y pulses
3	JP2	BIT BANG	5-pin header for access to the SEGDIO4 and SEGDIO9 pins.
4	JP1	BAT MODE	Selector for the operation of the IC when main power is removed, using the SEGDIO8 pin. A jumper across pins 2-3 (default) indicates that no external battery is available. The IC will stay in brownout mode when the system power is down and it will communicate at 9600bd. A jumper across pins 1-2 indicates that an external battery is available. The IC will be able to transition from brownout mode to sleep and LCD modes when the system power is down.
5	JP55/JP52	--	JP55: 2-pin header for the SDATA signal used by the serial EEPROM. JP52: 2-pin header for the SDATA signal used by the µWire EEPROM
6	U8	LCD	3-row LCD with 6 7-segment digits per row and special metering symbols.
7	J19	SPI	2X5 header providing access to the SPI slave interface.
8	BT3	--	Alternate footprint for BT2. A circular battery may be mounted in this location (on the bottom of the board).
9	BT1	--	Location of optional battery for the support of battery modes. (Located on the bottom)

Item #	Reference Designator	Name	Use
10	BT2	--	Location of optional battery for the support of RTC and non-volatile RAM. BT2 has an alternate circular footprint at location BT3.
11	J21	DEBUG	Connector for the optional Debug Board. 2x8 pin male header.
12	SW5	RESET	Chip reset switch: When the switch is pressed, the RESET pin of the IC is pulled high which resets the IC into a known state.
13	J12	--	2-pin header. If a jumper installed, the battery BT1 will be connected to the V3P3SYS net.
14	J13	--	2-pin pin header. If a jumper installed, the battery BT2/BT3 will be connected to the V3P3SYS net.
15	SW3	PB	Pushbutton connected to the PB pin on the IC. This push-button can be used in conjunction with the Demo Code to wake the IC from sleep mode or LCD mode to brown-out mode.
16	TP2	GND	GND test point.
17	J3	IAN_IN, IAP_IN	2-pin header for the connection of the non-isolated shunt used for neutral current measurement. This header is on the bottom of the board.
18	SW4	SEGDIO53	Pushbutton for optional software function.
18a	J25	ADC0/1	2-pin header that allows access to the neutral current input pins on the 71M6543.
19	JP6		A jumper is placed across JP6 to activate the internal AC power supply. **Caution: High Voltage! Do not touch!**
19a	J11, J15, J16	ADC8, ADC9, ADC10	2-pin headers that allow access to the voltage input pins on the 71M6543.
20	J9	NEUTRAL	The NEUTRAL voltage input. This input is connected to V3P3. This input is a spade terminal mounted on the bottom of the board.
21, 23, 25	J4, J6. J8	VA_IN, VB_IN, VC_IN	Phase voltage inputs to the board. Each input has a resistor divider that leads to the pin on the IC associated with the voltage input to the ADC. These inputs have spade terminals mounted on the bottom of the board. **Caution: High Voltage! Do not touch!**
22	TP1	TMUXOUT, TMUX2OUT	Test points for access to the TMUXOUT and TMU2XOUT pins on the 71M6543.
24	U5	--	The IC 71M6543 soldered to the PCB.
26, 28, 29	J17, J18, J20	--	Two-pin headers for connection of the external shunt resistors (REV 4.0) or CTs (REV 5.0) to the board.
27	JP53	V3P3D	2-pin header that connects the V3P3D pin to parts on the board that use the V3P3D net for their power supply. For supply current measurements in brownout mode, the jumper on JP53 may be removed.
29a	J22, J23, J24	ADC2/3, ADC4/5, ADC5/6	2-pin headers that allow access to the current input pins on the 71M6543.
30	J14	EMULATOR I/F	2x10 emulator connector port for the Signum ICE ADM-51 or for the Teridian TFP-2 Flash Programmer.
31	JP3	ICE_E	3-pin header for the control of the ICE_E signal. A jumper across pins 1-2 disables the ICE interface; a jumper across pins 2-3 enables it.

Item #	Reference Designator	Name	Use
32	JP44	GND	3-pin header that can be used to control the PE pin of the µWire EEPROM.
33	TP3	GND	GND test point.
34	JP54	--	2-pin header that connects the SDCK signal to the serial EEPROM.
35	JP51	--	Two-pin header for the clock signal to the µWire EEPROM. Inserting a jumper in this header enables the clock.
36	JP50	--	Two-pin header for pulling low the CS input of the µWire EEPROM.
37	CN1	USB PORT	This connector is an isolated USB port for serial communication with the 71M6543.
38	JP7	--	2-pin header connected to the VARh pulse LED
39	D6	VARh	VARh pulse LED.
40	JP8	WPULSE	2-pin header connected to the Wh pulse LED
41	JP5	UART_RX	2-pin header for connection of the RX output of the isolated USB port to the RX pin of the 71M6543. When the Demo Board is communicating via the USB port, a jumper should be installed on JP5. When the Demo Board is communicating via the Debug Board plugged into J21, the jumper should be removed.
42	JP20	5.0 VDC	Circular connector for supplying the board with DC power. **Do not exceed 5.0 VDC at this connector!**

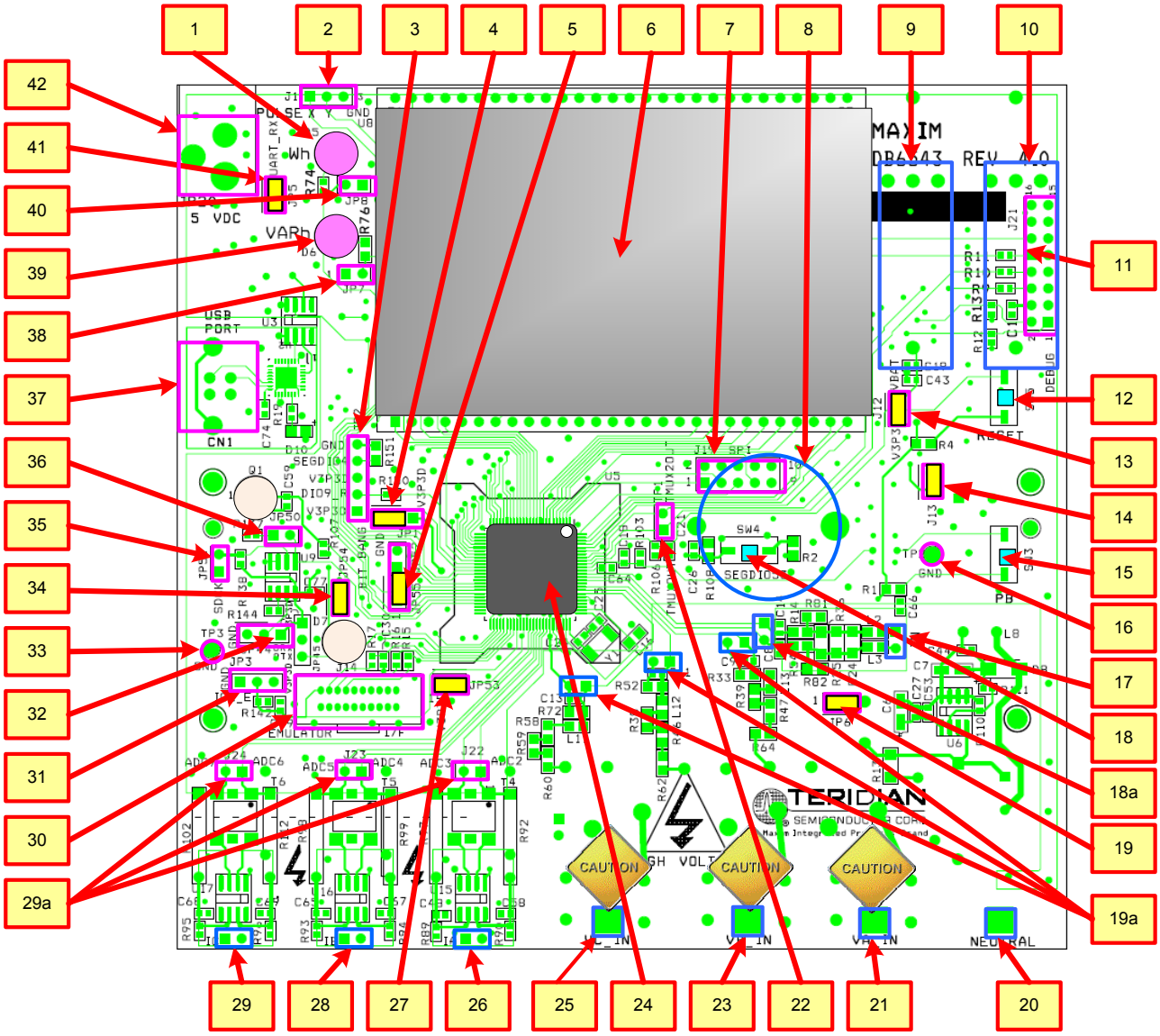

Figure 3-1: 71M6543 REV 4.0 Demo Board - Board Description

Default jumper settings are indicated in yellow. Elements shown in blue are on the bottom side of the board.

3.2 71M6543 REV 5.0 DEMO BOARD DESCRIPTION

The 71M6543 REV 5.0 Demo Board is largely identical to the 71M6543 REV 4.0 Demo Board. Figure 3-2 shows the top view of this board.

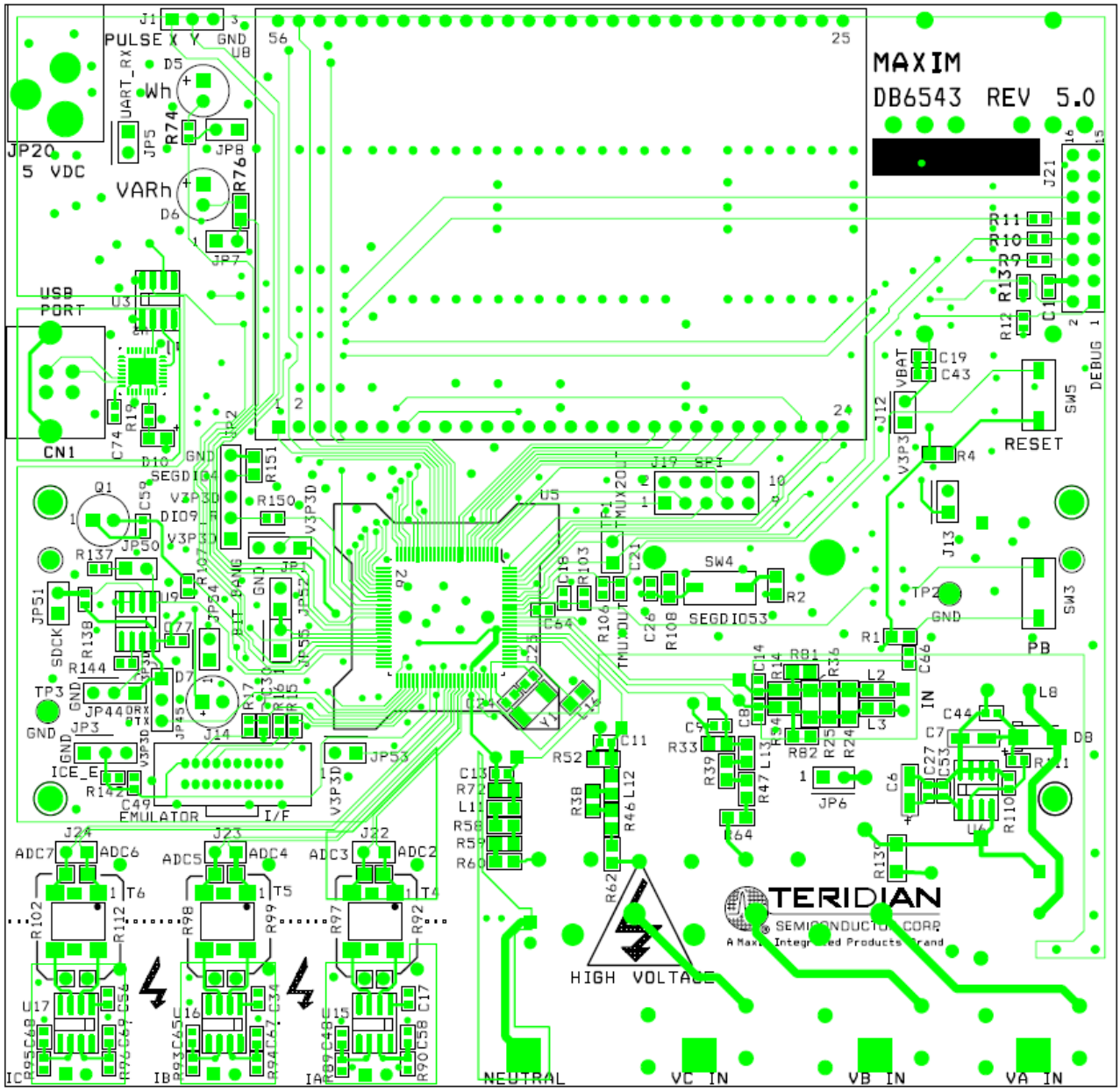

Figure 3-2: 71M6543 REV 5.0 Demo Board – Top View

3.3 BOARD HARDWARE SPECIFICATIONS

PCB Dimensions

Width, length	134 mm x 131 mm (5.276" x 5.157")
Thickness	1.6mm (0.062")
Height w/ components	40 mm (1.57")

Environmental

Operating Temperature	-40°…+85°C
Storage Temperature	-40°C…+100°C

Power Supply

Using internal AC supply	100 V…240 V RMS
DC Input Voltage (powered from DC supply)	5.0 VDC ±0.3 V
Supply Current	< 10 mA typical

Input Signal Range

AC Voltage Signal (VA, VB, VC)	0…240 V RMS
AC Current Signals (IA, IB, IC) from Shunt	0…19.64 mV RMS
AC Current Signals (IA, IB, IC) from CT	0…176.8 mV RMS

Interface Connectors

DC Supply (J20)	Circular connector
Emulator (J14)	10x2 header, 0.05" pitch
Voltage Input Signals	Spade terminals on PCB bottom
Current Input Signals	0.1" 1X2 headers on PCB bottom
USB port (PC Interface)	USB connector
Debug Board (J2)	8x2 header, 0.1" pitch
SPI Interface	5x2 header, 0.1" pitch

Functional Specification

Program Memory	64 KB FLASH memory
NV memory	1Mbit serial EEPROM
Time Base Frequency	32.768kHz, ±20PPM at 25°C

Controls and Displays

RESET	Push-button (SW5)
PB	Push-button (SW3)
Numeric Display	3X8-digit LCD, 7 segments per digit, plus meter symbols
"Wh"	red LED (D5)
"VARh"	red LED (D6)

Measurement Range

Voltage	120…600 V rms (resistor division ratio 1:3,398)
Current	Dependent on shunt resistance or CT winding ratio

4

4 APPENDIX

This appendix includes the following documentation, tables and drawings:

71M6543 Demo Board Description

71M6543 REV 4.0 Demo Board Electrical Schematic
71M6543 REV 4.0 Demo Board Bill of Materials
71M6543 REV 4.0 Demo Board PCB layers (copper, silk screen, top and bottom side)
Schematics comments
71M6543 REV 5.0 Demo Board Electrical Schematic
71M6543 REV 5.0 Demo Board Bill of Materials
71M6543 REV 5.0 Demo Board PCB layers (copper, silk screen, top and bottom side)

Debug Board Description

Debug Board Electrical Schematic
Debug Board Bill of Materials
Debug Board PCB layers (copper, silk screen, top and bottom side)

