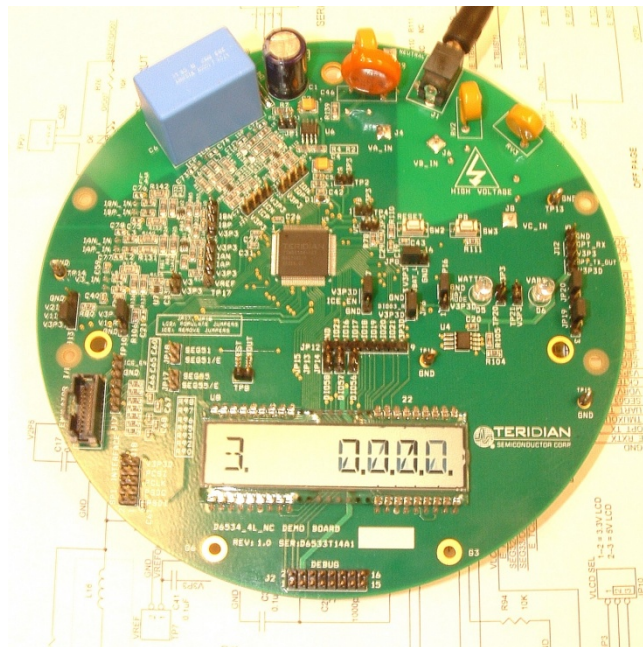




# 71M6534H Demo Board

## USER'S MANUAL



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V2-0

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# **71M6534H**

3-Phase Energy Meter IC

DEMO BOARD

## **USER'S MANUAL**

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# 1

## 1 GETTING STARTED

### 1.1 GENERAL

The TERIDIAN Semiconductor Corporation (TSC) 71M6534H Demo Board is a demonstration board for evaluating the 71M6534H device for 3-phase electronic power metering applications. It incorporates a 71M6534 or 71M6534H integrated circuit, peripheral circuitry such as a serial EEPROM, emulator port, and on board power supply as well as a companion Debug Board that allows a connection to a PC through a RS232 port. The demo board allows the evaluation of the 71M6534 or 71M6534H energy meter chip for measurement accuracy and overall system use.

The board is pre-programmed with a Demo Program in the FLASH memory of the 71M6534/6534H 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 71M6534/6534H IC on the Demo Board is pre-programmed with default calibration factors.

### 1.2 SAFETY AND ESD PRECAUTIONS

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!**

### 1.3 DEMO KIT CONTENTS

- Demo Board D6534T14A2 with 71M6534H IC and pre-loaded demo program:
- Debug Board
- Two 5VDC/1,000mA universal wall transformers with 2.5mm plug (Switchcraft 712A compatible)
- Serial cable, DB9, Male/Female, 2m length (Digi-Key AE1020-ND)
- CD-ROM containing documentation (data sheet, board schematics, BOM, layout), Demo Code (sources and executable), and utilities



The CD-ROM contains a file named **readme.txt** that describes all files found on the CD-ROM.

## 1.4 DEMO BOARD VERSIONS

At printing time of this document only the following version of the Demo Board is available:

- Demo Board D6534T14A2 (standard)

## 1.5 COMPATIBILITY

This manual applies to the following hardware and software revisions:

- 71M6534 or 71M6534H chip revision A03
- Demo Kit firmware revision 4p6q
- Demo Boards D6534T14A2

## 1.6 SUGGESTED EQUIPMENT NOT INCLUDED

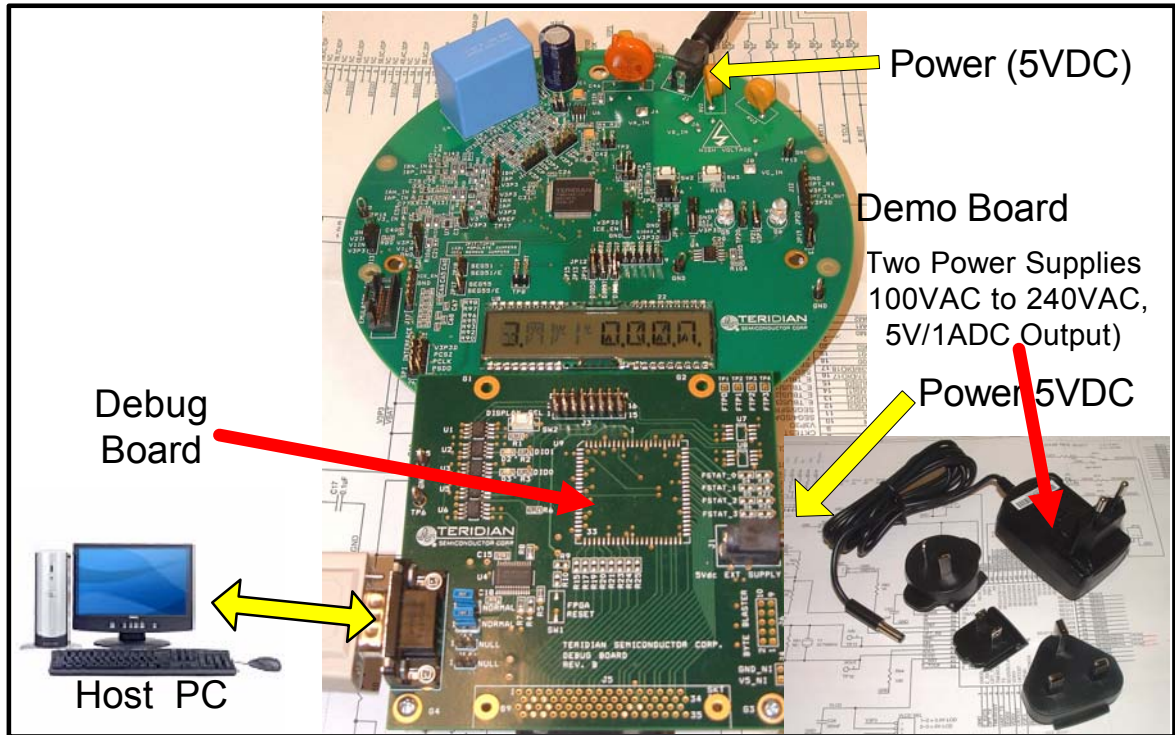
For functional demonstration:

- PC w/ MS-Windows® versions XP, ME, or 2000, equipped with RS232 port (COM port) via DB9 connector  
For software development (MPU code):

- Signum ICE (In Circuit Emulator): ADM-51 – **see update information in section 1.11**  
<http://www.signum.com>
- Keil 8051 “C” Compiler kit: CA51  
<http://www.keil.com/c51/ca51kit.htm>, <http://www.keil.com/product/sales.htm>

## 1.7 DEMO BOARD TEST SETUP

Figure 1-1 shows the basic connections of the Demo Board plus Debug Board with the external equipment for desktop testing, i.e. without live power applied. For desktop testing, both the Demo and Debug board may be powered with their 5VDC power supplies.



**Figure 1-1: TERIDIAN D6534T14A2 Demo Board with Debug Board: Basic Connections**

The D6534T14A2 Demo Board block diagram is shown in Figure 1-2. It consists of a stand-alone meter Demo Board and an optional Debug Board. The Demo Board contains all circuits necessary for operation as a meter, including display, calibration LED, and internal power supply. The Debug Board provides magnetic isolation from the meter and interfaces to a PC through a 9 pin serial port. For serial communication between the PC and the TERIDIAN 71M6534H, the Debug Board needs to be plugged with its connector J3 into connector J2 of the Demo Board.

Connections to the external signals to be measured, i.e. AC voltages and current signals derived from shunt resistors or current transformers, are provided on the rear side of the demo board (see Figure 3-1).



**Caution:** 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 V3P3 (3.3V power supply to the chip).

# DEMONSTRATION METER

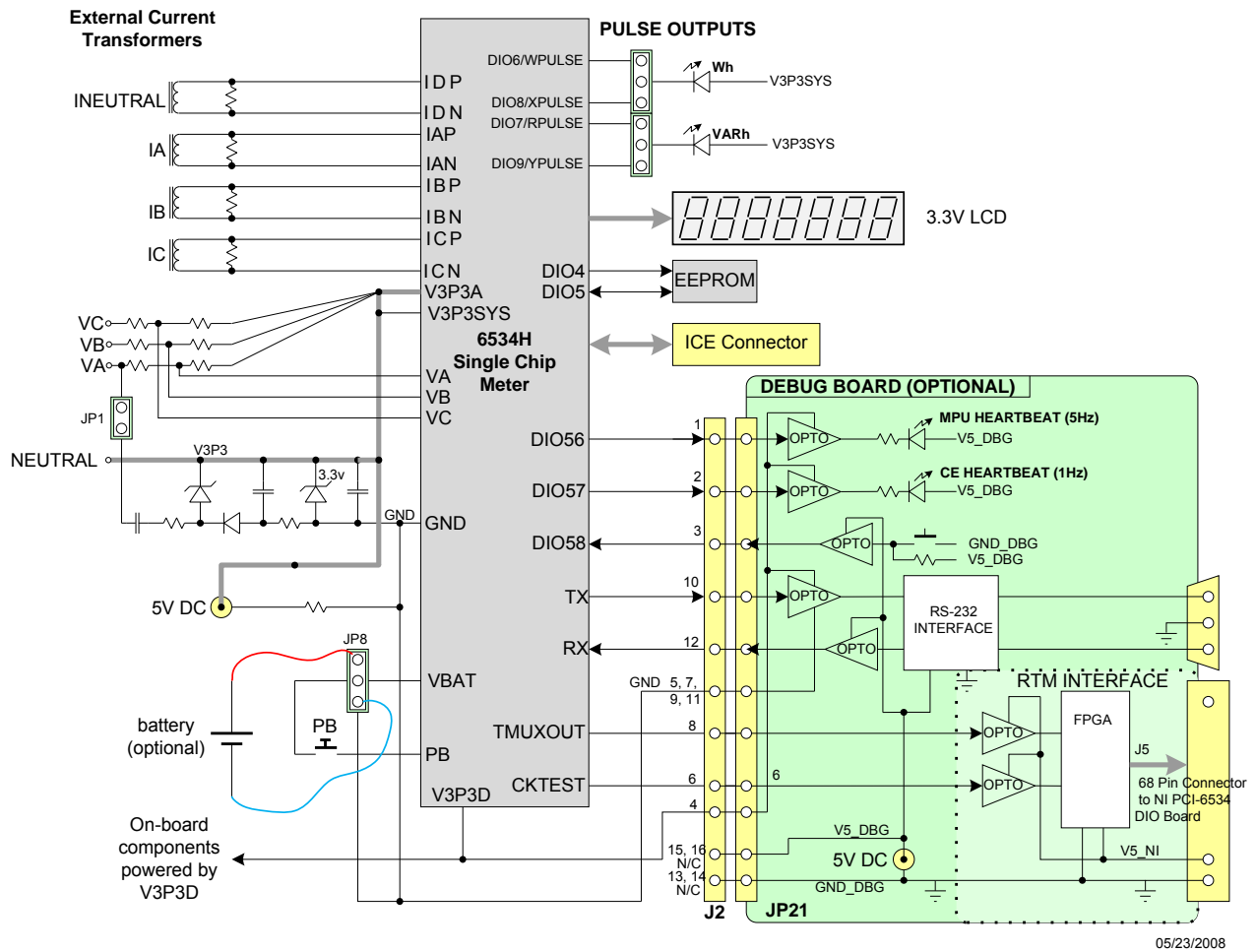


Figure 1-2: Block diagram for the TERIDIAN D6534T14A2 Demo Board with Debug Board

## 1.7.1 POWER SUPPLY SETUP

There are several choices for meter power supply:

- Internal (using phase A of the AC line voltage). The internal power supply is only suitable when phase A exceeds 220V RMS.
- External 5VDC connector (J1) on the Demo Board
- External 5VDC connector (J1) on the Debug Board.