71M6543 IC Description

71M6543 Pin Description
71M6543 Pin-out

4.1 71M6543 DEMO BOARD REV 4.0 ELECTRICAL SCHEMATIC

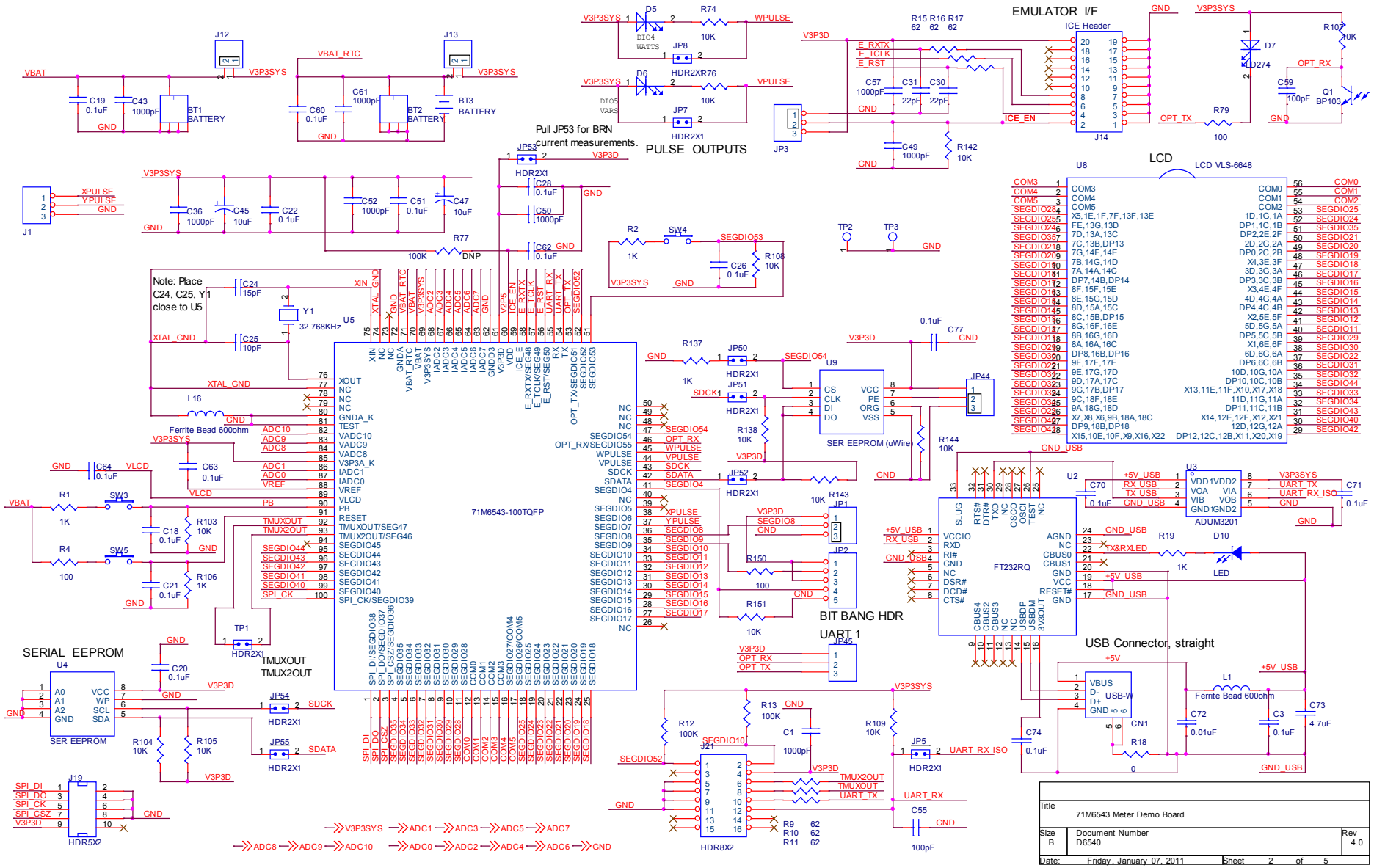

Figure 4-1: Teridian 71M6543 REV 4.0 Demo Board: Electrical Schematic 1/4

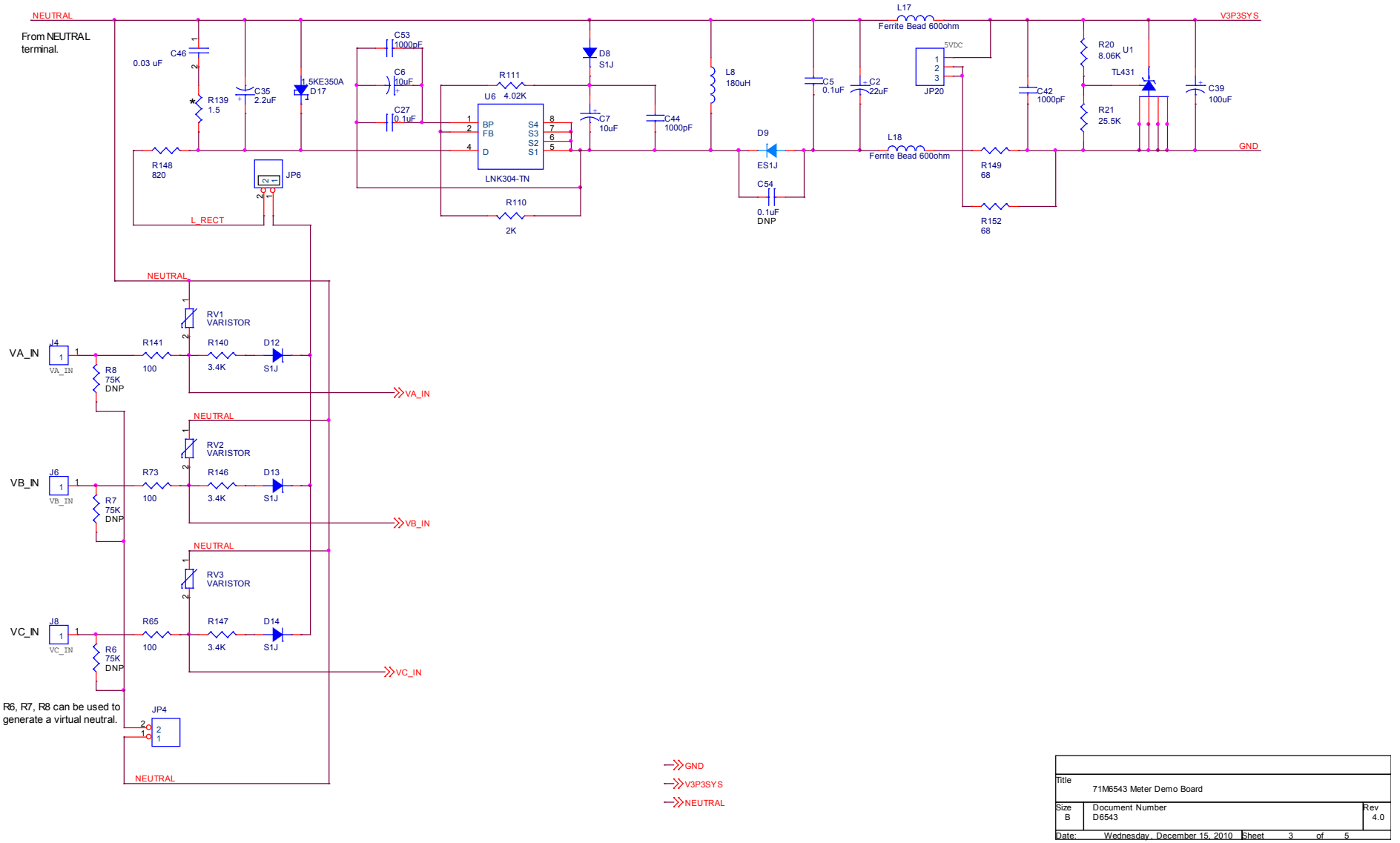

Figure 4-2: Teridian 71M6543 REV 4.0 Demo Board: Electrical Schematic 2/4

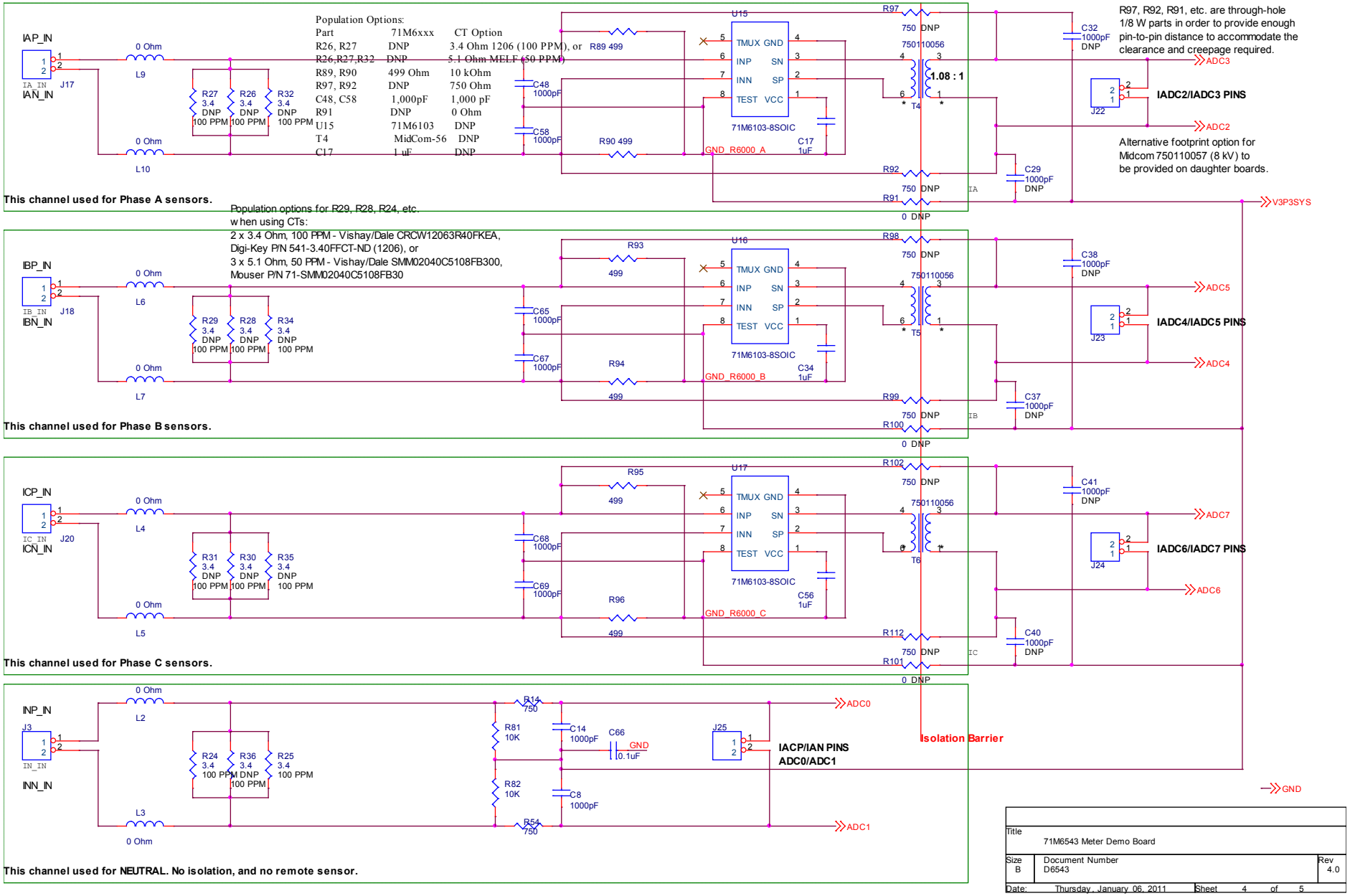

Figure 4-3: Teridian 71M6543 REV 4.0 Demo Board: Electrical Schematic 3/4

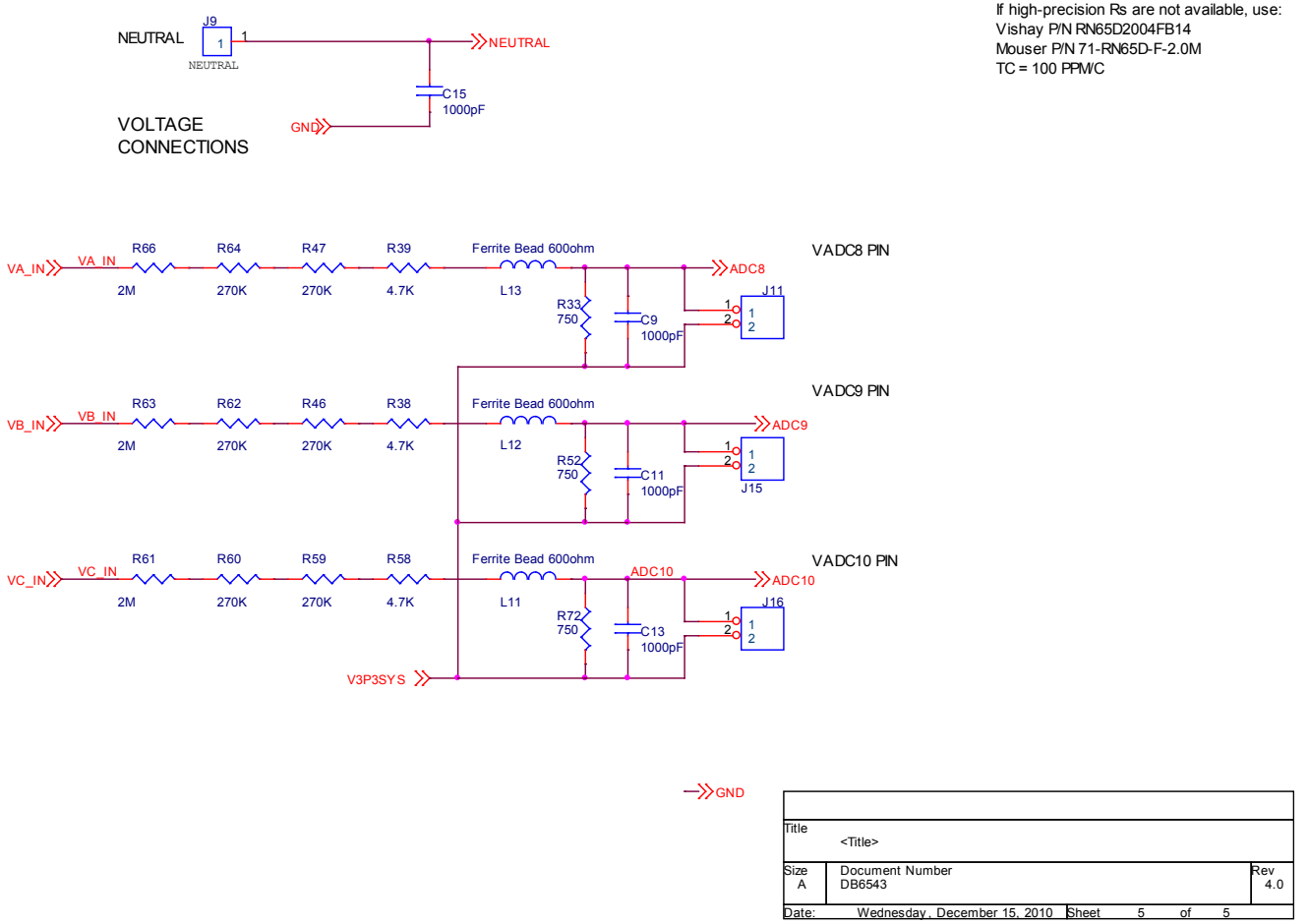

Figure 4-4: Teridian 71M6543 REV 4.0 Demo Board: Electrical Schematic 4/4

4.2 71M6543 DEMO BOARD REV 5.0 ELECTRICAL SCHEMATIC

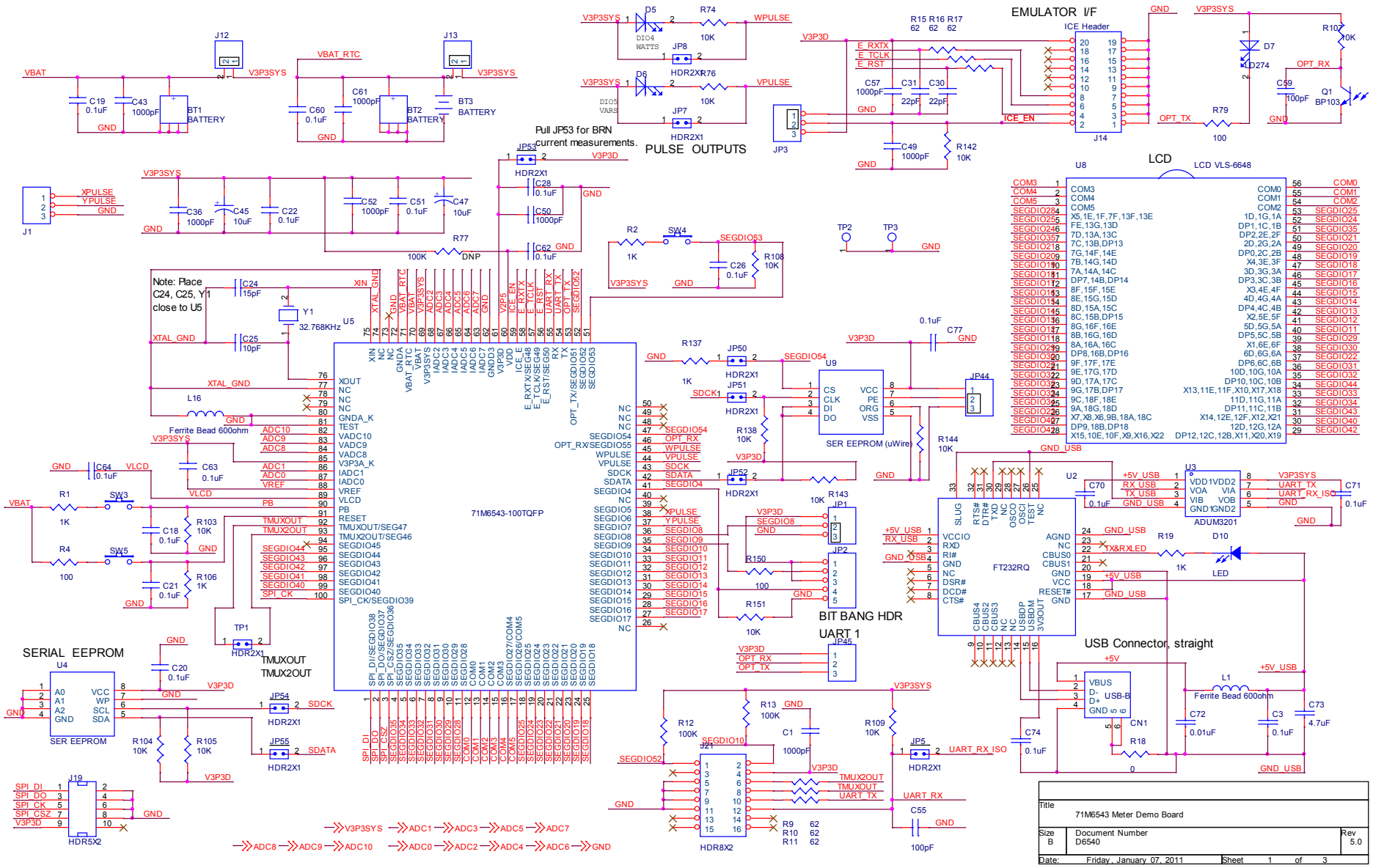

Figure 4-5: Teridian 71M6543 REV 5.0 Demo Board: Electrical Schematic 1/4

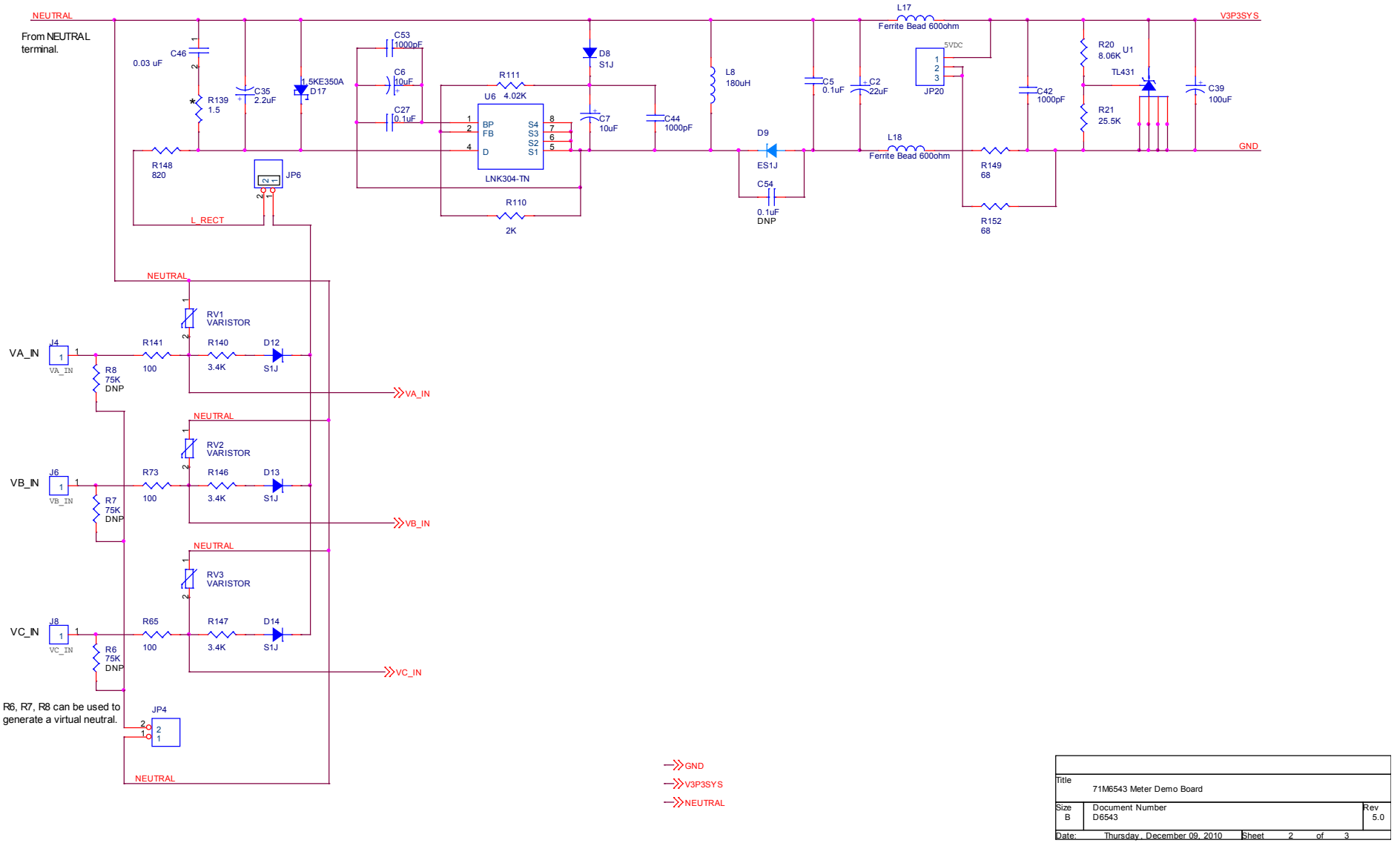

Figure 4-6: Teridian 71M6543 REV 5.0 Demo Board: Electrical Schematic 2/4

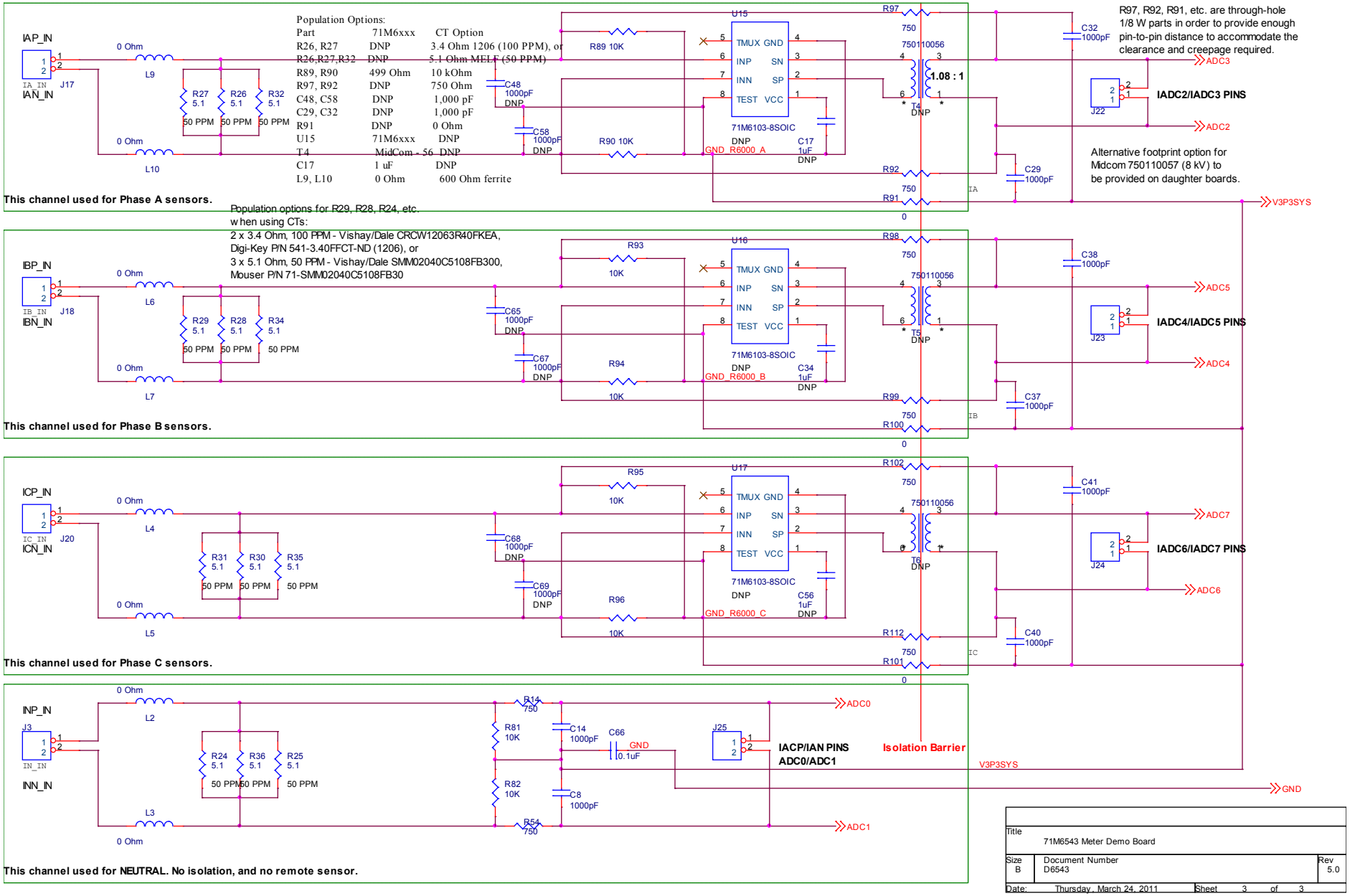

Figure 4-7: Teridian 71M6543 REV 5.0 Demo Board: Electrical Schematic 3/4

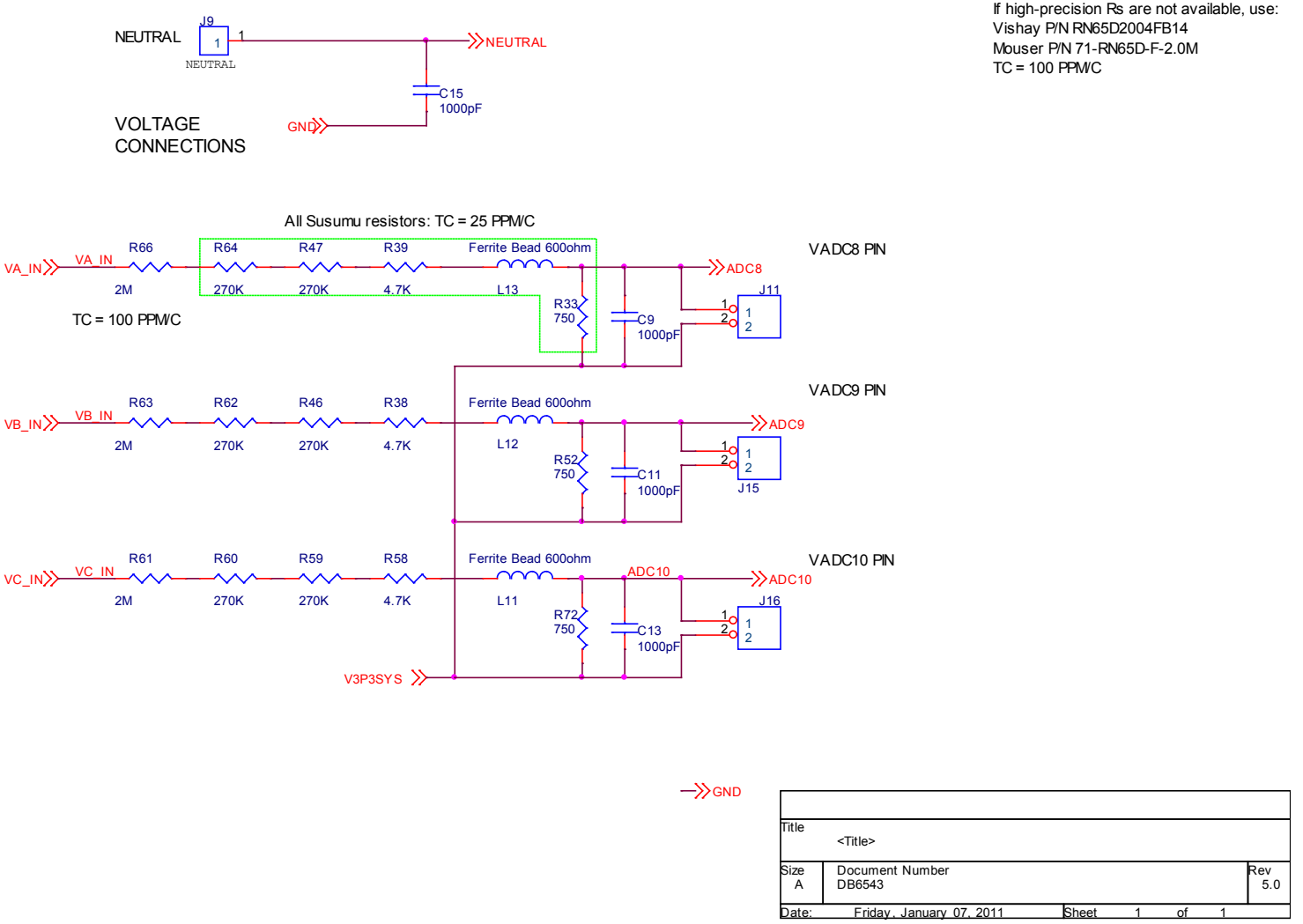

Figure 4-8: Teridian 71M6543 REV 5.0 Demo Board: Electrical Schematic 4/4

4.3 COMMENTS ON SCHEMATICS

4.3.1 GENERAL

The schematics shown in this document are provided for a Demo Meter that functions under laboratory conditions. Maxim does not guarantee proper function of a meter under field conditions when using the Demo Board schematics. Care should be taken by the meter designer that all applicable design rules as well as reliability, safety and legal regulations are met by the meter design.

4.3.2 USING FERRITES IN THE SHUNT SENSOR INPUTS

The 71M6543 Demo Board in shunt configuration has footprints on the PCB to accommodate ferrites between the shunt signal inputs and the 71M6xxxx Remote Sensors. These footprints, labeled L4, L5, L6, L7, L9, and L10, are populated with 0-Ohm resistors. It is not advisable to directly replace these resistors with ferrites without further changes, since this will degrade the low-current accuracy to some degree.

If ferrites are needed for EMC reasons, the input circuit should be modified as shown in Figure 4-9. The modifications are as follows:

- Positions L4, L5, L6, etc. are replaced with ferrites.
- A 10Ω resistor is added across the sensor input.
- The two 1,000 pF capacitors from INP to local ground and from INN to local ground are replaced with 10,000 pF or higher value capacitors.