The power supply jumper JP1 must be consistent with the power supply choice. JP1 connects the AC line voltage to the internal power supply. This jumper should usually be left in place.

## 1.7.2 CABLE FOR SERIAL CONNECTION (DEBUG BOARD)

For connection of the DB9 serial port to a PC, 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**

### 1.7.3 CHECKING OPERATION

A few seconds after power up, the LCD display on the Demo Board should display this brief greeting:

|  |  |   |   |   |   |   |  |
|--|--|---|---|---|---|---|--|
|  |  | H | E | L | L | O |  |
|--|--|---|---|---|---|---|--|

The "HELLO" message should be followed by the display of accumulated energy alternating with the text "Wh".

|    |  |  |  |    |   |   |   |
|----|--|--|--|----|---|---|---|
| 3. |  |  |  | 0. | 0 | 0 | 1 |
|----|--|--|--|----|---|---|---|

|  |   |   |  |  |  |  |  |
|--|---|---|--|--|--|--|--|
|  | W | h |  |  |  |  |  |
|--|---|---|--|--|--|--|--|

If the PB switch on the Demo Board is pressed and held down), the display will cycle through a series of parameters, as shown in Table 1-4.

| Step | Displayed Text | Description                                   | Step | Displayed Text | Description                                  |
|------|----------------|---|------|----------------|--|
| 1    | <b>DELTA C</b> | Deviation from nominal temperature [°C]       | 10   | <b>DATE</b>    | Date from RTC [yyyy.mm.dd]                   |
| 2    | <b>HZ</b>      | Line frequency [Hz]                           | 11   | <b>PF</b>      | Power factor, calculated from current Wh/VAh |
| 3    | <b>Wh</b>      | Accumulated real energy [Wh]                  | 12   |                |  |
| 4    | <b>Wh</b>      | Exported real energy [Wh]                     | 13   | <b>EDGES</b>   |  |
| 5    | <b>VARh</b>    | Accumulated reactive energy [VARh]            | 14   | <b>PULSES</b>  | Accumulated pulses                           |
| 6    | <b>VARh</b>    | Exported reactive energy [VARh]               | 15   | <b>A</b>       | Current                                      |
| 7    | <b>VAh</b>     | Accumulated apparent energy [VARh]            | 16   | <b>V</b>       | Voltage                                      |
| 8    | <b>HOURS</b>   | Hours of operation since last reset [1/100 h] | 17   | <b>VBAT</b>    | Battery voltage                              |
| 9    | <b>TIME</b>    | Real time from RTC [hh.mm.ss]                 | --   | --             | --   |

**Table 1-4: Selectable Display Parameters**

Once, the Debug Board is plugged into J2 of the Demo Board, LED DIO1 on the Debug Board will flash with a frequency of 1Hz, indicating CE activity. The LED DIO0 will flash with a frequency of 5Hz, indicating MPU activity.

## 1.7.4 SERIAL CONNECTION SETUP

After connecting the DB9 serial port to a PC, start the HyperTerminal application and create a session using the following parameters:

**Port Speed: 9600 bd or 300bd, depending on jumper JP16 (see section 3.1)**

**Data Bits: 8**

**Parity: None**

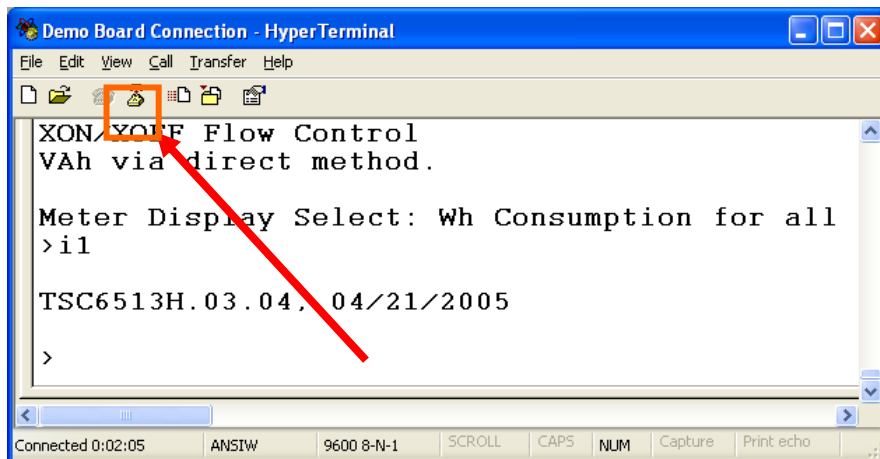
**Stop Bits: 1**

**Flow Control: XON/XOFF**

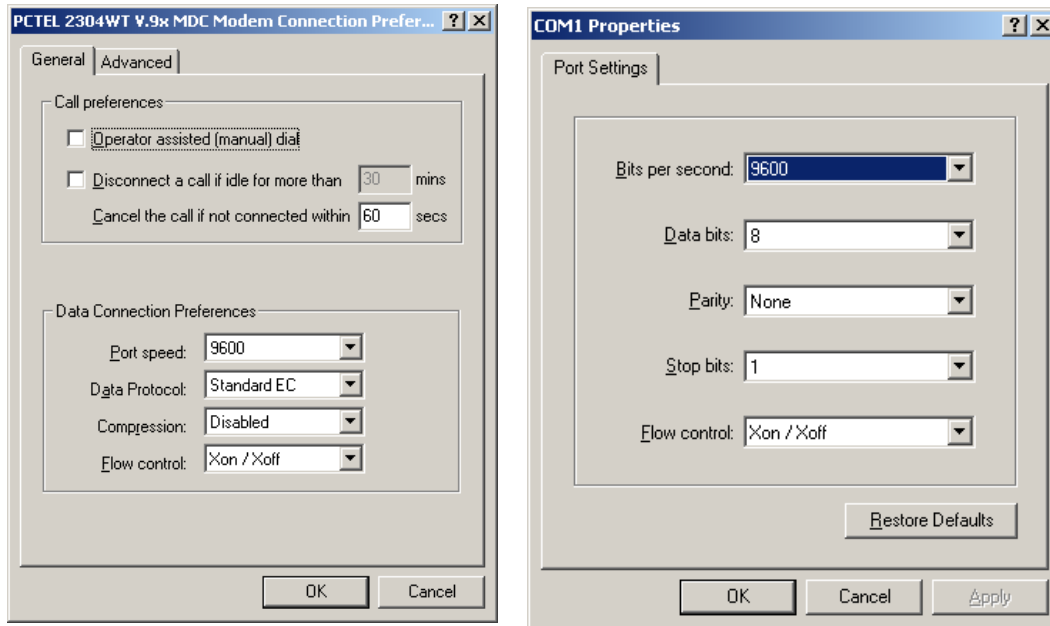
HyperTerminal can be found by selecting Programs → Accessories → Communications from the Windows® start menu. The connection parameters are configured by selecting File → Properties and then by pressing the Configure button. Port speed and flow control are configured under the General tab (Figure 1-4, left), bit settings are configured by pressing the Configure button (Figure 1-5, 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.



**Port parameters can only be adjusted when the connection is not active. The disconnect button, as shown in Figure 1-3 must be clicked in order to disconnect the port.**



**Figure 1-3: Hyperterminal Sample Window with Disconnect Button (Arrow)**



**Figure 1-4: Port Speed and Handshake Setup (left) and Port Bit setup (right)**

Once, the connection to the demo board is established, press <CR> and the 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 71M6534/6534H Demo Board is a ready-to-use meter prepared for use with external current transformers.

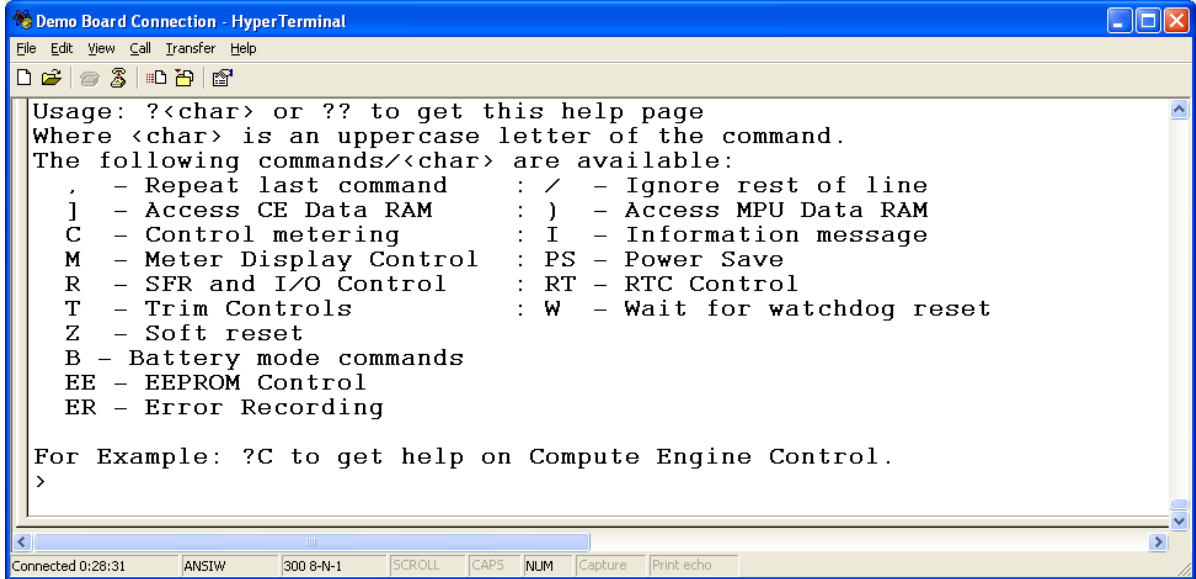
Using the Demo Board involves communicating with the Demo Code via the command line interface (CLI). The CLI allows modifications to the metering parameters, access to the EEPROM, initiation of auto-cal sequences, selection of the displayed parameters, changing of calibration factors and more operations that can be used to evaluate the 71M6534 chip.

Before evaluating the 71M6534/6534H 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 71M6534/6534H provides a convenient way of examining and modifying key meter parameters. Once the Demo Board is connected to a PC or terminal per the instructions given in Section 1.7.2 and 1.7.4, typing '?' will bring up the list of commands shown in Figure 1-5.



```
Demo Board Connection - HyperTerminal
File Edit View Call Transfer Help
Usage: ?<char> or ?? to get this help page
Where <char> is an uppercase letter of the command.
The following commands/<char> are available:
. - Repeat last command      : / - Ignore rest of line
] - Access CE Data RAM      : ) - Access MPU Data RAM
C - Control metering        : I - Information message
M - Meter Display Control    : PS - Power Save
R - SFR and I/O Control     : RT - RTC Control
T - Trim Controls           : W - Wait for watchdog reset
Z - Soft reset
B - Battery mode commands
EE - EEPROM Control
ER - Error Recording

For Example: ?C to get help on Compute Engine Control.
>
```

**Figure 1-5: Command Line Help Display**

The tables in this chapter describe the commands in detail.

### Commands to Display Help on the CLI Commands:

| ?                     | HELP  | Comment   |
|-----------------------|---|---|
| Description:          | Command help available for each of the options below. |   |
| Command combinations: | ?   | Command line interpreter help menu.             |
|                       | ?]  | Display help on access CE data RAM              |
|                       | ?)  | Display help on access MPU RAM                  |
|                       | ?,  | Display help on repeat last command             |
|                       | ?/  | Display help on ignore rest of line             |
|                       | ?C  | Display help on compute engine control.         |
|                       | ?CL   | Display help on calibration.                    |
|                       | ?EE   | Display help on EEPROM control                  |
|                       | ?ER   | Display help on error recording                 |
|                       | ?I  | Display help on information message             |
|                       | ?M  | Display help on meter display control           |
|                       | ?MR   | Display help on meter RMS display control       |
|                       | ?R  | Display help on SFR control                     |
|                       | ?RT   | Display help on RTC control                     |
|                       | ?T  | Display help on trim control                    |
|                       | ?W  | Display help on the wait/reset command          |
|                       | ?Z  | Display help on reset                           |
| Examples:             | ??  | Display the command line interpreter help menu. |
|                       | ?C  | Displays compute engine control help.           |

### 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  $0x1000 + 4 * A = 0x1028$ .

**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 0xFFFF). 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: | Rlx...   | 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.                           |

DIO or Configuration RAM space is the address range 0x2000 to 0x20FF. This RAM contains registers used for configuring basic hardware and functional properties of the 71M6534/6534H and is organized in bytes (8 bits). The 0x2000 offset is automatically added when the command RI is typed.

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 and write to EEPROM. |  |
| Usage:                | EE [option] [arguments]                         |  |
| Command combinations: | EEN   | 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<br>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.

**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 CONTROL                                      | Comment  |
|-----------------------|---|--|
| Description:          | Allows the user to enable and configure the compute engine. |  |
| Usage:                | C [option] [argument]                                       |  |
| Command combinations: | CEN   | Compute Engine Enable (1 → Enable, 0 → Disable)  |
|                       | CTn   | Select input n for TMUX output pin. n is interpreted as a decimal number.                              |
|                       | CREn  | RTM output control (1 → Enable, 0 → Disable)   |
|                       | CRSa.b.c.d  | Selects CE addresses for RTM output  |
| Example:              | CE0   | Disables CE, followed by "CE OFF" display on LCD. The Demo Code will reset if the WD timer is enabled. |
|                       | CT3   | Selects the VBIAS signal for the TMUX output pin   |

### Commands controlling the Auto-Calibration Function:

| CL                    | AUTO-CALIBRATION CONTROL  | Comment   |
|-----------------------|---|---|
| Description:          | Allows the user to initiate auto-calibration and to store calibration values. |   |
| Usage:                | CL [option]   |   |
| Command combinations: | CLB   | Begin auto-calibration. Prior to auto-calibration, the calibration coefficients are automatically restored from flash memory. |
|                       | CLS   | Save calibration coefficients to EEPROM starting at address 0x0004  |
|                       | CLR   | Restore calibration coefficients from EEPROM  |
|                       | CLD   | Restore coefficients from flash memory  |
| Example:              | CLB   | Starts auto-calibration and saves data automatically.   |



Before starting the auto-calibration process, target values for voltage, duration and current must be entered in MPU RAM (see section 1.9.5), and the target voltage and current must be applied constantly during calibration. Calibration factors can be saved to EEPROM using the CLS command.

### Commands controlling the Pulse Counter Function

| CP                    | PULSE-COUNT CONTROL                                   | Comment   |
|-----------------------|---|---|
| Description:          | Allows the user to control the pulse count functions. |   |
| Usage:                | CP [option]   |   |
| Command combinations: | CPA   | Start pulse counting for time period defined with the CPD command. Pulse counts will display with commands M15.2, M16.2 |
|                       | CPC   | Clear the absolute pulse count displays (shown with commands M15.1, M16.1)  |
|                       | CPDn  | Set time window for pulse counters to n seconds, n is interpreted as a decimal number.                                  |
| Example:              | CPD60   | Set time window to 60 seconds.  |



Pulse counts accumulated over a time window defined by the CPD command will be displayed by M15.2 or M16.2 **after** the defined time has expired.

Commands M15.1 and M16.1 will display the **absolute** pulse count for the W and VAR outputs. These displays are reset to zero with the CPC command (or the XRAM write )1=2).



Commands M15.2 and M16.2 will display the number of pulses counted during the interval defined by the CPD command. These displays are reset only after a new reading, as initiated by the CPA command.

### Commands for Identification and Information:

| I            | INFORMATION MESSAGES                      | Comment                               |
|--------------|---|---------------------------------------|
| Description: | Allows user to read information messages. |                                       |
| Usage:       | I   | Displays complete version information |

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

### Commands for Controlling the RMS Values Shown on the LCD Display:

| MR | METER RMS DISPLAY | Comment |
|----|-------------------|---------|
|----|-------------------|---------|

|                       | <b>CONTROL (LCD)</b>  |                                    |
|-----------------------|---|------------------------------------|
| Description:          | Allows user to select meter RMS display for voltage or current. |                                    |
| Usage:                | MR [option]. [option]   |                                    |
| Command combinations: | MR1. [phase]  | Displays instantaneous RMS current |
|                       | MR2. [phase]  | Displays instantaneous RMS voltage |
| Example:              | MR1.3   | Displays phase C RMS current.      |

**Phase 4 is the measured neutral current.**



**No error message is issued when an invalid parameter is entered, e.g. MR1.8.**

**Commands for Controlling the MPU Power Save Mode:**

| <b>PS</b>    | <b>POWER SAVE MODE</b> | <b>Comment</b>   |
|--------------|------------------------|--|
| Description: | Enters power save mode | Disables CE, ADC, CKOUT, ECK, RTM, SSI, TMUX VREF, and serial port, sets MPU clock to 38.4KHz. |
| Usage:       | PS                     |  |

Return to normal mode is achieved by resetting the MPU (Z command).

**Commands for Controlling the RTC:**

| <b>RT</b>             | <b>REAL TIME CLOCK CONTROL</b>                       | <b>Comment</b>   |
|-----------------------|--|--|
| 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.<br>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. |
| Example:              | RTD05.03.17.5  | Programs the RTC to Thursday, 3/17/2005  |
|                       | RTA1.+1234   | Speeds up the RTC by 1234 PPB.   |



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 71M6534H (0.1%) parts. When used on a 71M6534 (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 Controlling the Metering Values Shown on the LCD Display:**

| M                     | METER DISPLAY CONTROL (LCD)                               | Comment  |
|-----------------------|---|--|
| Description:          | Allows user to select internal variables to be displayed. |  |
| Usage:                | M [option]. [option]                                      |  |
| Command combinations: | M   | Wh Total Consumption (display wraps around at 999.999)               |
|                       | M0  | Wh Total Consumption (display wraps around at 999.999)               |
|                       | M1  | Temperature (C° delta from nominal)                                  |
|                       | M2  | Frequency (Hz)   |
|                       | M3. [phase]   | Wh Total Consumption (display wraps around at 999.999)               |
|                       | M4. [phase]   | Wh Total Inverse Consumption (display wraps around at 999.999)       |
|                       | M5. [phase]   | VARh Total Consumption (display wraps around at 999.999)             |
|                       | M6. [phase]   | VARh Total Inverse Consumption (display wraps around at 999.999)     |
|                       | M7. [phase]   | VAh Total (display wraps around at 999.999)                          |
|                       | M8  | Operating Time (in hours)  |
|                       | M9  | Real Time Clock  |
|                       | M10   | Calendar Date  |
|                       | M11. [phase]  | Power factor   |
|                       | M13   | Mains edge count for the last accumulation interval                  |
|                       | M13.1   | Main edge count (accumulated) – zero transitions of the input signal |
|                       | M13.2   | CE main edge count for the last accumulation interval                |
|                       | M14.1   | Absolute count for W pulses. Reset with CPC command.                 |
|                       | M14.2   | Count for W pulses in time window defined by the CPD command.        |
|                       | M15.1   | Absolute count for VAR pulses. Reset with CPC command.               |
|                       | M15.2   | Count for W pulses in time window defined by the CPD command.        |
| Example:              | M3.3  | Displays Wh total consumption of phase C.                            |
|                       | M5.0  | Displays VARh total consumption for all phases.                      |



**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.**

**When entering the phase parameter, use 1 for phase A, 2 for phase B, 3 for phase C, and 0 or blank for all phases.**



## 1.8.2 USING THE DEMO BOARD FOR ENERGY MEASUREMENTS

The 71M6534/6534H Demo Board was designed for use with current transformers (CT).

The Demo Board may immediately be used with current transformers having 2,000:1 winding ratio and is programmed for a Kh factor of 3.2 and (see Section 1.8.4 for adjusting the Demo Board for transformers with different turns ratio).

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 71M6534/6534H Demo Board is shipped with a pre-programmed scaling factor Kh of 3.2, i.e. 3.2Wh 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. The current transformers should be connected to the dual-pin headers on the bottom of the board. The connection is the same for single-ended or differential mode. See chapter 3.1 for proper jumper settings.

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:

$$Kh = IMAX * VMAX * 66.1782 / (In\_8 * WRATE * N_{ACC} * X) = 3.19902 \text{ Wh/pulse.}$$

The small deviation between the adjusted Kh of 3.19902 and the ideal Kh of 3.2 is covered by calibration. The default values used for the 71M6534/6534H Demo Board are:

|                          |      |                                       |
|--------------------------|------|---------------------------------------|
| <i>WRATE</i> :           | 171  |                                       |
| <i>IMAX</i> :            | 208  |                                       |
| <i>VMAX</i> :            | 600  |                                       |
| <i>In_8</i> :            | 1    | (controlled by <i>IA_SHUNT</i> = -15) |
| <i>N<sub>ACC</sub></i> : | 2520 |                                       |
| <i>X</i> :               | 6    |                                       |

### Explanation of factors used in the Kh calculation:

|                          |  |
|--------------------------|--|
| <i>WRATE</i> :           | The factor input by the user to determine Kh   |
| <i>IMAX</i> :            | The current input scaling factor, i.e. the input current generating 176.8mVrms at the IA/IB/IC input pins of the 71M6534. 176.8mV rms is equivalent to 250mV peak. |
| <i>VMAX</i> :            | The voltage input scaling factor, i.e. the voltage generating 176.8mVrms at the VA/VB/VC input pins of the 71M6534   |
| <i>In_8</i> :            | The setting for the additional ADC gain (8 or 1) determined by the CE register <i>IA_SHUNT</i>   |
| <i>N<sub>ACC</sub></i> : | The number of samples per accumulation interval, i.e. <i>PRE_SAMPS * SUM_CYCLES</i>  |
| <i>X</i> :               | The pulse rate control factor determined by the CE registers <i>PULSE_SLOW</i> and <i>PULSE_FAST</i>   |

Almost any desired Kh factor can be selected for the Demo Board by resolving the formula for *WRATE*:

$$WRATE = (IMAX * VMAX * 66.1782) / (Kh * In\_8 * N_{ACC} * X)$$

For the Kh of 3.2Wh, the value 171 (decimal) should be entered for *WRATE* at CE location 0x21 (using the CLI command `>]21=+171`).

## 1.8.4 ADJUSTING THE DEMO BOARDS TO DIFFERENT CURRENT TRANSFORMERS

The Demo Board is prepared for use with 2000:1 current transformers (CTs). This means that for the unmodified Demo Board, 208A on the primary side at 2000:1 ratio result in 104mA on the secondary side, causing 176.8mV at the 1.7 $\Omega$  resistor pairs R24/R25, R36/R37, R56/R57 (2 x 3.4 $\Omega$  in parallel).

In general, when  $IMAX$  is applied to the primary side of the CT, the voltage  $V_{in}$  at the IA, IB, or IC input of the 71M6534 IC is determined by the following formula:

$$V_{in} = R * I = R * IMAX/N$$

where N = transformer winding ratio, R = resistor on the secondary side

If, for example, if the current corresponding to  $IMAX = 208A$  is applied to a CT with a 2500:1 ratio, only 83.2mA will be generated on the secondary side, causing only 141mV of voltage drop.

The steps required to adapt a 71M6534 Demo Board to a transformer with a winding ratio of 2500:1 are outlined below:

- 1) The formula  $R_x = 176.8mV/(IMAX/N)$  is applied to calculate the new resistor  $R_x$ . We calculate  $R_x$  to 2.115 $\Omega$
- 2) **Changing the resistors R24/R25, R106/R107 to a combined resistance of 2.115 $\Omega$**  (for each pair) will cause the desired voltage drop of 176.8mV appearing at the IA, IB, or IC inputs of the 71M6534 IC.