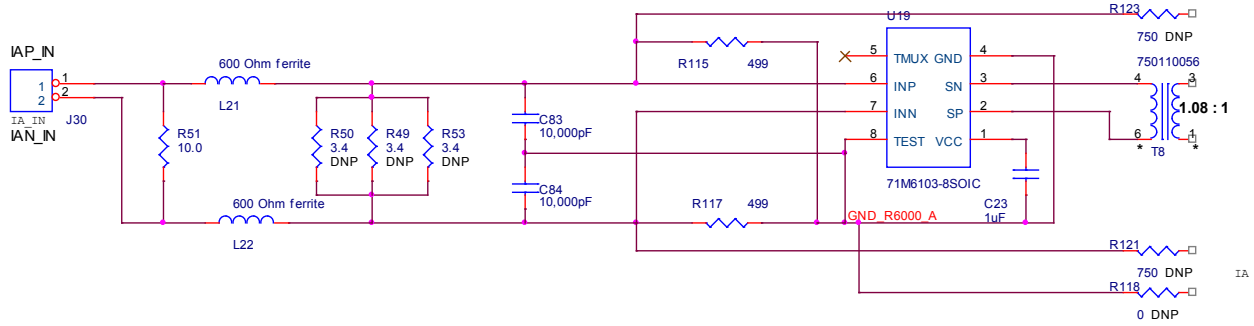

Figure 4-9: Input Circuit with Ferrites

4.4 71M6543 DEMO BOARD REV 4.0 BILL OF MATERIAL

Table 4-1: 71M6543 REV 4.0 Demo Board: Bill of Material (1/2)

Item	Q	Reference	Part	Footprint	Digi-Key P/N	Mouser P/N	Manufacturer	Manufacturer P/N	Tol	Rating	HDR	DNP
1	2	BT1,BT2	BATTERY	BAT 3 PIN BARREL COMBO								DNP
2	1	BT3	BATTERY	BAT CR2032 MAX								DNP
3	1	CN1	USB-W	USBV		806-KUSBVX-BS1N-W	Kycon	KUSBVX-BS1N-W				
4	23	C1,C8,C9,C11,C13,C14,C15,	1000pF	603	445-1298-1-ND		TDK	C1608X7R2A102K	10%	100V		
		C36,C42,C43,C44,C48,C49,										
		C50,C52,C53,C57,C58,C61,										
		C65,C67,C68,C69										
5	1	C2	22uF	SM/CT_3216	478-1663-1-ND		AVX	TAJA226K010RNJ	10%	10V		
6	18	C3,C5,C18,C19,C20,C21,	0.1uF	603	445-1314-1-ND		TDK	C1608X7R1H104K	0.1	50V		
		C22,C26,C27,C28,C51,C60,										
		C62,C63,C64,C66,C74,C77										
7	4	C6,C7,C45,C47	10uF	SM/CT_3216	478-1654-1-ND		AVX	TAJA106K010R	0.1	10V		
8	3	C17,C34,C56	1uF	603	445-1604-1-ND		TDK	C1608X7R1C105K	10%	16V		
9	1	C24	15pF	603	445-1271-1-ND		TDK	C1608C0G1H150J	5%	50V		
10	1	C25	10pF	603	445-1269-1-ND		TDK	C1608C0G1H100D	5%	50V		
11	6	C29,C32,C37,C38,C40,C41	1000pF	603	445-1298-1-ND		TDK	C1608X7R2A102K	10%	100V		DNP
12	2	C30,C31	22pF	603	445-1273-1-ND		TDK	C1608C0G1H220J	0.05	50V		
13	1	C35	2.2uF	CYL/D.400/LS.200/.034	493-1227-ND		Nichicon	UVR2G2R2MPD		400V		
14	1	C39	100uF	CYL/D.400/LS.200/.034	P963-ND		Panasonic	ECE-A1AKS101	20%	10V		
15	1	C46	0.03 uF	HIGH VOLT DISC CAP		75-125LS30-R	Vishay/BC	125LS30-R		1000V		
16	1	C54	0.1uF	603	445-1314-1-ND		TDK	C1608X7R1H104K	0.1	50V		DNP
17	2	C55,C59	100pF	603	445-1281-1-ND		TDK	C1608C0G1H101J	5%	50V		
18	2	C70,C71	0.1uF	805	478-3351-1-ND		AVX Corporatic	08055C104MAT2A	20%	50V		
19	1	C72	0.01uF	603	478-1227-1-ND		AVX Corporatic	06035C103KAT2A	0.1	50V		
20	1	C73	4.7uF	805	587-1782-1-ND		Taiyo Yuden	TMK212BJ475KG-T	0.1	25V		
21	2	D5,D6	LED_1	LED6513	67-1612-ND		Lumex	SSL-LX5093SRC/E				
22	1	D7	LD274	LED6513	475-1461-ND		Osram	SFH 4511				
23	4	D8,D12,D13,D14	S1J	SMA/DIODE	S1J-E3/61TGICT-ND		Vishay/Genera	S1J-E3/61T				
24	1	D9	ES1J	SMA/DIODE	ES1JFSCT-ND		Vishay	ES1J				
25	1	D10	LED	805	L62415CT-ND		CML	CMD17-21UGC/TR8				
26	1	D17	1.5KE350A	DO-41	1.5KE350CALFCT-ND		Littelfuse	1.5KE350CA				
27	5	JP1,J1,JP3,JP44,JP45	HDR3X1	BLKCON.100/VH/TM1SQ/W.100/3	S1011E-36-ND		Sullins	PBC36SAAN			0.1	
28	1	JP2	HDR5X1	BLKCON.100/VH/TM1SQ/W.100/5	S1011E-36-ND		Sullins	PBC36SAAN			0.2	
29	25	TP1,J3,JP4,JP5,JP6,JP7,	HDR2X1	BLKCON.100/VH/TM1SQ/W.100/2	S1011E-36-ND		Sullins	PBC36SAAN			0.1	
		JP8,J11,J12,J13,J15,J16,										
		J17,J18,J20,J22,J23,J24,										
		J25,JP50,JP51,JP52,JP53,										
		JP54,JP55										
30	1	JP20	SWITCHCRAFT	SWITCHCRAFT	SC237-ND		Switchcraft Inc	RAPC712X				
31	4	J4,J6,J8,J9	Spade Terminal	FASTON	A24747CT-ND		Tyco/AMP	62395-1				
32	1	J14	ICE Header	RIBBON6513OUTLINE	A33555-ND	571-5-104068-1	Tyco/AMP	5-104068-1				
33	1	J19	HDR5X2	BLKCON.100/VH/TM2OE/W.200/10	S2011E-36-ND		Sullins	PBC36DAAN			0.2	
34	1	J21	HDR8X2	BLKCON.100/VH/TM2OE/W.200/16	S2011E-36-ND		Sullins	PBC36DAAN			0.3	
35	7	L1,L11,L12,L13,L16,L17,	Ferrite Bead 600ol	805	445-1556-1-ND		TDK	MMZ2012S601A		0.5A		
		L18										
36	8	L2,L3,L4,L5,L6,L7,L9,L10	0 Ohm	805	RMCF0805ZT0R00CT-ND		Stackpole	RMCF0805ZT0R00		0.5A		
37	1	L8	180uH	RFB0807			CoilCraft	RFB0807-181L				
38	1	Q1	BP103	LED6513	475-1437-ND		Osram	SFH 300-3/4				DNP
39	3	RV1,RV2,RV3	VARISTOR	MOV CPS 2381594		594-2381-594-55116	AVX	2381 594 55116				

Table 4-2: 71M6543 REV 4.0 Demo Board: Bill of Material (2/2)

Item	Q	Reference	Part	Footprint	Digi-Key P/N	Mouser P/N	Manufacturer	Manufacturer P/N	Tol	Rating	HDR	DNP
40	2	R1,R2	1K	805	541-1.0KACT-ND		Vishay/Dale	CRCW08051K00JNEA	5%	0.125W		
41	1	R4	100	805	541-100ACT-ND		Vishay/Dale	CRCW0805100RJNEA	5%	0.125W		
42	3	R6,R7,R8	75K	AXLE FLAME UPRIGHT	75KW-2-ND		Yageo	RSF200JB-75K	5%	2W		DNP
43	6	R9,R10,R11,R15,R16,R17	62	603	P62GCT-ND		Panasonic	ERJ-3GEYJ620V	5%	0.1W		
44	2	R12,R13	100K	603	P100KGCT-ND		Panasonic	ERJ-3GEYJ104V	5%	0.1W		
45	5	R14,R33,R52,R54,R72	750	805	RR12P750DCT-ND		Susumu	RR1220P-751-D	0.01	0.1W		
46	1	R18	0	1206	RHM0.0ECT-ND		Rohm Semicon	MCR18EZHJ000	0.05	0.25W		
47	3	R19,R106,R137	1K	603	P1.00KHCT-ND		Panasonic	ERJ-3EKF1001V	1%	0.1W		
48	1	R20	8.06K	805	RHM8.06KCCT-ND		Rohm	MCR10EZHF8061	1%	0.125W		
49	1	R21	25.5K	805	P25.5KCCT-ND		Panasonic	ERJ-6ENF2552V	1%	0.125W		
50	2	R24,R25	3.4	1206	541-3.40FFCT-ND		Vishay/Dale	CRCW08053R40FNEA	1%	0.125W		
51	10	R26,R27,R28,R29,R30,R31,	3.4	1206	541-3.40FFCT-ND		Vishay/Dale	CRCW08053R40FNEA	0.01	0.125W		DNP
		R32,R34,R35,R36										
52	3	R38,R39,R58	4.7K	805	RG20P4.7KBCT-ND		TDK	RG2012P-472-B-T5	0%	0.125W		
53	6	R46,R47,R59,R60,R62,R64	270K	805	RG20P270KBCT-ND		Susumu	RG2012P-274-B-T5	0%	0.125W		
54	3	R61,R63,R66	2M	AXLE FLAME UPRIGHT		71-RN65D-F-2.0M	Vishay/Dale	RN65D2004FB14	0.01	0.5W		
55	3	R65,R73,R141	100	AXLE FLAME UPRIGHT	100W-2-ND		Yageo	RSF200JB-100R	5%	2W		
56	5	R74,R103,R109,R142,R144	10K	603	P10.0KHCT-ND		Panasonic	ERJ-3EKF1002V	0.01	0.1W		
57	8	R76,R81,R82,R104,R105,	10K	805	541-10KACT-ND		Vishay/Dale	CRCW080510K0JNEA	5%	0.125W		
		R107,R108,R151										
58	1	R77	100K	603	541-10KACT-ND		Panasonic	ERJ-3GEYJ104V	5%	0.1W		DNP
59	2	R79,R150	100	603	P100GCT-ND		Panasonic	ERJ-3GEYJ101V	5%	0.1W		
60	6	R89,R90,R93,R94,R95,R96	499	603	P499HCT-ND		Panasonic	ERJ-3EKF4990V	1%	0.1W		
61	3	R91,R100,R101	0	RES_TH_500	0.0EBK-ND		Yageo	ZOR-12-B-52	1%	0.1W		DNP
62	6	R92,R97,R98,R99,R102,	750	RES_TH_500		270-750-RC	Xicon	270-750-RC	1%	0.1W		DNP
		R112										
63	1	R110	2K	603	P2.00KHCT-ND		Panasonic	ERJ-3EKF2001V	1%	0.1W		
64	1	R111	4.02K	603	P4.02KHCT-ND		Panasonic	ERJ-3EKF4021V	1%	0.1W		
65	2	R138,R143	10K	603	P10.0KHCT-ND		Panasonic	ERJ-3EKF1002V	1%	0.1W		DNP
66	1	R139	1.5	1206	541-1.5ECT-ND		Vishay/Dale	CRCW12061R50JNEA	5%	0.25W		
67	3	R140,R146,R147	3.4K	805	541-3.40KCCT-ND		Vishay/Dale	CRCW08053K40FKEA	1%	0.125W		
68	1	R148	820	AXLE FLAME UPRIGHT	P820W-2BK-ND		Panasonic	ERG2SJ821	5%	2W		
69	2	R149,R152	68	1206	P68.0FTR-ND		Panasonic	ERJ-8ENF68R0V	1%	0.25W		
70	3	SW3,SW4,SW5	PB	PB	P13598SCT-ND		Panasonic	EVQ-PNF05M				
71	2	TP2,TP3	TESTPOINT	TESTPOINTSMALL	5011K-ND		KEYSTONE	5011				
72	3	T4,T5,T6	750110056	XFORM/566543			Midcom	750110056				
73	1	U1	TL431	SO8-NARROW	296-1288-1-ND		Texas Instrume	TL431AIDR				
74	1	U2	FT232RQ	32QFNW/NOSPT		806-KUSBVX-BS1N-W	Kycon	KUSBVX-BS1N-W				
75	1	U3	ADUM3201	SO8-NARROW	ADUM3201ARZ-ND		Analog Devices	ADUM3201ARZ				
76	1	U4	SER EEPROM	SO8-NARROW	AT24C1024BW-SH25-B-ND		ATMEL	AT24C1024BW-SH25-B				
77	1	U5	71M6543-100TQFP	IC149100TQFP_SS			Teridian	71M6540F-IGT/F				
78	1	U6	LNK304-TN	SO8-NARROW	596-1237-1-ND		Power Integrat	LNK304DG-TL				
79	1	U8	LCD VLS-6648	LCD VLS-6648			VARITRONIX	VL_6648_V00				
80	1	U9	SER EEPROM (uWire	SO8-NARROW	93LC76C-I/SN-ND		MICROCHIP	93LC76CT-I/SN				
81	3	U15,U16,U17	71M6103-8SOIC	SO8-NARROW			Maxim	71M6103-IL/F				
82	1	Y1	32.768KHz	XTAL-ECS-39			Suntsu	SPC6-32.768KHZTR				

4.5 71M6543 DEMO BOARD REV 5.0 BILL OF MATERIAL

Table 4-3: 71M6543 REV 5.0 Demo Board: Bill of Material (1/3)

Item	Q	Reference	Part	Footprint	Digi-Key P/N	Mouser P/N	Manufacturer	Manufacturer P/N	Tol	Rating	HDR	DNP
1	2	BT1,BT2	BATTERY	BAT 3 PIN BARREL COMBO								DNP
2	1	BT3	BATTERY	BAT CR2032 MAX								DNP
3	1	CN1	USB-B	USBV		806-KUSBVX-BS	Kycon	KUSBVX-BS1N-W				
4	23	C1,C8,C9,C11,C13,C14,C15,	1000pF	603	445-1298-1-ND		TDK	C1608X7R2A102K	10%	100V		
		C29,C32,C36,C37,C38,C40,										
		C41,C42,C44,C49,C50,C52,C53,										
		C57,C61										
5	1	C2	22uF	SM/CT_3216	478-1663-1-ND		AVX	TAJA226K010RNJ	10%	10V		
6	18	C3,C5,C18,C19,C20,C21,	0.1uF	603	445-1314-1-ND		TDK	C1608X7R1H104K	0.1	50V		
		C22,C26,C27,C28,C51,C60,										
		C62,C63,C64,C66,C74,C77										
7	4	C6,C7,C45,C47	10uF	SM/CT_3216	478-1654-1-ND		AVX	TAJA106K010R	0.1	10V		
8	3	C17,C34,C56	1uF	603	445-1604-1-ND		TDK	C1608X7R1C105K	10%	16V		DNP
9	1	C24	15pF	603	445-1271-1-ND		TDK	C1608C0G1H150J	5%	50V		
10	1	C25	10pF	603	445-1269-1-ND		TDK	C1608C0G1H100D	5%	50V		
11	2	C30,C31	22pF	603	445-1273-1-ND		TDK	C1608C0G1H220J	5%	50V		
12	6	C48,C58,C65,	1000pF	603	445-1298-1-ND		TDK	C1608X7R2A102K	0.1	100V		DNP
		C67,C68,C69										
13	1	C35	2.2uF	CYL/D.400/LS.200/.034	493-1227-ND		Nichicon	UVR2G2R2MPD		400V		
14	1	C39	100uF	CYL/D.400/LS.200/.034	P963-ND		Panasonic	ECE-A1AKS101	0.2	10V		
15	1	C46	0.03 uF	HIGH VOLT DISC CAP		75-125LS30-R	Vishay/BC	125LS30-R		1000V		
16	1	C54	0.1uF	603	445-1314-1-ND		TDK	C1608X7R1H104K	10%	50V		DNP
17	2	C55,C59	100pF	603	445-1281-1-ND		TDK	C1608C0G1H101J	5%	50V		
18	2	C70,C71	0.1uF	805	478-3351-1-ND		AVX Corporatic	08055C104MAT2A	0.2	50V		
19	1	C72	0.01uF	603	478-1227-1-ND		AVX Corporatic	06035C103KAT2A	0.1	50V		
20	1	C73	4.7uF	805	587-1782-1-ND		Taiyo Yuden	TMK212BJ475KG-T	0.1	25V		
21	2	D5,D6	LED_1	LED6513	67-1612-ND		Lumex	SSL-LX5093SRC/E				
22	1	D7	LD274	LED6513	475-1461-ND		Osram	SFH 4511				
23	4	D8,D12,D13,D14	S1J	SMA/DIODE	RS1J-E3/61TGICT-ND		Vishay/Genera	S1J-E3/61T				
24	1	D9	ES1J	SMA/DIODE	ES1JFSCT-ND		Vishay	ES1J				
25	1	D10	LED	805	L62415CT-ND		CML	CMD17-21UGC/TR8				
26	1	D17	1.5KE350A	DO-41	1.5KE350CALFCT-ND		Littelfuse	1.5KE350CA				
27	5	JP1,J1,JP3,JP44,JP45	HDR3X1	BLKCON.100/VH/TM1SQ/W.100/3	S1011E-36-ND		Sullins	PBC36SAAN			0.1	
28	1	JP2	HDR5X1	BLKCON.100/VH/TM1SQ/W.100/5	S1011E-36-ND		Sullins	PBC36SAAN			0.2	
29	25	TP1,J3,JP4,JP5,JP6,JP7,	HDR2X1	BLKCON.100/VH/TM1SQ/W.100/2	S1011E-36-ND		Sullins	PBC36SAAN			0.1	
		JP8,J11,J12,J13,J15,J16,										
		J17,J18,J20,J22,J23,J24,										
		J25,JP50,JP51,JP52,JP53,										
		JP54,JP55										
30	1	JP20	SWITCHCRAFT	SWITCHCRAFT	SC237-ND		Switchcraft Inc	RAPC712X				
31	4	J4,J6,J8,J9	Spade Terminal	FASTON	A24747CT-ND		Tyco/AMP	62395-1				
32	1	J14	ICE Header	RIBBON6513OUTLINE	A33555-ND	571-5-104068-1	Tyco/AMP	5-104068-1				
33	1	J19	HDR5X2	BLKCON.100/VH/TM2OE/W.200/10	S2011E-36-ND		Sullins	PBC36DAAN			0.2	
34	1	J21	HDR8X2	BLKCON.100/VH/TM2OE/W.200/16	S2011E-36-ND		Sullins	PBC36DAAN			0.3	
35	15	L1,L2,L3,L4,L5,L6,L7,L9,	Ferrite Bead 600ol	805	445-1556-1-ND		TDK	MMZ2012S601A		0.5A		
		L10,L11,L12,L13,L16,L17,										
		L18										
36	1	L8	180uH	RFB0807			CoilCraft	RFB0807-181L				
37	1	Q1	BP103	LED6513	475-1437-ND		Osram	SFH 300-3/4				DNP
38	3	RV1,RV2,RV3	VARISTOR	MOV CPS 2381594		594-2381-594-55116	AVX	2381 594 55116				