Simply scaling  $IMAX$  is not recommended, since peak voltages at the 71M6534 inputs should always be in the range of 0 through  $\pm 250mV$  (equivalent to 176.8mV rms). If a CT with a much lower winding ratio than 1:2,000 is used, higher secondary currents will result, causing excessive voltages at the 71M6534 inputs. Conversely, CTs with much higher ratio will tend to decrease the useable signal voltage range at the 71M6534 inputs and may thus decrease resolution.

## 1.8.5 ADJUSTING THE DEMO BOARDS TO DIFFERENT VOLTAGE DIVIDERS

The 71M6534 Demo Board comes equipped with its own network of resistor dividers for voltage measurement mounted on the PCB. The resistor values are 2.5477M $\Omega$  (for channel A, R15-R21, R26-R31 combined) and 750 $\Omega$  (R32), resulting in a ratio ( $R_R$ ) 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 overvoltages. This choice need not be of concern, since the ADC in the 71M6534 has enough resolution, even when operating at 120Vrms.

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

In the following example we assume that the line voltage is not applied to the resistor divider for VA formed by R15-R21, R26-R31, 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 71M6534 is the desired 176.8mV,  $V_s$  is then given by:

$$V_s = R_R * 176.8mV$$

Resolving for  $R_R$ , we get:

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

This divider ratio can be implemented, for example, with a combination of one 16.95k $\Omega$  and one 100 $\Omega$  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 71M6534/6534H chips. 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 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 can 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.

A complete calibration procedure is 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 71M6534/6534H chip in order to make the chip apply the modified gains and phase shifts necessary for accurate operation. Table 1-5 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*) for phase A.

The command

```
>]11=4005
```

stores the hexadecimal value 0x4005 (decimal 16389) in the CE RAM location controlling the gain of the voltage channel for phase A (*CAL\_VA*).

| Constant   | CE Address (hex)     | Description  |
|--|----------------------|--|
| <i>CAL_VA</i><br><i>CAL_VB</i><br><i>CAL_VC</i>    | 0x11<br>0x13<br>0x15 | 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%. |
| <i>CAL_IA</i><br><i>CAL_IB</i><br><i>CAL_IC</i>    | 0x10<br>0x12<br>0x14 | 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%. |
| <i>PHADJ_A</i><br><i>PHADJ_B</i><br><i>PHADJ_C</i> | 0x18<br>0x19<br>0x1A | This constant controls the CT phase compensation. No compensation occurs when PHADJ=0. As PHADJ is increased, more compensation is introduced.   |

Table 1-5: CE RAM Locations for Calibration Constants

## 1.9.2 CALIBRATION MACRO FILE

The macro file in Figure 1-6 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.

```

CEO          /disable CE
]10=+16022   /CAL_IA (gain=CAL_IA/16384)
]11=+16381   /CAL_VA (gain=CAL_VA/16384)
]12=+16019   /CAL_IB (gain=CAL_IB/16384)
]13=+16370   /CAL_VB (gain=CAL_VB/16384)
]14=+15994   /CAL_IC (gain=CAL_IC/16384)
]15=+16376   /CAL_VC (gain=CAL_VC/16384)
]18=+115     /PHADJ_A (default 0)
]19=+113     /PHADJ_B (default 0)
]1A=+109     /PHADJ_C (default 0)
CE1         /enable CE

```

**Figure 1-6: Typical Calibration Macro File**

It is possible to send the calibration macro file to the 71M6534H 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 6534\_DEMO.HEX FILE

The *d\_merge* program updates the *6534\_demo.hex* file 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\_6534\_demo.hex* into *new\_6534\_demo.hex*, use the command:

```
d_merge old_6534_demo.hex macro.txt new_6534_demo.hex
```

The new hex file can be written to the 71M6534H through the ICE port using the ADM51 in-circuit emulator. This step makes the calibration to the meter permanent.

## 1.9.4 UPDATING CALIBRATION DATA IN FLASH MEMORY WITHOUT USING THE ICE OR A PROGRAMMER

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:

```
>]U
```

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.



**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 AUTOMATIC CALIBRATION (AUTO-CAL)

The Demo Code is able to perform a single-point fast automatic calibration, as described in section 2.2.3. This calibration is performed for channels A, B, and C only, not for the NEUTRAL channel. The steps required for the calibration are:

1. Enter operating values for voltage and current in I/O RAM. The voltage is entered at MPU address 0x10 (e.g. with the command )10=+2400 for 240V), the current is entered at 0x11 (e.g. with the command )11=+300 for 30A) and the duration measured in accumulation intervals is entered at 0x0F.
2. The operating voltage and current defined in step 1 must be applied at a zero degree phase angle to the meter (Demo Board).
3. The CLB (Begin Calibration) command must be entered via the serial interface. The operating voltage and current must be maintained accurately while the calibration is being performed.
4. The calibration procedure will automatically reset CE addresses used to store the calibration factors to their default values prior to starting the calibration. Automatic calibration also reads the chip temperature and enters it at the proper CE location temperature compensation.
5. CE addresses 0x10 to 0x15 and 0x18 to 0x1A will now show the new values determined by the auto-calibration procedure. These values can be stored in EEPROM by issuing the CLS command.



Tip: Current transformers of a given type usually have very similar phase angle for identical operating conditions. If the phase angle is accurately determined for one current transformer, the corresponding phase adjustment coefficient *PHADJ\_X* can be entered for all calibrated units.

## 1.9.6 LOADING THE 6534\_DEMO.HEX FILE INTO THE DEMO BOARD

**Hardware Interface for Programming:** The 71M6534/6534H 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 header J14. Production meters may be equipped with much simpler programming connectors, e.g. a 6x1 header.

Programming of the flash memory requires a specific in-circuit emulator, the ADM51 by Signum Systems (<http://www.signumsystems.com>) or the Flash Programmer (TFP-2) provided by TERIDIAN Semiconductor.

Chips may also be programmed before they are soldered to the board. The TGP1 gang programmer suitable for high-volume production is available from TERIDIAN. It must be equipped with LQFP-120 sockets.

**In-Circuit Emulator:** If firmware exists in the 71M6534/6534H flash memory; it has to be erased before loading a new file into memory. Figure 1-7 and Figure 1-8 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 ().

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 1-8 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 71M6534/6534H IC.

At this point, the emulator probe (cable) can be removed. Once the 71M6534/6534H IC is reset using the reset button on the Demo Board, the new code starts executing.

**Flash Programmer Module (TFP-2):** Follow the instructions given in the User Manual for the TFP-2.

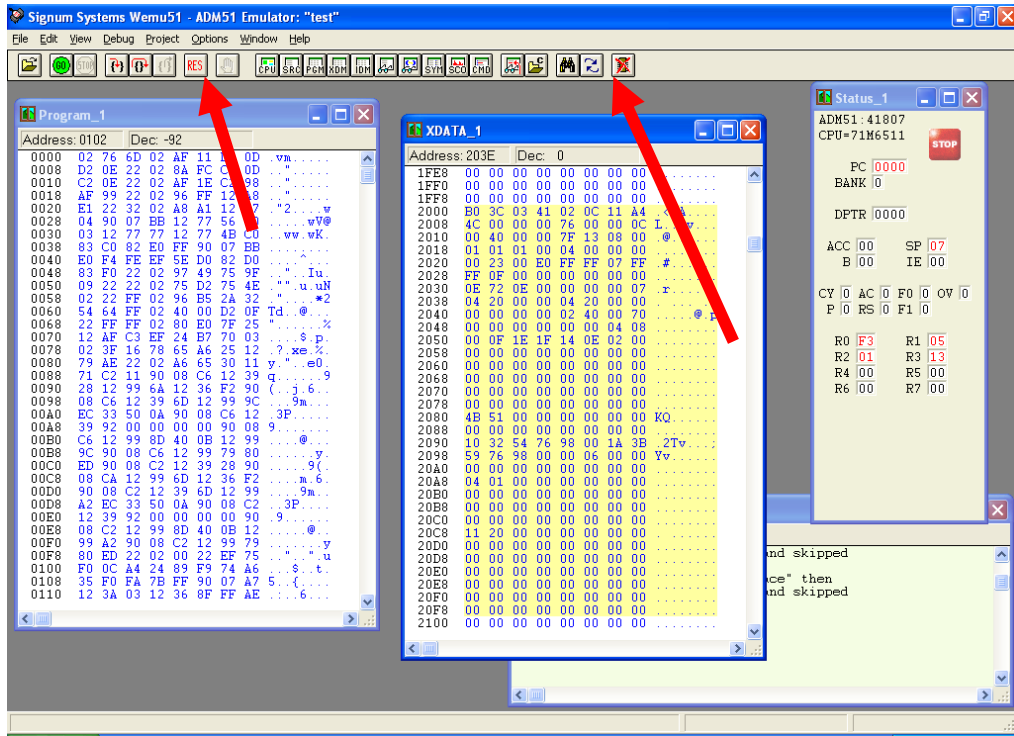


Figure 1-7: Emulator Window Showing Reset and Erase Buttons (see Arrows)

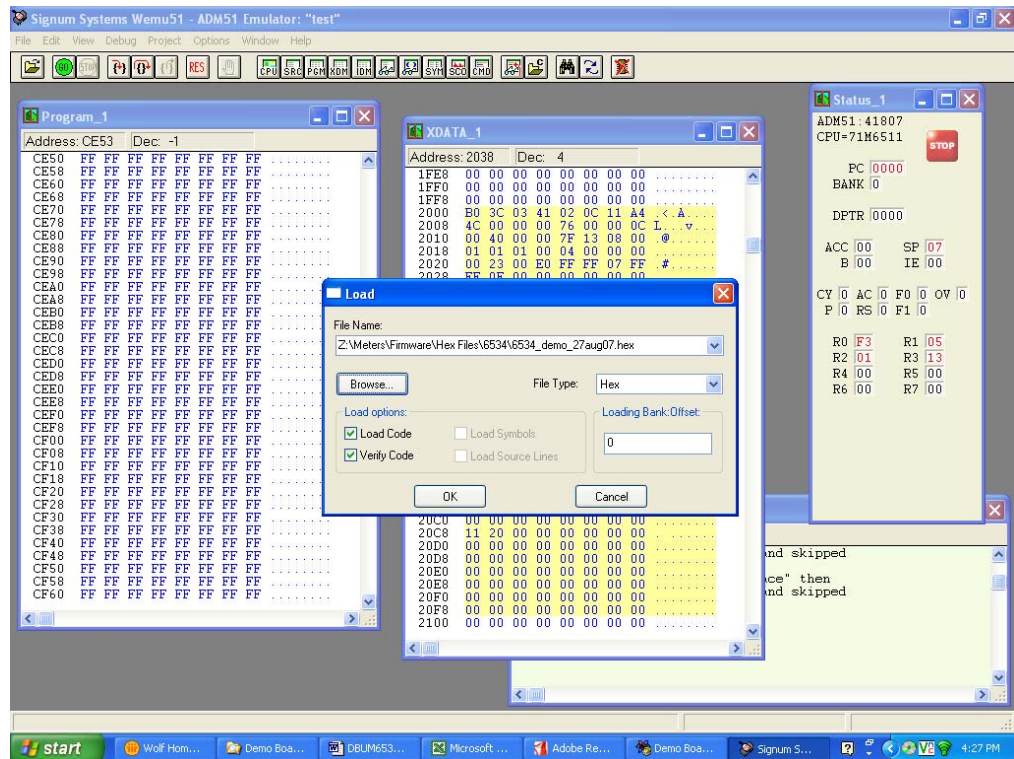


Figure 1-8: Emulator Window Showing Erased Flash Memory and File Load Menu



## 1.9.7 THE PROGRAMMING INTERFACE OF THE 71M6534/6534H

### Flash Downloader/ICE Interface Signals

The signals listed in Table 1-6 are necessary for communication between the Flash Downloader or ICE and the 71M6534/6534H.

| Signal | Direction                  | Function   |
|--------|----------------------------|--|
| E_TCLK | Output from 71M6534/6534H  | Data clock   |
| E_RXTX | Bi-directional             | Data input/output  |
| E_RST  | Input to the 71M6534/6534H | Flash Downloader Reset (active low)  |
| ICE_E  | Input to the 71M6534/6534H | Enable signal for the ICE interface. Must be high for all emulation or programming operations. |

**Table 1-6: Flash Programming Interface Signals**



The other signals accessible at the emulator interface connector J14 (E\_TBUS[0]-E\_TBUS[3], E\_ISYNC) can be used for an optional trace debugger.

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 revision 4.6q or later in the 71M6534 or 71M6534H 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 TERIDIAN representative or FAE for the latest revision.

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 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 IMPORTANT DEMO CODE MPU PARAMETERS

In the Demo Code, certain MPU **XRAM** parameters have been given fixed addresses in order to permit easy external access. These variables can be read via the serial interface, as described in section 1.7.1, 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. Default values are the values assigned by the Demo Code on start-up.

All MPU Input Parameters are loaded by the MPU at startup and should not need adjustment during meter calibration.

### MPU Input Parameters for Metering

| XRAM Word Address | Default Value | Name              | Description  |
|-------------------|---------------|-------------------|--|
| 0x00              | 433199        | <i>ITHRSHLDA</i>  | <p>For each element, if <i>WSUM_X</i> or <i>VARSUM_X</i> of that element exceeds <i>WCREEP_THR</i>, the sample values for that element are not zeroed. Otherwise, the accumulators for Wh, VARh, and VAh are not updated and the instantaneous value of IRMS for that element is zeroed.</p> $LSB = \sqrt{I0SQSUM} \cdot 2^{16}$ <p>The default value is equivalent to 0.08A. Setting <i>ITHRSHLDA</i> to zero disables creep control.</p> |
| 0x01              | 0             | <i>CONFIG</i>     | <p>Bit 0: Sets VA calculation mode.</p> <p>0: <math>V_{RMS} \cdot A_{RMS}</math>    1: <math>\sqrt{W^2 + VAR^2}</math></p> <p>Bit 1: Clears accumulators for Wh, VARh, and VAh. This bit need not be reset.</p>  |
| 0x02              | 764569660     | <i>PK_VTHR</i>    | <p>When the voltage exceeds this value, bit 5 in the MPU status word is set, and the MPU might choose to log a warning. Event logs are not implemented in Demo Code.</p> $LSB = \sqrt{V0SQSUM} \cdot 2^{16}$ <p>The default value is equivalent to 20% above 240Vrms.</p>  |
| 0x03              | 275652520     | <i>PK_ITHR</i>    | <p>When the current exceeds this value, bit 6 in the MPU status word is set, and the MPU might choose to log a warning. Event logs are not implemented in Demo Code.</p> $LSB = \sqrt{I0SQSUM} \cdot 2^{16}$ <p>The default value is equivalent to 20% above <math>30A_{RMS}</math>.</p>   |
| 0x04              | 0             | <i>Y_CAL_DEG0</i> | RTC adjust, 100ppb. Read only at reset in demo code.   |
| 0x05              | 0             | <i>Y_CAL_DEG1</i> | RTC adjust, linear by temperature, 10ppb*ΔT, in 0.1°C. Provided for optional code.   |
| 0x06              | 0             | <i>Y_CAL_DEG2</i> | RTC adjust, squared by temperature, 1ppb*ΔT <sup>2</sup> , in 0.1°C. Provided for optional code.   |

| XRAM Word Address | Default Value | Name               | Description   |
|-------------------|---------------|--------------------|---|
| 0x07              | 0             | <i>PULSEW_SRC</i>  | This address contains a number that points to the selected pulse source for the Wh output. Selectable pulse sources are listed in Table 1-8.  |
| 0x08              | 4             | <i>PULSER_SRC</i>  | This address contains a number that points to the selected pulse source for the VARh output. Selectable pulse sources are listed in Table 1-8.  |
| 0x09              | 6000          | <i>VMAX</i>        | The nominal external RMS voltage that corresponds to 250mV peak at the ADC input. The meter uses this value to convert internal quantities to external. LSB=0.1V                                      |
| 0x0A              | 2080          | <i>IMAX</i>        | The nominal external RMS current that corresponds to 250mV peak at the ADC input for channel A. The meter uses this value to convert internal quantities to external. LSB=0.1A                        |
| 0x0B              | 0             | <i>PPMC</i>        | PPM/C*26.84. Linear temperature compensation. A positive value will cause the meter to run faster when hot. This is applied to both V and I and will therefore have a double effect on products.      |
| 0x0C              | 0             | <i>PPMC2</i>       | PPM/C <sup>2</sup> *1374. Square law compensation. A positive value will cause the meter to run faster when hot. This is applied to both V and I and will therefore have a double effect on products. |
| 0x0D              |               | <i>PULSEX_SRC</i>  | This address contains a number that points to the selected pulse source for the XPULSE output. Selectable pulse sources are listed in Table 1-8.  |
| 0x0E              |               | <i>PULSEY_SRC</i>  | This address contains a number that points to the selected pulse source for the YPULSE output. Selectable pulse sources are listed in Table 1-8.  |
| 0x0F              | 2             | <i>SCAL</i>        | Count of accumulation intervals for auto-calibration.   |
| 0x10              | 2400          | <i>VCAL</i>        | Applied voltage for auto-calibration. LSB = 0.1V rms of AC signal applied to all elements during calibration.   |
| 0x11              | 300           | <i>ICAL</i>        | Applied current for auto-calibration. LSB = 0.1A rms of AC signal applied to all elements during calibration. Power factor must be 1.   |
| 0x12              | 75087832      | <i>VTHRSHLD</i>    | Voltage to be used for creep detection, measuring frequency, zero crossing, etc.  |
| 0x13              | 50            | <i>PULSE_WIDTH</i> | Pulse width in $\mu\text{s} = (2 * \text{PulseWidth} + 1) * 397$ . 0xFF disables this feature. Takes effect only at start-up.   |
| 0x14              | --            | <i>TEMP_NOM</i>    | Nominal (reference) temperature, i.e. the temperature at which calibration occurred. LSB = Units of <i>TEMP_RAW</i> , from CE.  |
| 0x15              | --            | <i>NCOUNT</i>      | The count of accumulation intervals that the neutral current must be above <i>INTHRSHLD</i> required to set the "excess neutral" error bit.   |
| 0x16              | --            | <i>INTHRSHLD</i>   | The neutral current threshold.<br>$LSB = \sqrt{I_x S Q S U M} \cdot 2^{16}$   |

**Table 1-7: MPU Input Parameters for Metering**

Any of the values listed in Table 1-8 can be selected for as a source for PULSEW and PULSER. The designation “source\_I” refers to values imported by the consumer; “source\_E” refers to energy exported by the consumer (energy generation).

| Number | Pulse Source   | Description                   | Number | Pulse Source     | Description                           |
|--------|----------------|-------------------------------|--------|------------------|---------------------------------------|
| 0      | <i>WSUM</i>    | <b>Default for PULSEW_SRC</b> | 18     | <i>VA2SUM</i>    |                                       |
| 1      | <i>WOSUM</i>   |                               | 19     | <i>WSUM_I</i>    | Sum of imported real energy           |
| 2      | <i>W1SUM</i>   |                               | 20     | <i>WOSUM_I</i>   | Imported real energy on element A     |
| 3      | <i>W2SUM</i>   |                               | 21     | <i>W1SUM_I</i>   | Imported real energy on element B     |
| 4      | <i>VARSUM</i>  | <b>Default for PULSER_SRC</b> | 22     | <i>W2SUM_I</i>   | Imported real energy on element C     |
| 5      | <i>VAROSUM</i> |                               | 23     | <i>VARSUM_I</i>  | Sum of imported reactive energy       |
| 6      | <i>VAR1SUM</i> |                               | 24     | <i>VAROSUM_I</i> | Imported reactive energy on element A |
| 7      | <i>VAR2SUM</i> |                               | 25     | <i>VAR1SUM_I</i> | Imported reactive energy on element B |
| 8      | <i>I0SQSUM</i> |                               | 26     | <i>VAR2SUM_I</i> | Imported reactive energy on element C |
| 9      | <i>I1SQSUM</i> |                               | 27     | <i>WSUM_E</i>    | Sum of exported real energy           |
| 10     | <i>I2SQSUM</i> |                               | 28     | <i>WOSUM_E</i>   | Exported real energy on element A     |
| 11     | <i>INSQSUM</i> |                               | 29     | <i>W1SUM_E</i>   | Exported real energy on element B     |
| 12     | <i>V0SQSUM</i> |                               | 30     | <i>W2SUM_E</i>   | Exported real energy on element C     |
| 13     | <i>V1SQSUM</i> |                               | 31     | <i>VARSUM_E</i>  | Sum of exported reactive energy       |
| 14     | <i>V2SQSUM</i> |                               | 32     | <i>VAROSUM_E</i> | Exported reactive energy on element A |
| 15     | <i>VASUM</i>   |                               | 33     | <i>VAR1SUM_E</i> | Exported reactive energy on element B |
| 16     | <i>VAOSUM</i>  |                               | 34     | <i>VAR2SUM_E</i> | Exported reactive energy on element C |
| 17     | <i>VA1SUM</i>  |                               |        |                  |                                       |

**Table 1-8: Selectable Pulse Sources**

#### MPU INSTANTANEOUS OUTPUT VARIABLES

The Demo Code processes CE outputs after each accumulation interval. It calculates instantaneous values such as VRMS, IRMS, W and VA as well as accumulated values such as Wh, VARh, and VAh. Table 1-9 lists the calculated instantaneous values.

| XRAM Word Address    | Name                                 | DESCRIPTION  |
|----------------------|--------------------------------------|--|
| 0x24<br>0x26<br>0x28 | Vrms_A<br>Vrms_B*<br>Vrms_C          | $V_{rms}$ from element 0, 1, 2.<br>$LSB = \sqrt{V_x S Q S U M} \cdot 2^{16}$                                       |
| 0x25<br>0x27<br>0x29 | Irms_A<br>Irms_B<br>Irms_C<br>Irms_N | $I_{rms}$ from element 0, 1, 2 or neutral<br>$LSB = \sqrt{I_x S Q S U M} \cdot 2^{16}$                             |
| 0x20                 | Delta_T                              | Deviation from Calibration (reference) temperature.<br>LSB = 0.1 °C.   |
| 0x21                 | Frequency                            | Frequency of voltage selected by CE input. If the selected voltage is below the sag threshold, Frequency=0. LSB Hz |

Table 1-9: MPU Instantaneous Output Variables

**MPU STATUS WORD**

The MPU maintains the status of certain meter and I/O related variables in the Status Word. The Status Word is located at address 0x21. The bit assignments are listed in Table 1-10.