Table 4-4: 71M6543 REV 5.0 Demo Board: Bill of Material (2/3)

Item	Q	Reference	Part	Footprint	Digi-Key P/N	Mouser P/N	Manufacturer	Manufacturer P/N	Tol	Rating	HDR	DNP
39	2	R1,R2	1K	805	541-1.0KACT-ND		Vishay/Dale	CRCW08051K00JNEA	5%	0.125W		
40	1	R4	100	805	541-100ACT-ND		Vishay/Dale	CRCW0805100RJNEA	5%	0.125W		
41	3	R6,R7,R8	75K	AXLE FLAME UPRIGHT	75KW-2-ND		Yageo	RSF200JB-75K	5%	2W		DNP
42	6	R9,R10,R11,R15,R16,R17	62	603	P62GCT-ND		Panasonic	ERJ-3GEYJ620V	5%	0.1W		
43	2	R12,R13	100K	603	P100KGCT-ND		Panasonic	ERJ-3GEYJ104V	0.05	0.1W		
44	5	R14,R33,R52,R54,R72	750	805	RR12P750DCT-ND		Susumu	RR1220P-751-D	0.01	0.1W		
45	1	R18	0	1206	RHM0.0ECT-ND		Rohm Semicon	MCR18EZHJ000	5%	0.25W		
46	3	R19,R106,R137	1K	603	P1.00KHCT-ND		Panasonic	ERJ-3EKF1001V	1%	0.1W		
47	1	R20	8.06K	805	RHM8.06KCCT-ND		Rohm	MCR10EZHF8061	1%	0.125W		
48	1	R21	25.5K	805	P25.5KCCT-ND		Panasonic	ERJ-6ENF2552V	1%	0.125W		
49	12	R24,R25,R26,R27,R28,R29,	5.1	MELF		71-SMM02040C5108FB30	Vishay/Dale	SMM02040C5108FB30	0.01	0.125W		
		R30,R31,R32,R34,R35,R36										
50	3	R38,R39,R58	4.7K	805	RG20P4.7KBCT-ND		TDK	RG2012P-472-B-T5	0%	0.125W		
51	6	R46,R47,R59,R60,R62,R64	270K	805	RG20P270KBCT-ND		Susumu	RG2012P-274-B-T5	0%	0.125W		
52	3	R61,R63,R66	2M	AXLE FLAME UPRIGHT		71-RN65D-F-2.0M	Vishay/Dale	RN65D2004FB14	0.01	0.5W		
53	3	R65,R73,R141	100	AXLE FLAME UPRIGHT	100W-2-ND		Yageo	RSF200JB-100R	5%	2W		
54	12	R74,R89,R90,R93,R94,R95,	10K	603	P10.0KHCT-ND		Panasonic	ERJ-3EKF1002V	0.01	0.1W		
		R96,R103,R107,R109,R142,										
		R144										
55	7	R76,R81,R82,R104,R105,	10K	805	541-10KACT-ND		Vishay/Dale	CRCW080510K0JNEA	5%	0.125W		
		R108,R151										
56	1	R77	100K	603	541-10KACT-ND		Panasonic	ERJ-3GEYJ104V	5%	0.1W		DNP
57	2	R79,R150	100	603	P100GCT-ND		Panasonic	ERJ-3GEYJ101V	5%	0.1W		
58	3	R91,R100,R101	0	RES_TH_500	0.0EBK-ND		Yageo	ZOR-12-B-52	1%	0.1W		
59	6	R92,R97,R98,R99,R102,	750	RES_TH_500		270-750-RC	Xicon	270-750-RC	1%	0.1W		
		R112										
60	1	R110	2K	603	P2.00KHCT-ND		Panasonic	ERJ-3EKF2001V	1%	0.1W		
61	1	R111	4.02K	603	P4.02KHCT-ND		Panasonic	ERJ-3EKF4021V	1%	0.1W		
62	2	R138,R143	10K	603	P10.0KHCT-ND		Panasonic	ERJ-3EKF1002V	1%	0.1W		DNP
63	1	R139	1.5	1206	541-1.5ECT-ND		Vishay/Dale	CRCW12061R50JNEA	5%	0.25W		
64	3	R140,R146,R147	3.4K	805	541-3.40KCCT-ND		Vishay/Dale	CRCW08053K40FKEA	1%	0.125W		
65	1	R148	820	AXLE FLAME UPRIGHT	P820W-2BK-ND		Panasonic	ERG2SJ821	5%	2W		
66	2	R149,R152	68	1206	P68.0FTR-ND		Panasonic	ERJ-8ENF68R0V	1%	0.25W		
67	3	SW3,SW4,SW5	PB	PB	P13598SCT-ND		Panasonic	EVQ-PNF05M				
68	2	TP2,TP3	TESTPOINT	TESTPOINTSMALL	5011K-ND		KEYSTONE	5011				
69	3	T4,T5,T6	750110056	XFORM/566543			Midcom	750110056				DNP
70	1	U1	TL431	SO8-NARROW	296-1288-1-ND		Texas Instrume	TL431AIDR				
71	1	U2	FT232RQ	32QFNW/NOSPT	768-1008-1-ND		FTDI	FT232RQ-REEL				
72	1	U3	ADUM3201	SO8-NARROW	ADUM3201ARZ-ND		Analog Devices	ADUM3201ARZ				
73	1	U4	SER EEPROM	SO8-NARROW	AT24C1024BW-SH25-B-ND		ATMEL	AT24C1024BW-SH25-B				
74	1	U5	71M6543-100TQFI	IC149 100TQFP_SS			Teridian	71M6540F-IGT/F				
75	1	U6	LNK304-TN	SO8-NARROW	596-1237-1-ND		Power Integrat	LNK304DG-TL				
76	1	U8	LCD VLS-6648	LCD VLS-6648			VARITRONIX	VL_6648_V00				
77	1	U9	SER EEPROM (uWire	SO8-NARROW	93LC76C-I/SN-ND		MICROCHIP	93LC76CT-I/SN				
78	3	U15,U16,U17	71M6103-8SOIC	SO8-NARROW			Maxim	71M6103-IL/F				DNP
79	1	Y1	32.768KHz	XTAL-ECS-39			Suntsu	SPC6-32.768KHZTR				