| Status Word Bit | Name             | DESCRIPTION   |
|-----------------|------------------|---|
| 0               | <i>CREEP</i>     | Indicates that all elements are in creep mode. The CE's pulse variables will be "jammed" with a constant value on every accumulation interval to prevent spurious pulses. Note that creep mode therefore halts pulsing even when the CE's pulse mode is "internal".   |
| 1               | <i>MINVC</i>     | Element C has a voltage below VThrshld. This forces that element into creep mode.   |
| 2               | <i>PB_PRESS</i>  | A push button press was recorded at the most recent reset or wake from a battery mode.  |
| 3               | <i>SPURIOUS</i>  | An unexpected interrupt was detected.   |
| 4               | <i>MINVB</i>     | Element B has a voltage below VThrshld. This forces that element into creep mode.   |
| 5               | <i>MAXVA</i>     | Element A has a voltage above VThrshldP.  |
| 6               | <i>MAXVB</i>     | Element B has a voltage above VThrshldP.  |
| 7               | <i>MAXVC</i>     | Element C has a voltage above VThrshldP.  |
| 8               | <i>MINVA</i>     | Element A has a voltage below VThrshld. This forces that element into creep mode. It also forces the frequency and main edge count to zero.   |
| 9               | <i>WD_DETECT</i> | The most recent reset was a watchdog reset. This usually indicates a software error.  |
| 10              | <i>MAXIN</i>     | The neutral current is over INThrshld. In a real meter this could indicate faulty distribution or tampering.  |
| 11              | <i>MAXIA</i>     | The current of element A is over IThrshld. In a real meter this could indicate overload.  |
| 12              | <i>MAXIB</i>     | The current of element B is over IThrshld. In a real meter this could indicate overload.  |
| 13              | <i>MAXIC</i>     | The current of element C is over IThrshld. In a real meter this could indicate overload.  |
| 14              | <i>MINT</i>      | The temperature is below the minimum, -40C, established in option_gbl.h. This is not very accurate in the demo code, because the calibration temperature is usually poorly controlled, and the default temp_nom is usually many degrees off. -40C is the minimum recommended operating temperature of the chip. |

| Status Word Bit | Name                | DESCRIPTION  |
|-----------------|---------------------|--|
| 15              | <i>MAXT</i>         | The temperature is above the maximum, 85C, established in option_gbl.h. This is not very accurate in the demo code, because the calibration temperature is usually poorly controlled, and the default temp_nom is usually many degrees off. 85C is the maximum recommended operating temperature of the chip.  |
| 16              | <i>BATTERY_BAD</i>  | 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.  |
| 17              | <i>CLOCK_TAMPER</i> | Clock set to a new value more than two hours from the previous value.  |
| 18              | <i>CAL_BAD</i>      | Set after reset when the read of the calibration data has a bad longitudinal redundancy check or read failure.   |
| 19              | <i>CLOCK_UNSET</i>  | Set when the clock's current reading is A) More than a year after the previously saved reading, or B) Earlier than the previously saved reading, or C) There is no previously saved reading.   |
| 20              | <i>POWER_BAD</i>    | Set after reset when the read of the power register data has a bad longitudinal redundancy check or read failure in both copies. Two copies are used because a power failure can occur while one of the copies is being updated.   |
| 21              | <i>GNDNEUTRAL</i>   | Indicates that a grounded neutral was detected.  |
| 22              | <i>TAMPER</i>       | Tamper was detected †**  |
| 23              | <i>SOFTWARE</i>     | A software defect was detected.  |
| 25              | <i>SAGA</i>         | Element A has a sag condition. This bit is set in real time by the CE and detected by the ce_busy interrupt (ce_busy_isr() in ce.c) within 8 sample intervals, about 2.6ms. A transition from normal operation to SAGA causes the power registers to be saved, because the demo PCB is powered from element A. |
| 26              | <i>SAGB</i>         | Element B has a sag condition. This bit is set in real time by the CE and detected by the ce_busy interrupt (ce_busy_isr() in ce.c) within 8 sample intervals, about 2.6ms.  |
| 27              | <i>SAGC†</i>        | Element C has a sag condition. See the description of the other sag bits.  |
| 28              | <i>F0_CE</i>        | A square wave at the line frequency, with a jitter of up to 8 sample intervals, about 2.6ms.   |
| 31              | <i>ONE_SEC</i>      | Changes each accumulation interval.  |

Table 1-10: MPU Status Word Bit Assignment

## MPU ACCUMULATION OUTPUT VARIABLES

Accumulation values are accumulated from XFER cycle to XFER cycle (see Table 1-11). They are organized as two 32-bit registers. The first register stores the decimal number displayed on the LCD. For example, if the LCD shows "001.004", the value in the first register is 1004. This register wraps around after the value 999999 is reached. The second register holds fractions of the accumulated energy, with an LSB of  $9.4045 \times 10^{-13} \times V_{MAX} \times I_{MAX} \times I_{n\_8}$  Wh.

The MPU accumulation registers always hold positive values.

The CLI commands with two question marks, e.g. )39?? should be used to read the variables.

| XRAM Word Address | Name           | Description   |
|-------------------|----------------|---|
| 0x2C              | <i>Whi</i>     | Total Watt hours consumed (imported)                            |
| 0x44              | <i>Whe</i>     | Total Watt hours generated (exported)                           |
| 0x34              | <i>VARhi</i>   | Total VAR hours consumed  |
| 0x4C              | <i>VARhe</i>   | Total VAR hours generated (inverse consumed)                    |
| 0x3C              | <i>VAh</i>     | Total VA hours  |
| 0x2E              | <i>Whi_A</i>   | Total Watt hours consumed through element 0                     |
| 0x46              | <i>Whe_A</i>   | Total Watt hours generated (inverse consumed) through element 0 |
| 0x36              | <i>VARhi_A</i> | Total VAR hours consumed through element 0                      |
| 0x4E              | <i>VARhe_A</i> | Total VAR hours generated (inverse consumed) through element 0  |
| 0x3E              | <i>VAh_A</i>   | Total VA hours in element 0                                     |
| 0x30              | <i>Whi_B</i>   | Total Watt hours consumed through element 1                     |
| 0x48              | <i>Whe_B</i>   | Total Watt hours generated (inverse consumed) through element 1 |
| 0x38              | <i>VARhi_B</i> | Total VAR hours consumed through element 1                      |
| 0x50              | <i>VARhe_B</i> | Total VAR hours generated (inverse consumed) through element 1  |
| 0x40              | <i>Vah_B</i>   | Total VA hours in element 1                                     |
| 0x32              | <i>Whi_C</i>   | Total Watt hours consumed through element 2                     |
| 0x4A              | <i>Whe_C</i>   | Total Watt hours generated (inverse consumed) through element 2 |
| 0x3A              | <i>VARhi_C</i> | Total VAR hours consumed through element 2                      |
| 0x52              | <i>VARhe_C</i> | Total VAR hours generated (inverse consumed) through element 2  |
| 0x42              | <i>VAh_C</i>   | Total VA hours in element 2                                     |

**Table 1-11: MPU Accumulation Output Variables**

### 1.10.3 USEFUL CLI COMMANDS INVOLVING THE MPU AND CE

Table 1-12 shows a few essential commands involving MPU data memory.

| Command  | Description  |
|----------|--|
| )1=2     | Clears the accumulators for Wh, VARh, and VAh by setting bit 1 of the <i>CONFIG</i> register.  |
| )A=+2080 | Applies the value 208A to the IMAx register  |
| )9=+6000 | Applies the value 600V to the VMAx register  |
| )2F??    | Displays the total accumulated imported Wh energy  |
| MR2.1    | Displays the current RMS voltage in phase A  |
| MR1.2    | Displays the current RMS current in phase B  |
| RI5=26   | Disables the emulator clock by setting bit 5 in I/O RAM address 0x05. This command will disable emulator/programmer access to the 71M6534.   |
| RI5=6    | Re-enables the emulator clock by clearing bit 5 in I/O RAM address 0x05.   |
| ]U       | Stores the current CE RAM variables in EEPROM memory. The variables stored in flash memory will be applied by the MPU at the next reset or power-up if no valid data is available from the EEPROM. |

Table 1-12: CLI Commands for MPU Data Memory

## 1.11 USING THE ICE (IN-CIRCUIT EMULATOR)

The ADM51 ICE by Signum Systems ([www.signum.com](http://www.signum.com)) can be used to erase the flash memory, load code and debug firmware. Before using the ICE, the latest WEMU51 application program should be downloaded from the Signum website and installed.

**It is very important to create a new project and selecting the TERIDIAN 71M6534 IC in the project dialog when starting a 6534-based design. Using the ICE with project settings copied from a 6521 or 651X designs will lead to erratic results.**

For details on installing the WEMU51 program and on creating a project, see the SUG 653X (Software Users' Guide).



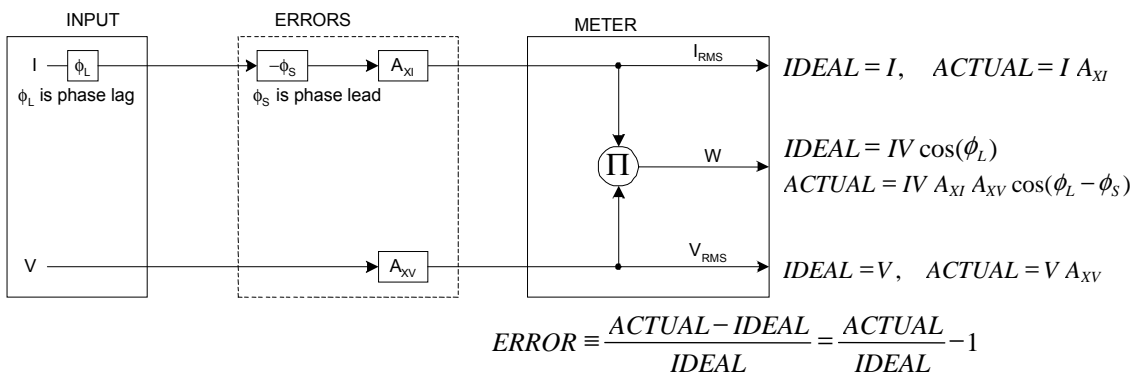


# 2

## 2 APPLICATION INFORMATION

### 2.1 CALIBRATION THEORY

A typical meter has phase and gain errors as shown by  $\phi_S$ ,  $A_{XI}$ , 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.

A fast method of calibration will also be introduced in section 2.1.3.

#### 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:  $CAL\_JA = 16384$ ,  $CAL\_VA = 16384$ ,  $PHADJA = 0$ .

From the voltage measurement, we determine that

$$1. \rightarrow A_{XV} = E_V + 1$$

We use the other two measurements to determine  $\phi_S$  and  $A_{XI}$ .

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

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

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

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

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

Combining 2a and 3a:

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

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

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

and from 2a:

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

Now that we know the  $A_{XV}$ ,  $A_{XI}$ , and  $\phi_S$  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  $\phi_S$ , the desired phase lag:

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

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.  $CAL\_IA = 16384$ ,  $CAL\_VA = 16384$ ,  $PHADJA = 0$ .

First, calculate  $A_{XV}$  from  $E_V$ :

$$1. \rightarrow A_{XV} = E_V + 1$$

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

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

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

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

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

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

Use above results along with  $E_{60}$  and  $E_{300}$  to calculate  $\phi_S$ .

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

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

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

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

Subtract 8 from 7

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

use equation 5:

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

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

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

Now that we know the  $A_{XV}$ ,  $A_{XI}$ , and  $\phi_s$  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  $\phi_s$ , 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.

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

### 2.1.3 FAST CALIBRATION

The calibration methods described so far require that the calibration system sequentially applies currents at various phase angles. A simpler approach is based on the calibration system applying a constant voltage and current at exactly zero degrees phase angle. This approach also requires much simpler mathematical operations.

Before starting the calibration process, the voltage and current calibration factors are set to unity (16384) and the phase compensation factors are set to zero.

During the calibration process, the meter measures for a given constant time, usually 30 seconds, and is then examined for its accumulated Wh and VARh energy values. Access to the internal accumulation registers is necessary for this method of calibration. The phase angle introduced by the voltage and/or current sensors is then simply determined by:

$$\phi = a \tan \frac{VARh}{Wh}$$

$CAL\_VA$  is determined by comparing the applied voltage to the measured voltage, or:

$$CAL\_VA = 16384 \cdot \frac{V_{applied}}{V_{measured}}$$

$CAL\_IA$  is determined by comparing applied real energy with the measured apparent energy (and compensating for the change applied to  $CAL\_VA$ ):

$$CAL\_IA = \frac{16384 \cdot Wh_{applied}}{VAh_{measured} \cdot CAL\_VA}$$

The derivation of these formulae is shown in the Appendix.

## 2.2 CALIBRATION PROCEDURES

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.