4.6 71M6543 REV 4.0 DEMO BOARD PCB LAYOUT

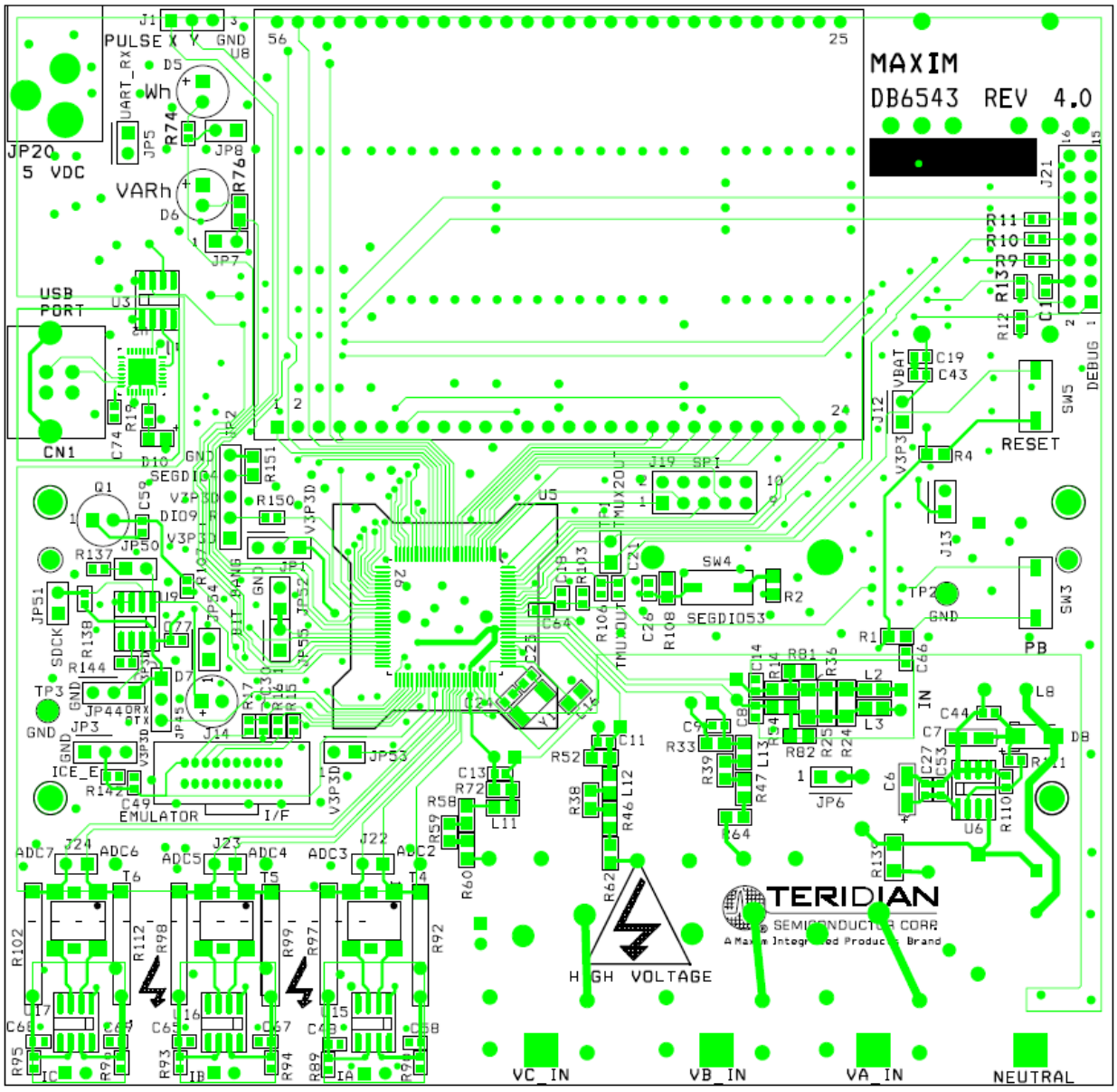

Figure 4-10: Teridian 71M6543 REV 4.0 Demo Board: Top View

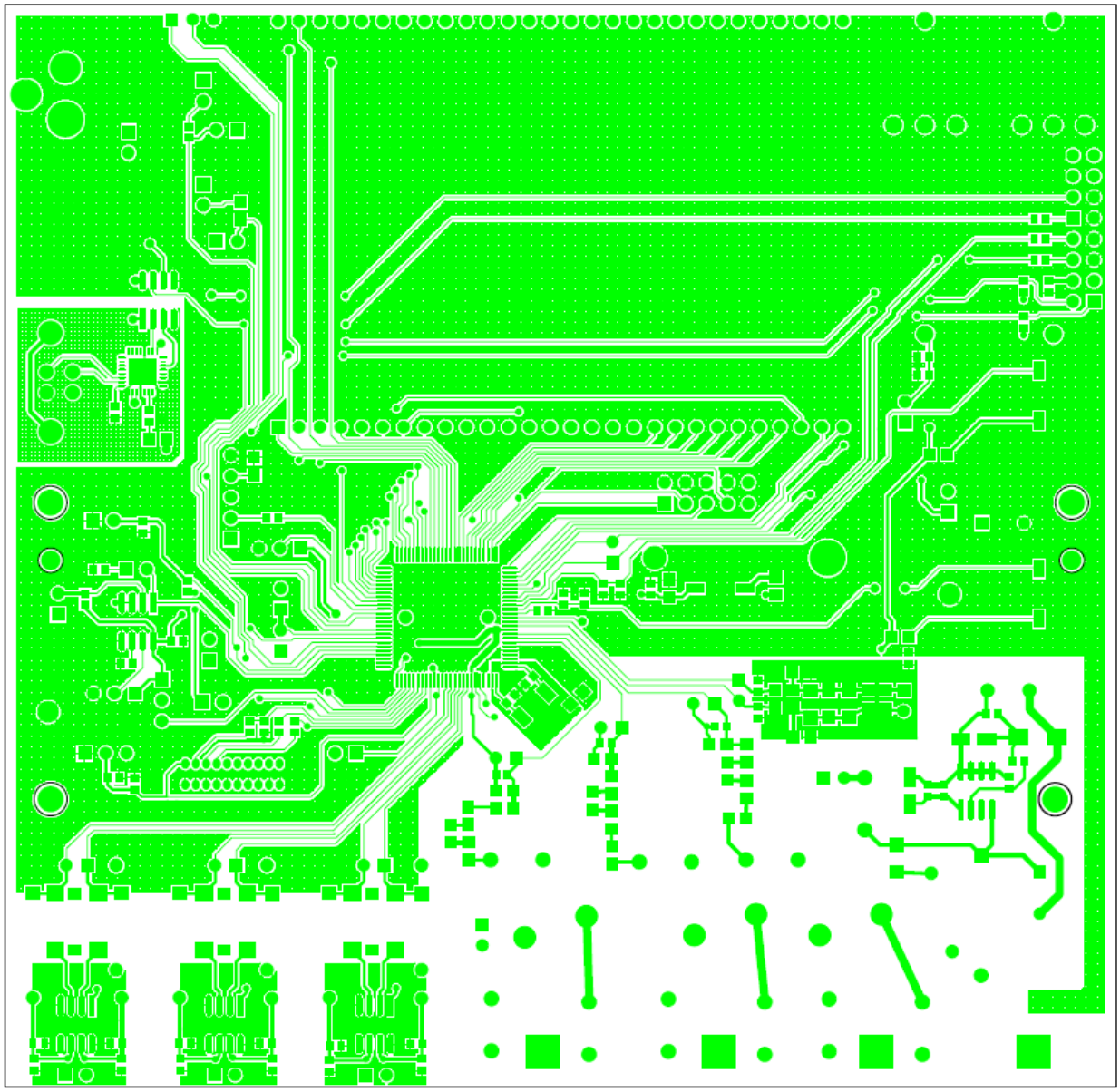

Figure 4-11: Teridian 71M6543 REV 4.0 Demo Board: Top Copper

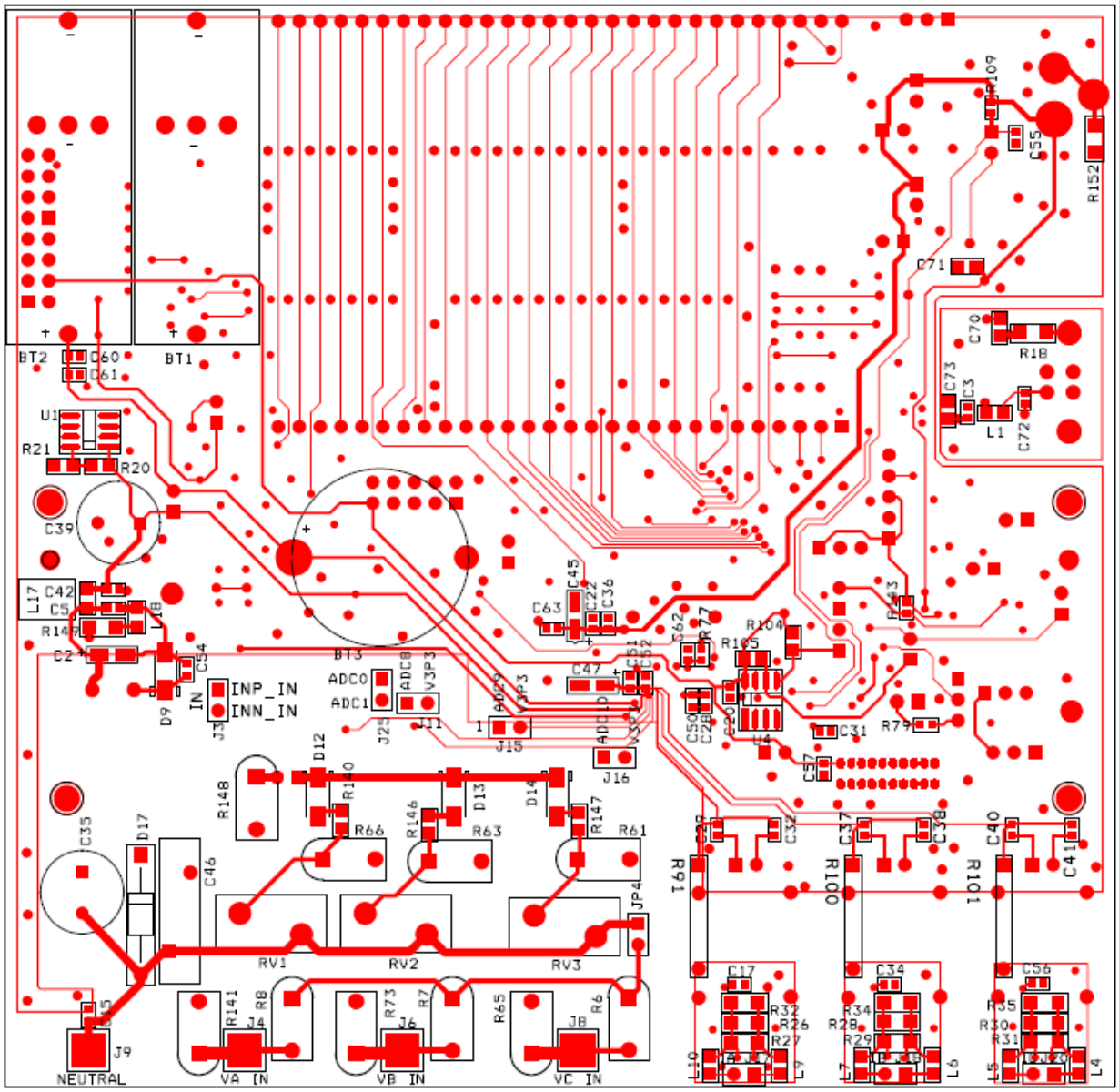

Figure 4-12: Teridian 71M6543 REV 4.0 Demo Board: Bottom View

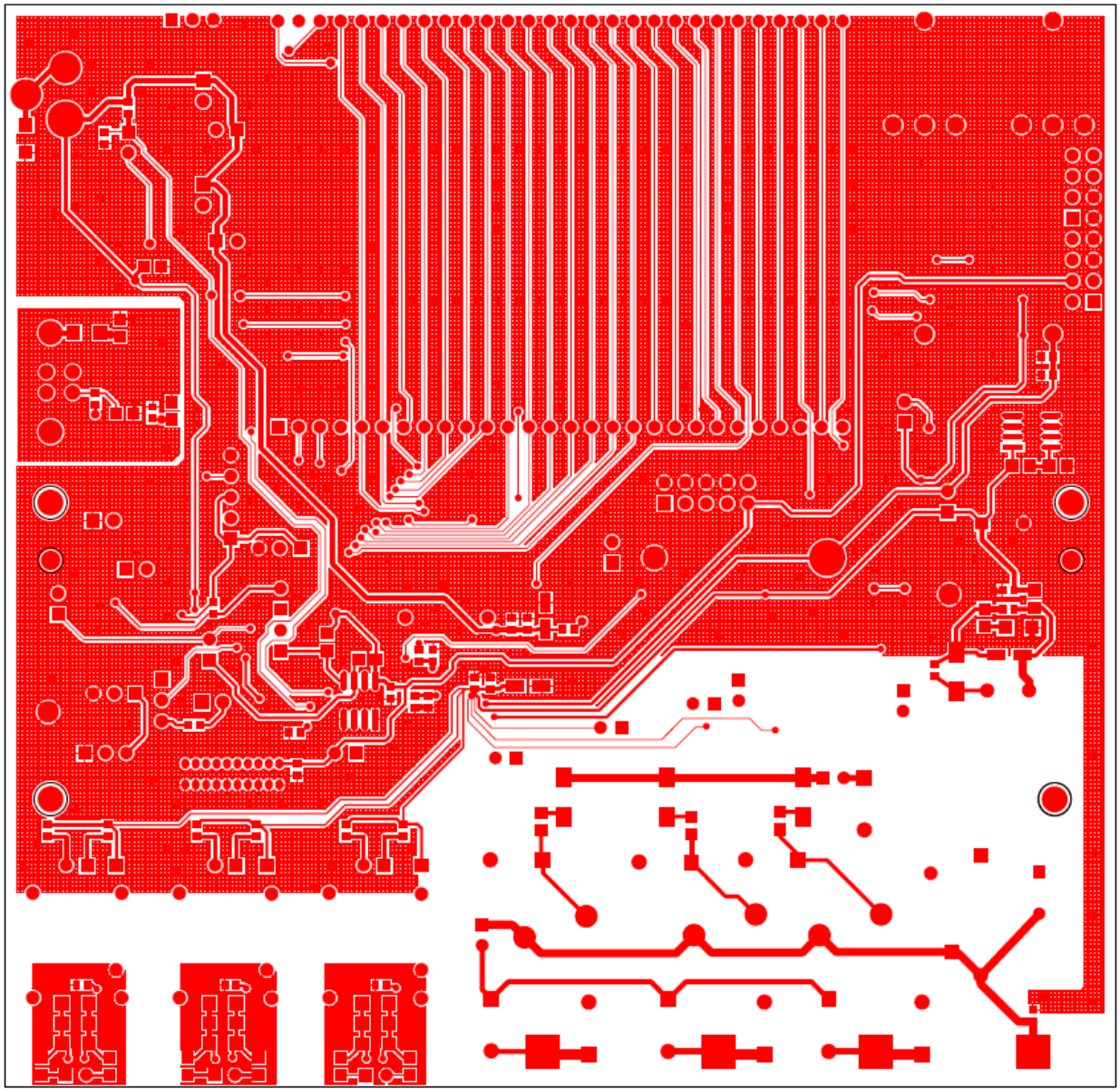

Figure 4-13: Teridian 71M6543 REV 4.0 Demo Board: Bottom Copper

4.7 71M6543 REV 5.0 DEMO BOARD PCB LAYOUT

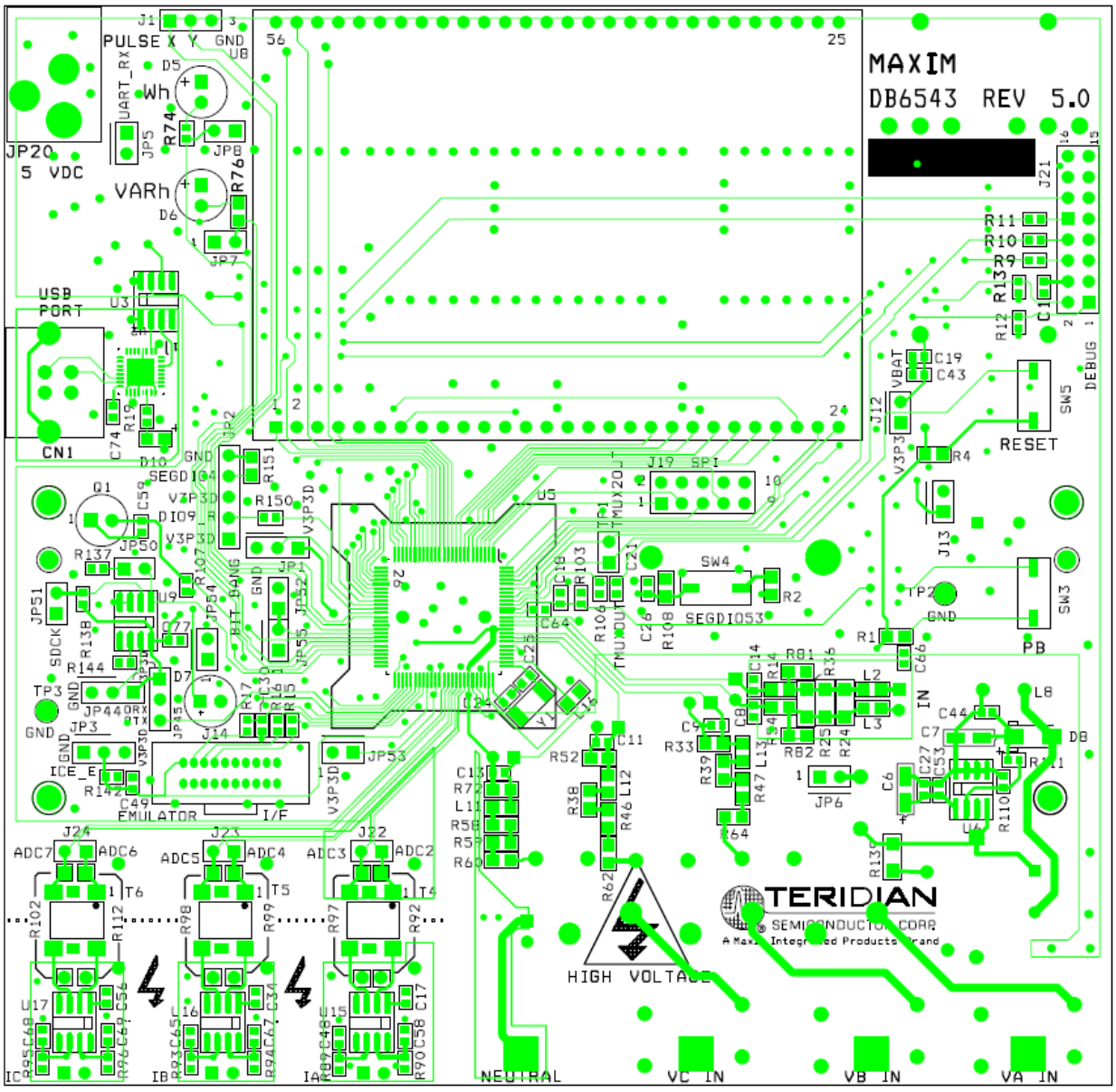

Figure 4-14: Teridian 71M6543 REV 5.0 Demo Board: Top View

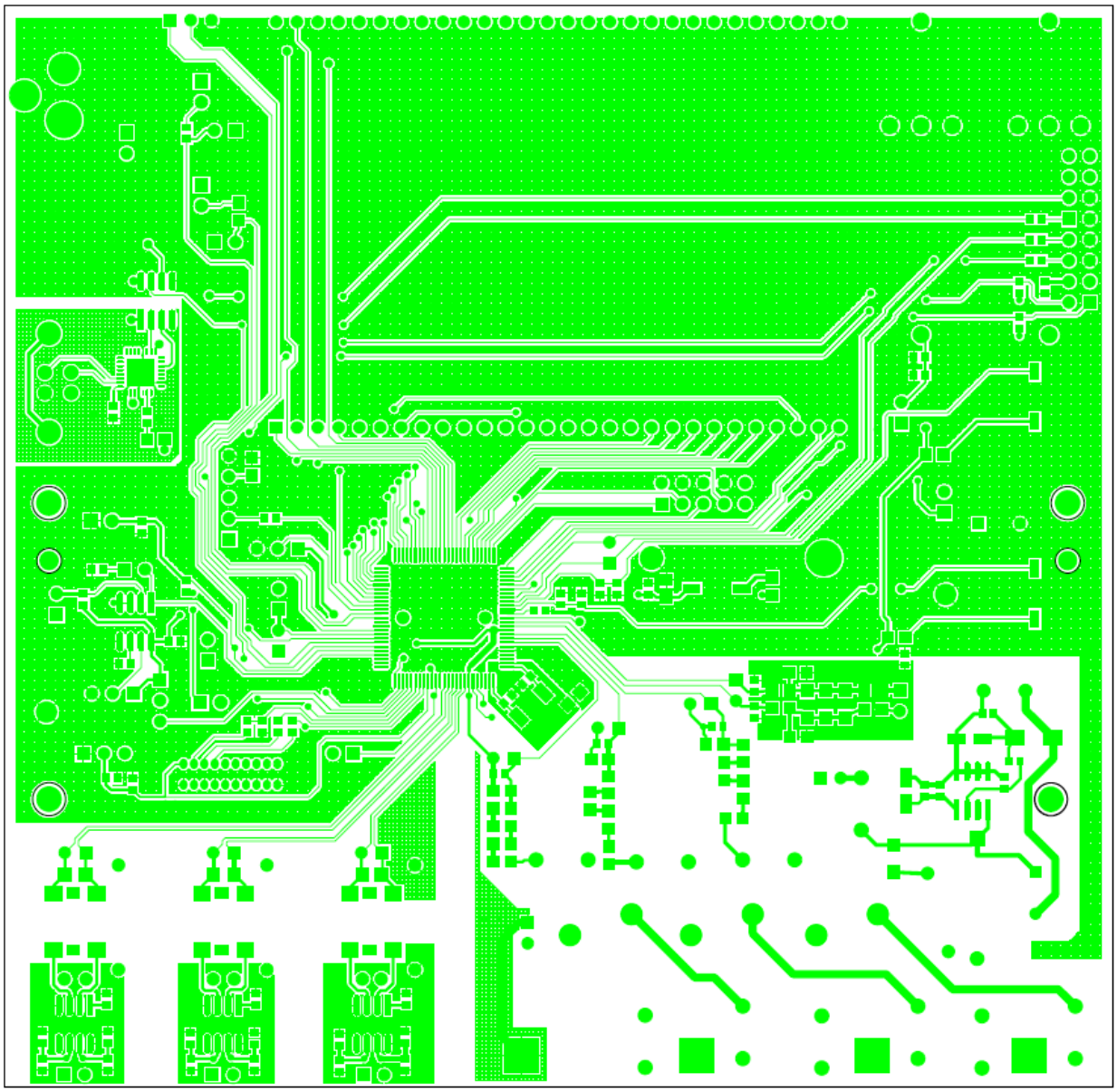

Figure 4-15: Teridian 71M6543 REV 5.0 Demo Board: Top Copper

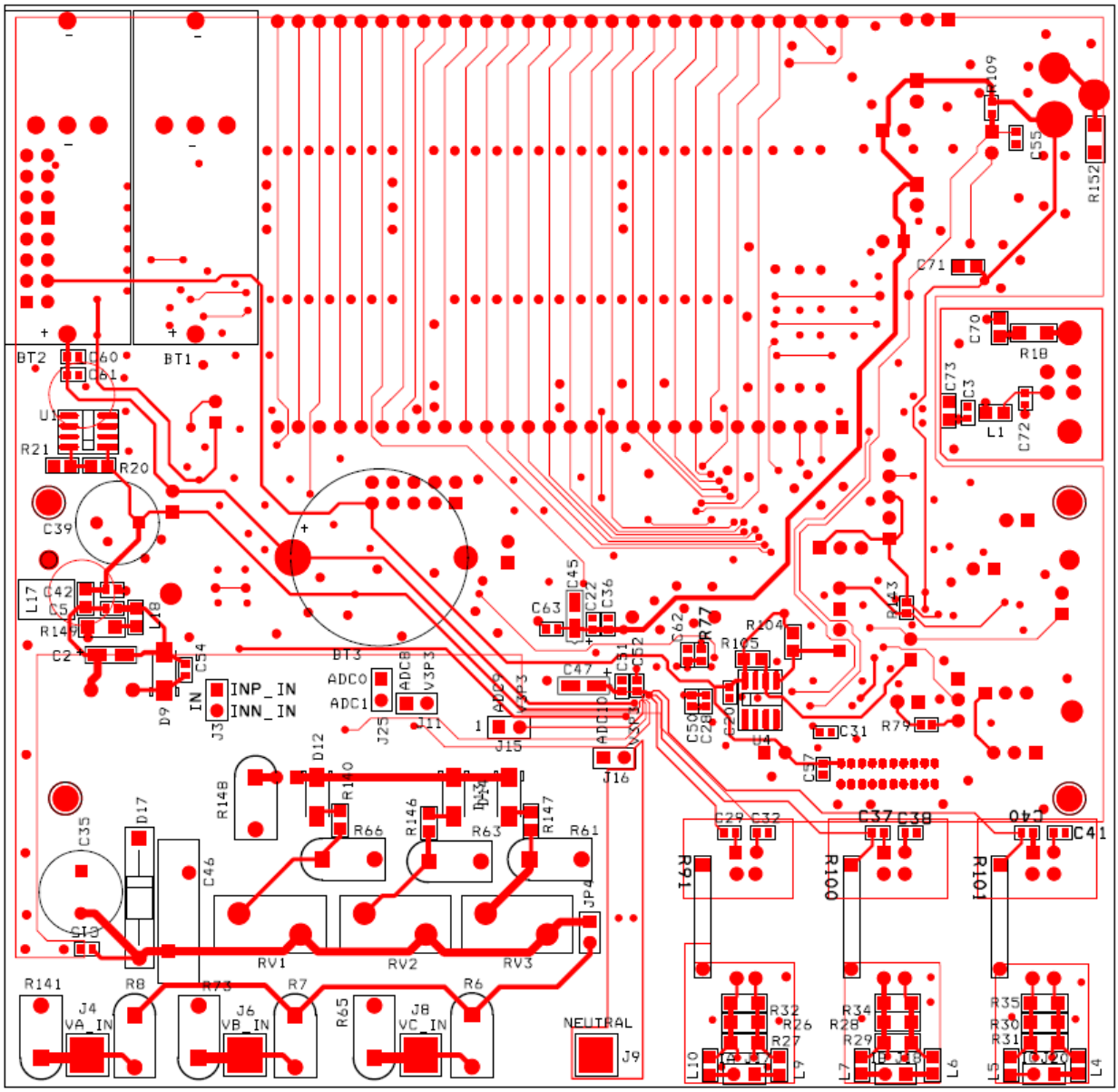

Figure 4-16: Teridian 71M6543 REV 5.0 Demo Board: Bottom View

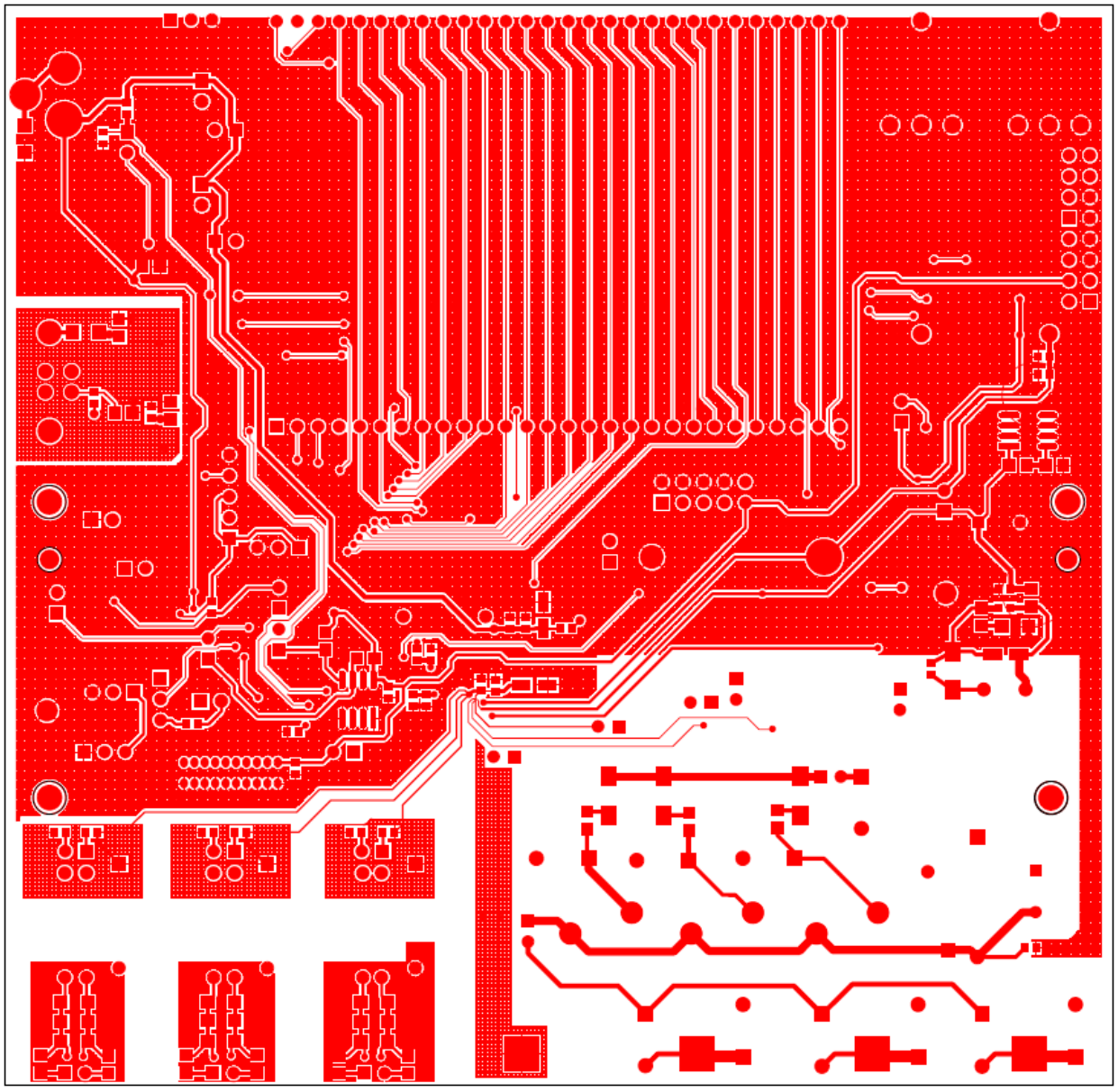

Figure 4-17: Teridian 71M6543 REV 5.0 Demo Board: Bottom Copper

4.8 DEBUG BOARD BILL OF MATERIAL

Item	Q	Reference	Value	PCB Footprint	P/N	Manufacturer	Vendor	Vendor P/N
1	21	C1-C3,C5-C10,C12-C23	0.1uF	0805	C2012X7R1H104K	TDK	Digi-Key	445-1349-1-ND
2	1	C4	33uF/10V	1812	TAJB336K010R	AVX	Digi-Key	478-1687-1-ND
3	1	C11	10uF/16V, B Case	1812	TAJB106K016R	AVX	Digi-Key	478-1673-1-ND
4	2	D2,D3	LED	0805	LTST-C170KGKT	LITEON	Digi-Key	160-1414-1-ND
5	4	JP1,JP2,JP3,JP4	HDR2X1	2x1pin	PZC36SAAN	Sullins	Digi-Key	S1011-36-ND
6	1	J1	RAPC712		RAPC712	Switchcraft	Digi-Key	SC1152-ND
7	1	J2	DB9	DB9	A2100-ND	AMP	Digi-Key	A2100-ND
8	1	J3	HEADER 8X2	8x2pin	PPTC082LFBN	Sullins	Digi-Key	S4208-ND
9	4	R1,R5,R7,R8	10K	0805	ERJ-6GEYJ103V	Panasonic	Digi-Key	P10KACT-ND
10	2	R2,R3	1K	0805	ERJ-6GEYJ102V	Panasonic	Digi-Key	P1.0KACT-ND
11	1	R4	NC	0805	N/A	N/A	N/A	N/A
12	1	R6	0	0805	ERJ-6GEY0R00V	Panasonic	Digi-Key	P0.0ACT-ND
13	1	SW2	PB Switch	PB	EVQ-PJX05M	Panasonic	Digi-Key	P8051SCT-ND
14	2	TP5,TP6	test point	TP	5011	Keystone	Digi-Key	5011K-ND
15	5	U1,U2,U3,U5,U6	ADUM1100	SOIC8	ADUM1100AR	ADI	Digi-Key	ADUM1100AR-ND
16	1	U4	MAX3237CAI	SOG28	MAX3237CAI	MAXIM	Digi-Key	MAX3237CAI-ND
17	4		spacer		2202K-ND	Keystone	Digi-Key	2202K-ND
18	4		4-40, 1/4" screw		PMS4400-0025PH	Building Fasteners	Digi-Key	H342-ND
19	2		4-40, 5/16" screw		PMS4400-0031PH	Building Fasteners	Digi-Key	H343-ND
20	2		4-40 nut		HNZ440	Building Fasteners	Digi-Key	H216-ND

Table 4-5: Debug Board: Bill of Material

4.9 DEBUG BOARD SCHEMATICS

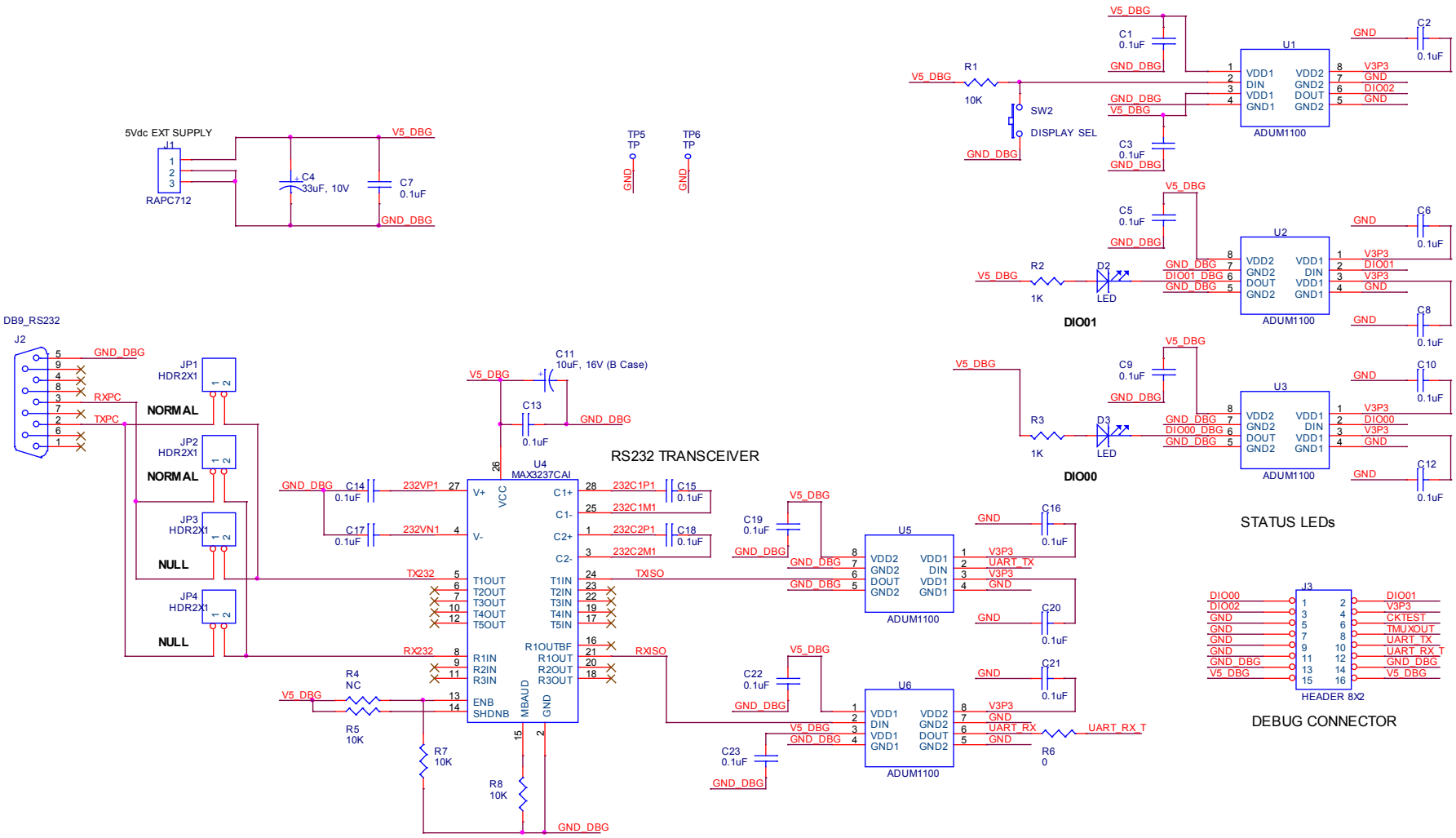

Figure 4-18: Debug Board: Electrical Schematic

4.10 OPTIONAL DEBUG BOARD PCB LAYOUT

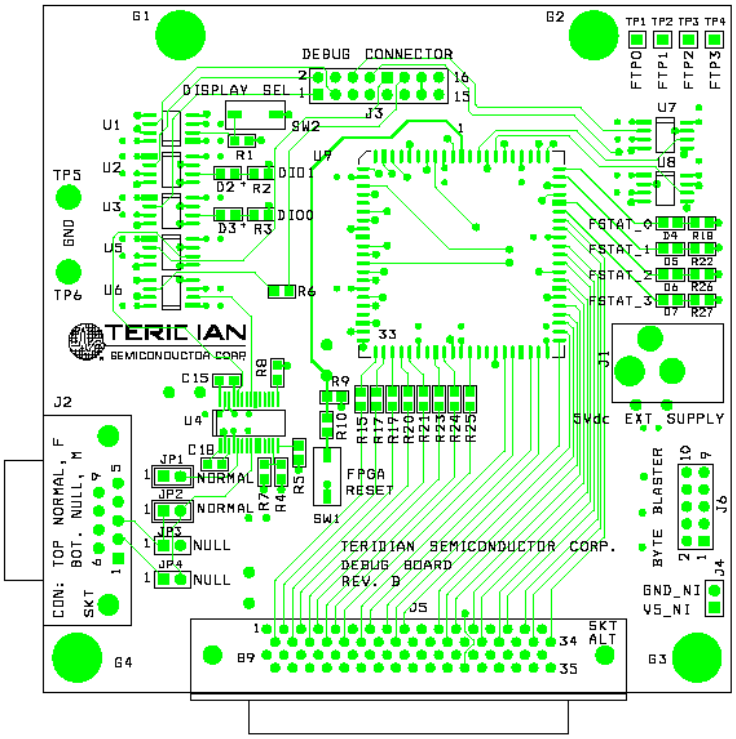

Figure 4-19: Debug Board: Top View

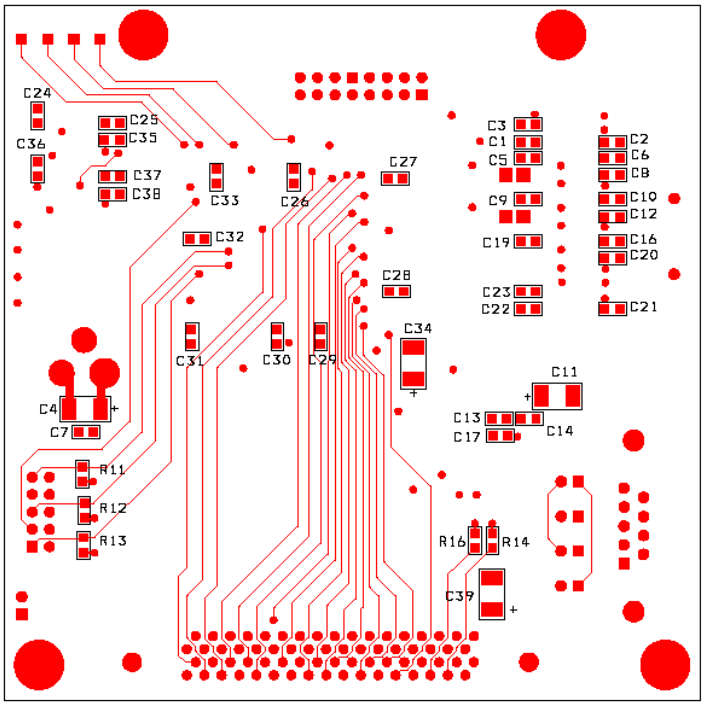

Figure 4-20: Debug Board: Bottom View

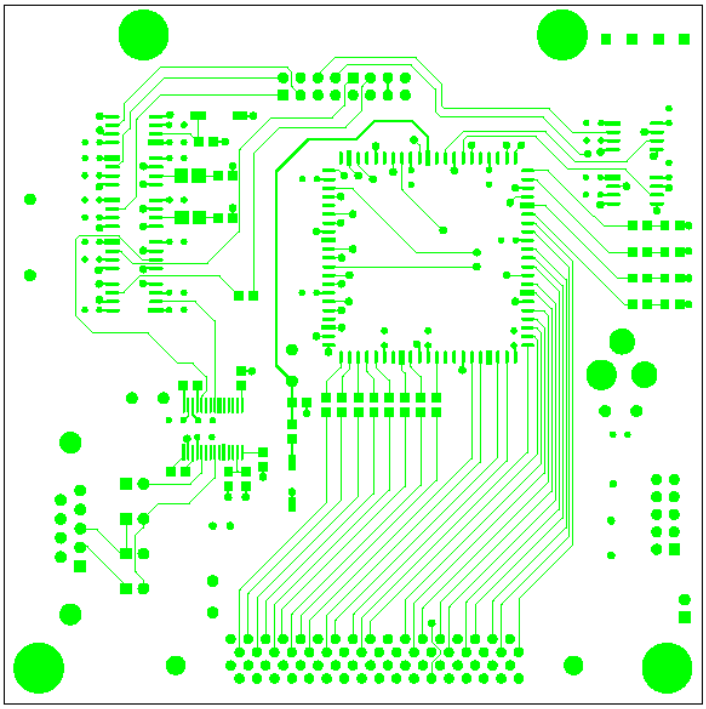

Figure 4-21: Debug Board: Top Signal Layer

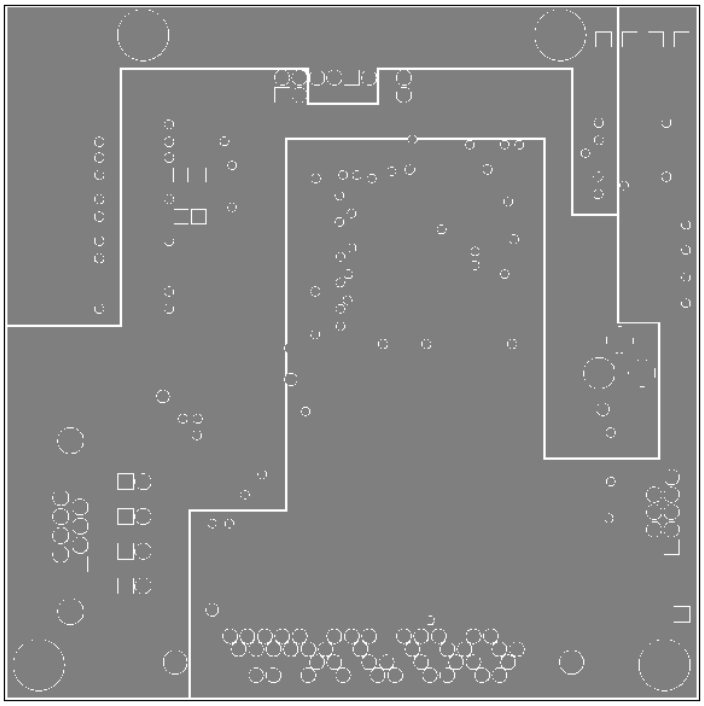

Figure 4-22: Debug Board: Middle Layer 1 (Ground Plane)