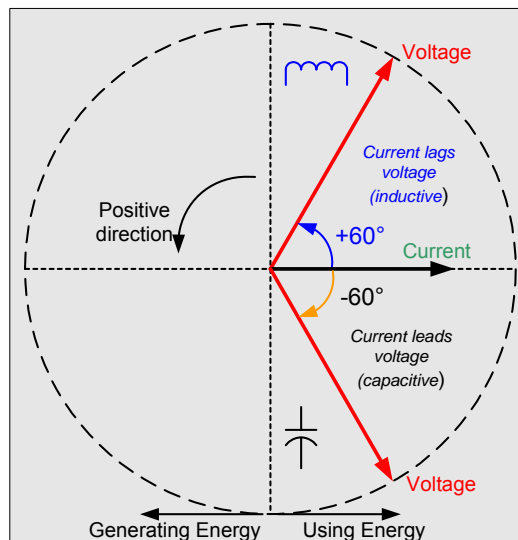


**It is essential for a valid meter calibration to have the voltage stabilized a few seconds before the current is applied. This enables the Demo Code to initialize the 71M6534/6534H and to stabilize the PLLs and filters in the CE. This method of operation is consistent with meter applications in the field as well as with metering standards.**

Each meter phase must be calibrated individually. 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).



**During calibration of any phase, a stable mains voltage has to be present on phase A. This enables the CE processing mechanism of the 71M6534/6534H necessary to obtain a stable calibration.**



**Figure 2-2: Phase Angle Definitions**

The calibration procedures described below should be followed after interfacing the voltage and current sensors to the 71M6534/6534H 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 71M6534/6534H, is scaled to be less than 250mV (peak).

## 2.2.1 CALIBRATION PROCEDURE WITH THREE MEASUREMENTS

The calibration procedure is as follows:

- 1) All calibration factors are reset to their default values, i.e. CAL\_IA = CAL\_VA = 16384, and PHADJ\_A = 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  $A_{xv}$  is determined as
$$A_{xv} = (V_{actual} - V_{ideal}) / V_{ideal}$$
- 3) Apply the nominal load current at phase angles  $0^\circ$  and  $60^\circ$ , measure the Wh energy and record the errors  $E_0$  AND  $E_{60}$ .
- 4) Calculate the new calibration factors CAL\_IA, CAL\_VA, and PHADJ\_A, 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\_IA, CAL\_VA, and PHADJ\_A 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\_IA, CAL\_VA, and PHADJ\_A in the flash memory of the meter. If the calibration is performed on a TERIDIAN Demo Board, the methods shown in sections 1.9.3 and 1.9.4 can be used.
- 8) Repeat the steps 1 through 7 for each phase.
- 9) For added temperature compensation, read the value in CE RAM location 0x54 and write it to CE RAM location 0x11. This will automatically calculate the correction coefficients PPMC and PPMC2 from the nominal temperature entered in CE location 0x11 and from the characterization data contained in the on-chip fuses.



**Tip: Step 2 and the energy measurement at  $0^\circ$  of step 3 can be combined into one step.**

## 2.2.2 CALIBRATION PROCEDURE WITH FIVE MEASUREMENTS

The calibration procedure is as follows:

- 1) All calibration factors are reset to their default values, i.e. CAL\_IA = CAL\_VA = 16384, and PHADJ\_A = 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  $0^\circ$ ,  $60^\circ$ ,  $180^\circ$  and  $-60^\circ$  ( $-300^\circ$ ). 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\_IA, CAL\_VA, and PHADJ\_A, 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\_IA, CAL\_VA, and PHADJ\_A 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\_IA, CAL\_VA, and PHADJ\_A in the flash memory of the meter. If a Demo Board is calibrated, the methods shown in sections 1.9.3 and 1.9.4 can be used.
- 8) Repeat the steps 1 through 7 for each phase.
- 9) For added temperature compensation, read the value in CE RAM location 0x54 and write it to CE RAM location 0x11. This will automatically calculate the correction coefficients PPMC and PPMC2 from the nominal temperature entered in CE location 0x11 and from the characterization data contained in the on-chip fuses.



**Tip:** Step 2 and the energy measurement at  $0^\circ$  of step 3 can be combined into one step.

## 2.2.3 FAST CALIBRATION – AUTO-CALIBRATION

The fast calibration procedure is supported by the Demo Code when the Auto-Cal function is executed. This procedure requires the following steps:

- 1) Establish load voltage and current from the calibration system. The load angle must be exactly 0.00 degrees.
- 2) Enter the expected voltage and current using CLI commands. For example, to calibrate for 240V, 30A for two seconds, enter `) F=2=+2400=+300`.
- 3) Issue the CLI command `CLB`.
- 4) Wait the specified number of seconds.

Check the calibration factors established by the automatic procedure.

## 2.2.4 CALIBRATION PROCEDURE FOR ROGOWSKI COIL SENSORS

Demo Code containing CE code that is compatible with Rogowski coils is available from TERIDIAN Semiconductor.

Rogowski coils generate a signal that is the derivative of the current. The CE code implemented in the Rogowski CE image digitally compensates for this effect and has the usual gain and phase calibration adjustments. Additionally, calibration adjustments are provided to eliminate voltage coupling from the sensor input.

Current sensors built from Rogowski coils have relatively high output impedance that is susceptible to capacitive coupling from the large voltages present in the meter. The most dominant coupling is usually capacitance between the primary of the coil and the coil's output. This coupling adds a component proportional to the derivative of voltage to the sensor output. This effect is compensated by the voltage coupling calibration coefficients.

As with the CT procedure, the calibration procedure for Rogowski sensors uses the meter's display to calibrate the voltage path and the pulse outputs to perform the remaining energy calibrations. The calibration procedure must be done to each phase separately, making sure that the pulse generator is driven by the accumulated real energy for just that phase. In other words, the pulse generator input should be set to WhA, WhB, or WhC, depending on the phase being calibrated.

In preparation of the calibration, all calibration parameters are set to their default values. *VMAX* and *IMAX* are set to reflect the system design parameters. *WRATE* and *PULSE\_SLOW*, *PULSE\_FAST* are adjusted to obtain the desired Kh.

**Step 1: Basic Calibration:** After making sure *VFEED\_A*, *VFEED\_B*, and *VFEED\_C* are zero, perform either the three measurement procedure (2.2.1) or the five measurement calibration procedure (2.2.2) described in the CT section. Perform the procedure at a current large enough that energy readings are immune from voltage coupling effects.

The one exception to the CT procedure is the equation for PHADJ—after the phase error,  $\phi_s$ , has been calculated, use the PHADJ equation shown below. Note that the default value of PHADJ is not zero, but rather -3973.

$$PHADJ = PHADJ_{PREVIOUS} - \phi_s 1786 \frac{50}{f_0}$$

If voltage coupling at low currents is introducing unacceptable errors, perform step 2 below to select non-zero values for *VFEED\_A*, *VFEED\_B*, and *VFEED\_C*.

**Step 2: Voltage Cancellation:** Select a small current,  $I_{RMS}$ , where voltage coupling introduces at least 1.5% energy error. At this current, measure the errors  $E_0$  and  $E_{180}$  to determine the coefficient *VFEED*.

$$VFEED = \frac{E_0 - E_{180}}{2} 2^{25} \frac{I_{RMS} V_{MAX}}{I_{MAX} V_{RMS}} - VFEED_{PREVIOUS}$$



## 2.2.5 CALIBRATION SPREADSHEETS

Calibration spreadsheets are available from TERIDIAN Semiconductor. They are also included in the CD-ROM shipped with any Demo Kit. Figure 2-3 shows the spreadsheet for three measurements. Figure 2-4 shows the spreadsheet for five measurements with three phases.

For CT and shunt 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 PHADJ\_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).

A spreadsheet is also available for Rogowski coil calibration (see Figure 2-5). Data entry is as follows:

1. All nominal values are entered in the fields of step one.
2. The applied voltage is entered in the yellow field labeled "Input Voltage Applied" of step 2. The entered value will automatically show in the green fields of the two other channels.
3. After measuring the voltages displayed by the meter, these are entered in the yellow fields labeled "Measured Voltage". The spreadsheet will show the calculated calibration factors for voltage in the green fields labeled "CAL\_Vx".
4. The default values (-3973) for PHADJ\_x are entered in the yellow fields of step 3. If the calibration factors for the current are not at default, their values are entered in the fields labeled "Old CAL\_Ix".
5. The errors of the energy measurements at 0°, 60°, -60°, and 180° are entered in the yellow fields labeled "% Error ...". The spreadsheet will then display phase error, the current calibration factor and the PHADJ\_x factor in the green fields, one for each phase.
6. If a crosstalk measurement is necessary, it should be performed at a low current, where the effects of crosstalk are noticeable. First, if (old) values for VFEEDx exist in the meter, they are entered in the spreadsheet in the row labeled "Old VFEEDx", one for each phase. If these factors are zero, "0" is entered for each phase.
7. Test current and test voltage are entered in the yellow fields labeled VRMS and IRMS.
8. The crosstalk measurement is now conducted at a low current with phase angles of 0° and 180°, and the percentage errors are entered in the yellow fields labeled "% error, 0 deg" and "% error, 180 deg", one pair of values for each phase. The resulting VFEEDx factors are then displayed in the green fields labeled VFEEDx.