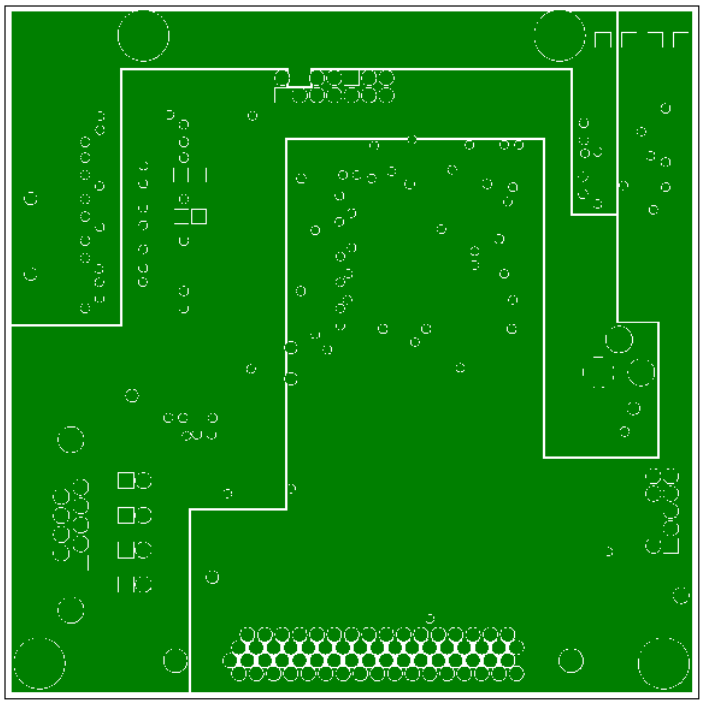

Figure 4-23: Debug Board: Middle Layer 2 (Supply Plane)

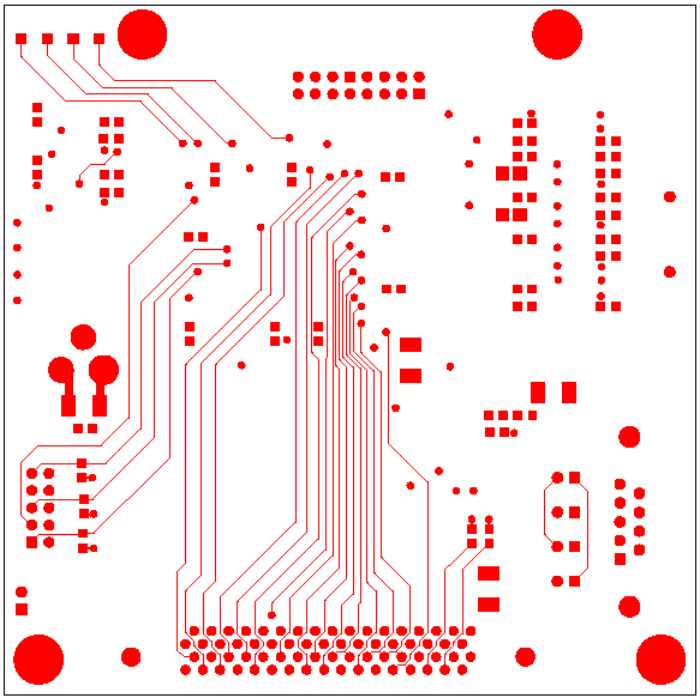

Figure 4-24: Debug Board: Bottom Trace Layer

4.11 71M6543 PIN-OUT INFORMATION

Power/Ground/NC Pins:

Table 4-6: 71M6543 Pin Description Table 1/3

Name	Type	Description
GNDA	P	Analog ground: This pin should be connected directly to the ground plane.
GNDD	P	Digital ground: This pin should be connected directly to the ground plane.
V3P3A	P	Analog power supply: A 3.3 V power supply should be connected to this pin. V3P3A must be the same voltage as V3P3SYS.
V3P3SYS	P	System 3.3 V supply. This pin should be connected to a 3.3 V power supply.
V3P3D	O	Auxiliary voltage output of the chip. In mission mode, this pin is connected to V3P3SYS by the internal selection switch. In BRN mode, it is internally connected to VBAT. V3P3D is floating in LCD and sleep mode. A bypass capacitor to ground should not exceed 0.1 µF.
VDD	O	The output of the 2.5V regulator. This pin is powered in MSN and BRN modes. A 0.1 µF bypass capacitor to ground should be connected to this pin.
VLCD	O	The output of the LCD DAC. A 0.1 µF bypass capacitor to ground should be connected to this pin.
VBAT	P	Battery backup pin to support the battery modes (BRN, LCD). A battery or super-capacitor is to be connected between VBAT and GNDD. If no battery is used, connect VBAT to V3P3SYS.
VBAT_RTC	P	RTC and oscillator power supply. A battery or super-capacitor is to be connected between VBAT and GNDD. If no battery is used, connect VBAT_RTC to V3P3SYS.

Analog Pins:

Table 4-7: 71M6543 Pin Description Table 2/3

Name	Type	Description
IAP/IAN, IBP/IBN, ICP/ICN IDP/IDN	I	Differential or single-ended Line Current Sense Inputs: These pins are voltage inputs to the internal A/D converter. Typically, they are connected to the outputs of current sensors. **Unused pins must be tied to V3P3A**. Pins IBP/IBN, ICP/ICN, and IDP/IDN may be configured for communication with the remote sensor interface (71M6x0x).
VA, VB, VC	I	Line Voltage Sense Inputs: These pins are voltage inputs to the internal A/D converter. Typically, they are connected to the outputs of resistor dividers. **Unused pins must be tied to V3P3A.**
VREF	O	Voltage Reference for the ADC. This pin should be left unconnected (floating).
XIN XOUT	I O	Crystal Inputs: A 32 kHz crystal should be connected across these pins. Typically, a 15 pF capacitor is also connected from XIN to GNDA and a 10 pF capacitor is connected from XOUT to GNDA. It is important to minimize the capacitance between these pins. See the crystal manufacturer datasheet for details. If an external clock is used, a 150 mV (p-p) clock signal should be applied to XIN, and XOUT should be left unconnected.

Pin types: P = Power, O = Output, I = Input, I/O = Input/Output

Digital Pins:

Table 4-8: 71M6543 Pin Description Table 3/3

Name	Type	Description
COM3,COM2, COM1,COM0	O	LCD Common Outputs: These 4 pins provide the select signals for the LCD display.
SEGDIO0 … SEGDIO45	I/O	Multi-use pins, configurable as either LCD segment driver or DIO. Alternative functions with proper selection of associated I/O RAM registers are: SEGDIO0 = WPULSE SEGDIO1 = VPULSE SEGDIO2 = SDCK SEGDIO3 = SDATA SEGDIO6 = XPULSE SEGDIO7 = YPULSE **Unused pins must be configured as outputs or terminated to V3P3/GNDD.**
SEGDIO26/ COM5, SEGDIO27/ COM4	I/O	Multi-use pins, configurable as either LCD segment driver or DIO with alternative function (LCD common drivers).
SEGDIO36/ SPI_CSZ, SEGDIO37/ SPI_DO, SEGDIO38/ SPI_DI, SEGDIO39/ SPI_CKI	I/O	Multi-use pins, configurable as either LCD segment driver or DIO with alternative function (SPI interface).
SEGDIO51/ OPT_TX, SEGDIO55/ OPT_RX	I/O	Multi-use pins, configurable as either LCD segment driver or DIO with alternative function (optical port/UART1)
E_RXTX/SEG48	I/O	Multi-use pins, configurable as either emulator port pins (when ICE_E pulled high) or LCD segment drivers (when ICE_E tied to GND).
E_RST/SEG50		
E_TCLK/SEG49	O	
ICE_E	I	ICE enable. When zero, E_RST, E_TCLK, and E_RXTX become SEG50, SEG49, and SEG48 respectively. For production units, this pin should be pulled to GND to disable the emulator port.
TMUXOUT/ SEG47, TMUX2OUT/ SEG46	O	Multi-use pins, configurable as either multiplexer/clock output or LCD segment driver using the I/O RAM registers.
RESET	I	Chip reset: This input pin is used to reset the chip into a known state. For normal operation, this pin is pulled low. To reset the chip, this pin should be pulled high. This pin has an internal 30 µA (nominal) current source pull-down. No external reset circuitry is necessary.
RX	I	UART0 input. **If this pin is unused it must be terminated to V3P3D or GNDD.**
TX	O	UART0 output.
TEST	I	Enables Production Test. **This pin must be grounded in normal operation.**
PB	I	Push button input. This pin must be at GNDD when not active or unused. A rising edge sets the IE_PB flag. It also causes the part to wake up if it is in SLP or LCD mode. PB does not have an internal pull-up or pull-down resistor.
NC	N/C	Do not connect this pin.

Pin types: P = Power, O = Output, I = Input, I/O = Input/Output,

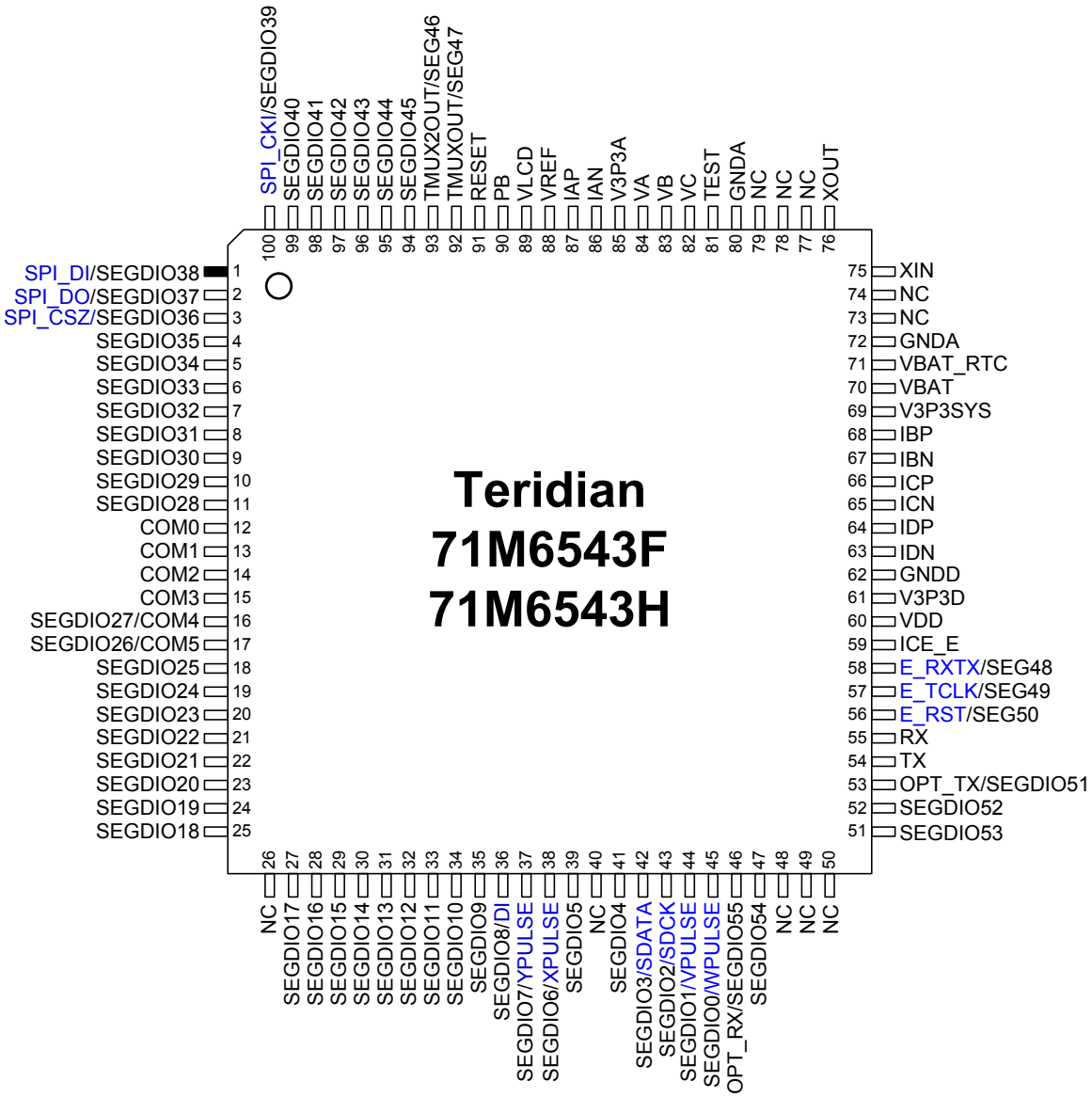

Figure 4-25: 71M6543, LQFP100: Pin-out (top view)

4.12 REVISION HISTORY

Revision	Date	Description
2.0	02-19-2010	Initial release based on DBUM revision 1.0 for 6543 REV 1.0 Demo Board.
2.1	02-23-2010	Minor corrections. Added more figures illustrating shunt arrangements.
2.2	03-01-2010	Specified type of Remote Sensor used on REV 2.0 board (71M6113 or 71M6203). Improved Table 1-9. Added description for *i_max2* variable used to control neutral current. Improved page layout.
2.3	03-04-2010	Changed type of Remote Sensor Interface from 71M6113 to 71M6103. Updated schematics and BOM of the REV 2.0 Demo Board.
2.4	06-16-2010	Corrected "X" factor for *WRATE* calculation to 0.09375. Changed section on shunt arrangement. Improved description on temperature compensation. Added Figure 1.7 and section 1.10.7.
2.5	06-21-2010	Added part numbers for shunt resistors.
3.0	07-26-2010	Added documentation for 6543 REV 3.0 Demo Board. Updated calibration spread sheets.
3.1	08-10-2010	Fixed display of calibration spread sheets in PDF file. Replaced Teridian Logo with Maxim Logo.
3.2	12-10-2010	Updated information on temperature compensation and on Demo Board revision 3.0.
4.0	02-16-2011	Updated to match board revisions 4.0 and 5.0. Removed information on older board revisions (3.0). Added comments on schematics.
4.1	03-28-2011	Updated schematics and BOM for DB6543 REV5.0. Added explanation and table of Demo Code versions.
4.2	05-06-2011	Added explanation on technique to avoid cross-talk between shunt resistors.
5	7/2012	Corrected addresses for auto-calibration parameter in CLI table. Corrected entries in table 1-11 (meter accuracy classes). Changed color for all table headings from yellow to gray. Corrected formula in 2.3.3.1. Removed text stating that the Demo Code and documents/tools are delivered on a CD-ROM in the kit. Added attribute 'optional' for all references to the 'Debug Board'. Added USB Interface Module as part of Demo Kit Contents. Added text stating that spreadsheets are available on the Maxim web site. Updated graphs and text in Serial Connection Setup (1.7.4) and updated Demo Code version in Compatibility (1.5). Updated images for calibration spreadsheets and changed description of calibration to reflect the usage of *LCOMP2_n* coefficients used in newer codes. Added section 1.10.8 (Bootloader Feature).