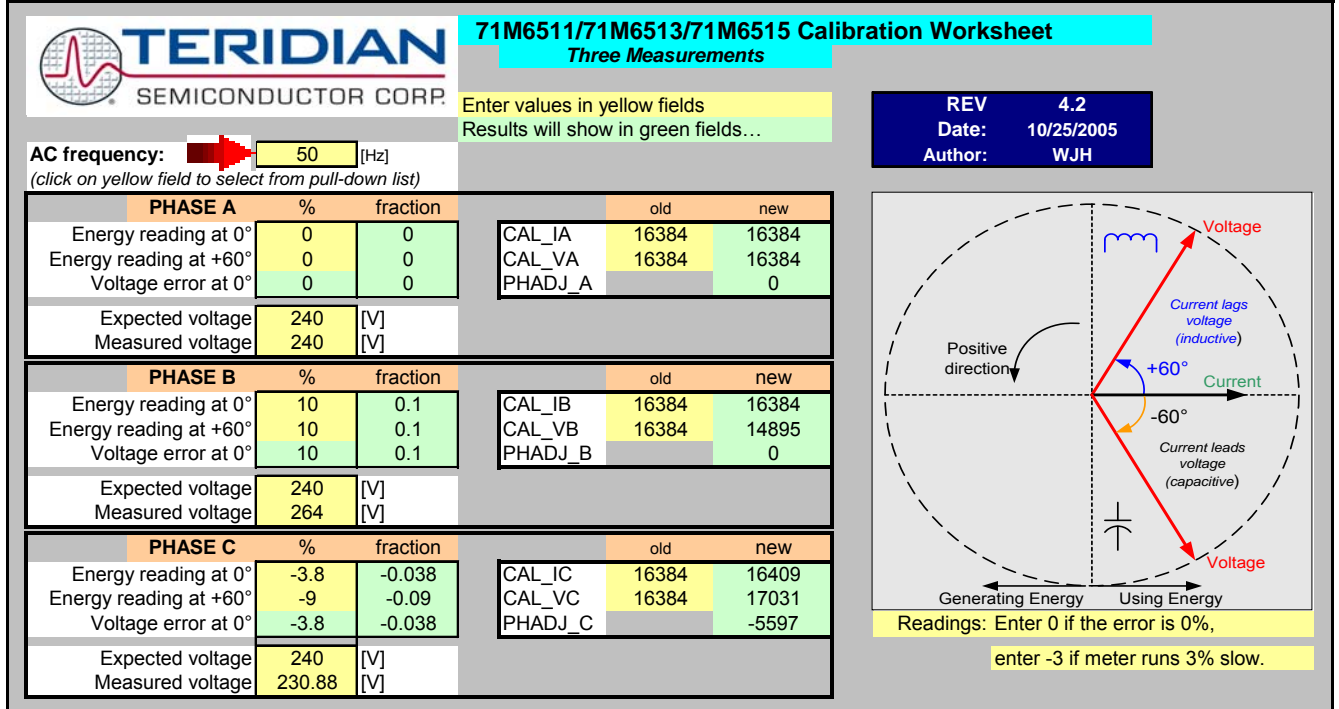


Figure 2-3: Calibration Spreadsheet for Three Measurements

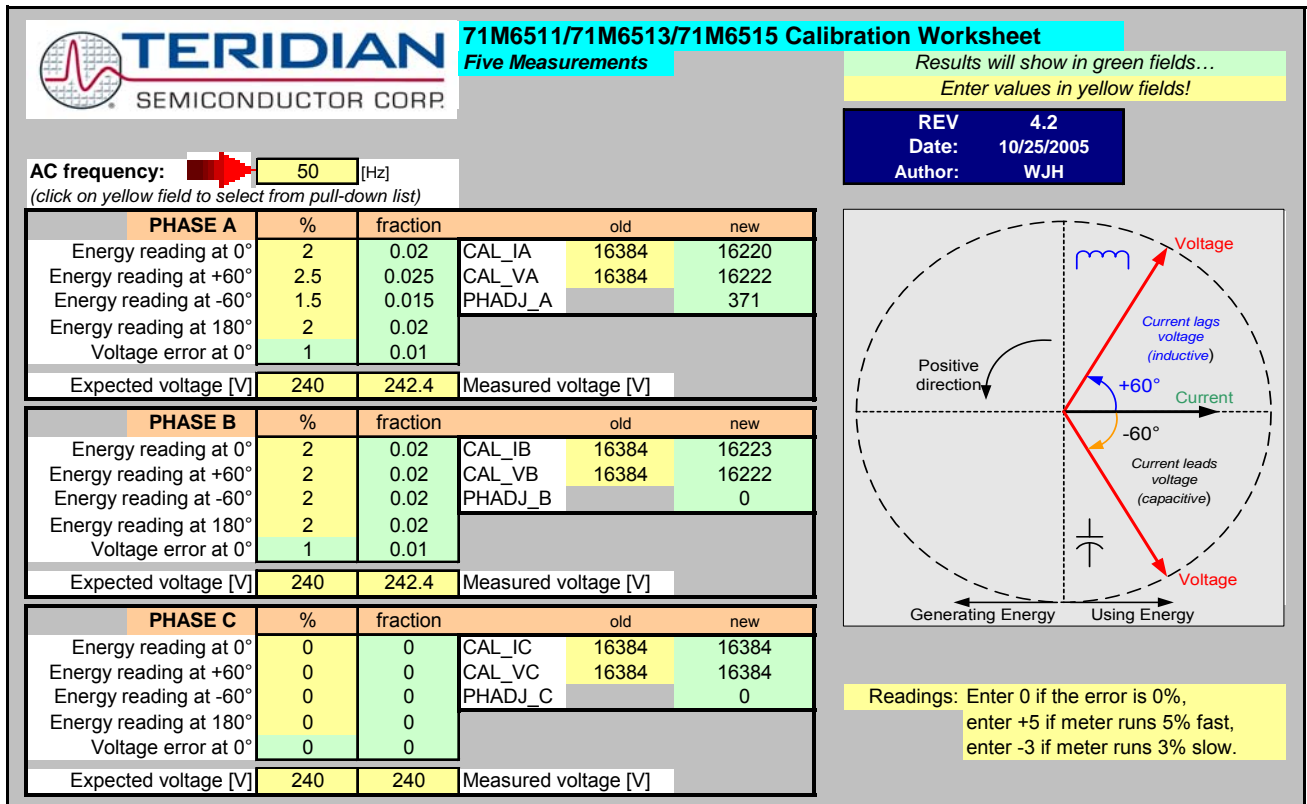


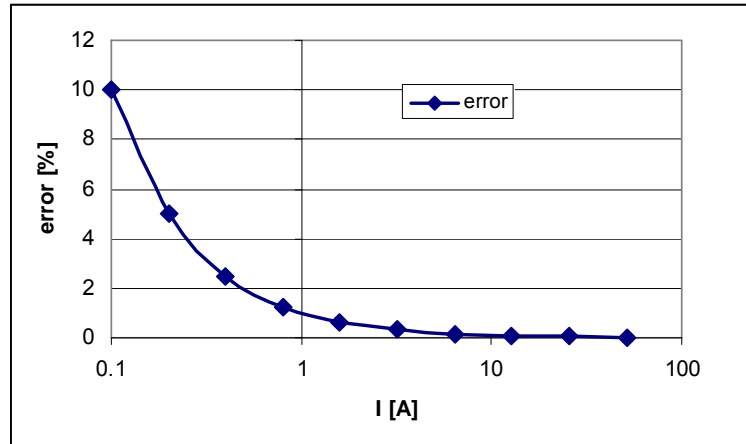
Figure 2-4: Calibration Spreadsheet for Five Measurements

| Calibration Procedure for Rogowski Coils  |           |                             |                  |
|---|-----------|-----------------------------|------------------|
| Enter values in yellow fields!<br>Results will show in green fields...  |           |                             |                  |
| <b>Step 1: Enter Nominal Values:</b>  |           |                             |                  |
| Nominal CAL_V   | 16384     | Resulting Nominal           | REV 4.3          |
| Nominal CAL_I   | 16384     | Values: X                   | Date: 11/18/2005 |
| PHADJ   | -3973     | Kh (Wh)                     | Author: WJH      |
| WRATE   | 179       | Angle Sensitivity (deg/LSB) |                  |
| VMAX  | 600       | 50Hz                        | 5.60E-04         |
| Calibration Frequency [Hz]  | 50        |                             |                  |
| IMAX (incl. ISHUNT)   | 30.000    |                             |                  |
| PULSE_FAST  | -1        |                             |                  |
| PULSE_SLOW  | -1        |                             |                  |
| NACC  | 2520      |                             |                  |
| <b>Step 2: VRMS Calibration:</b>  |           |                             |                  |
|   |           | Phase A                     | Phase B          |
| Enter old CAL_VA  | 16384     | 16384                       | 16384            |
| Input Voltage Applied   | 240       | 240                         | 240              |
| Measured Voltage  | 235.612   | 236.55                      | 234.72           |
| CAL_Vx  | 16689     | 16623                       | 16753            |
| <b>Step 3: Current Gain and Phase Calibration</b>   |           |                             |                  |
|   |           | Deg/ct 5.60E-04             |                  |
|   |           | Phase A                     | Phase B          |
| old PHADJ   | -3973     | -3973                       | -3973            |
| Old CAL_Ix  | 16384     | 16384                       | 16384            |
| %Error, 60°   | -3.712    | -3.912                      | -5.169           |
| %Error, -60°  | -3.381    | -2.915                      | -4.241           |
| %Error, 0°  | -3.591    | -3.482                      | -4.751           |
| %Error, 180°  | -3.72     | -3.56                       | -4.831           |
| Phase Error (°)   | 0.0547319 | 0.1647659                   | 0.1533716        |
| PHADJ   | -4070.74  | -4267.22                    | -4246.88         |
| CAL_Ix  | 17005.641 | 16981.934                   | 17208.457        |
| <b>Step 4: Crosstalk Calibration (Equalize Gain for 0° and 180°)</b>  |           |                             |                  |
| VRMS  | 240       |                             |                  |
| IRMS  | 0.30      | Phase A                     | Phase B          |
| Old VFEEDx  | 0         | 0                           | 0                |
| % Error, 0deg   | 1.542     | 1.61                        | 1.706            |
| %Error, 180deg  | -1.634    | -1.743                      | -1.884           |
| VFEEDx  | -13321    | -14064                      | -15058           |
| <ol style="list-style-type: none"> <li>Rogowski coils have significant crosstalk from voltage to current. This contributes to gain and phase errors.</li> <li>Therefore, before calibrating a Rogowski meter, a quick 0° load line should be run to determine at what current the crosstalk contributes at least 1% error.</li> <li>Crosstalk calibration should be performed at this current or lower.</li> <li>If crosstalk contributes an E0 error at current Ix, there will be a 0.1% error in E60 at 15*Ix.</li> </ol> |           |                             |                  |

Figure 2-5: Calibration Spreadsheet for Rogowski coil

## 2.2.6 COMPENSATING FOR NON-LINEARITIES

Nonlinearity is most noticeable at low currents, as shown in Figure 2-6, and can result from input noise and truncation. Nonlinearities can be eliminated individually for each channel by using the  $QUANT_n$  variables ( $QUANT_A$ ,  $QUANT_B$ ,  $QUANT_C$ ).



**Figure 2-6: Non-Linearity Caused by Quantification Noise**

The error can be seen as the presence of a virtual constant noise current. Assuming a noise current of 10mA, this current hardly contributes any error at currents of 10A and above, whereas the same noise current becomes dominant at small measurement currents.

The value that should to be used for  $QUANT_n$  can be determined by the following formula:

$$QUANT_n = -\frac{\frac{error}{100} V \cdot I}{V_{MAX} \cdot I_{MAX} \cdot LSB}$$

Where error = observed error at a given voltage (V) and current (I),  
 $V_{MAX}$  = voltage scaling factor, as described in section 1.8.3,  
 $I_{MAX}$  = current scaling factor, as described in section 1.8.3,  
 $LSB = QUANT_n$  LSB value =  $1.04173 \cdot 10^{-9} W$

**Example:** Assuming an observed error in channel A as in Figure 2-6, we determine the error at 1A to be +1%. If  $V_{MAX}$  is 600V and  $I_{MAX} = 208A$ , and if the measurement was taken at 240V, we determine  $QUANT_A$  as follows:

$$QUANT_A = -\frac{\frac{1}{100} 240 \cdot 1}{600 \cdot 208 \cdot 1.04173 \cdot 10^{-9}} = -1,846,042$$

$QUANT_A$  is to be written to the CE location 0x26 (see the Data Sheet). 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  $QUANT_A$ ).

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 using the same formula as  $QUANT_n$ .

## 2.3 CALIBRATING AND COMPENSATING THE RTC

The real-time clock (RTC) of the 71M6534 is controlled by the crystal oscillator and thus only as accurate as the oscillator. The 71M6534 has two rate adjustment mechanisms:

- Analog rate adjustment, using the I/O RAM register *RTCA\_ADJ[6:0]*. This adjustment is used to set the oscillator frequency at room temperature close to the target (ideal) value. Adjusting *RTCA\_ADJ[6:0]* will change the time base used for energy measurements and thus slightly influence these energy measurements. Therefore it is recommended to adjust the RTC before calibrating a meter.
- Digital rate adjustment is used to dynamically correct the oscillator rate under MPU control. This is necessary when the IC is at temperatures other than room temperature to correct for frequency deviations.

The analog rate adjustment uses the I/O RAM register *RTCA\_ADJ[6:0]*, which trims the crystal load capacitance. Setting *RTCA\_ADJ[6:0]* to 00 minimizes the load capacitance, maximizing the oscillator frequency. Setting *RTCA\_ADJ[6:0]* to 3F maximizes the load capacitance, minimizing the oscillator frequency.

The maximum adjustment is approximately  $\pm 60$ ppm. The precise amount of adjustment will depend on the crystal and on the PCB properties. The adjustment may occur at any time, and the resulting clock frequency can be measured over a one-second interval using a frequency counter connected to the TMUXOUT pin, while 0x10 or 0x11 is selected for the I/O RAM register *TMUX[4:0]*. Selecting 0x10 will generate a 1-second output; selecting 0x11 will generate a 4-second output. The 4-second output is useful to adjust the oscillator at high accuracy. It is also possible to set *TMUX[4:0]* to 0x1D to generate a 32.768kHz output.

The adjustment of the oscillator frequency using *RTCA\_ADJ[6:0]* at room temperature will cause the 71M6534 IC to maintain the adjusted frequency

The digital rate adjustment can be used to adjust the clock rate up to  $\pm 988$ ppm, with a resolution of 3.8ppm. The clock rate is adjusted by writing the appropriate values to *PREG[16:0]* and *QREG[1:0]*. The default frequency is 32,768 RTCLK cycles per second. To shift the clock frequency by  $\Delta$  ppm, calculate *PREG* and *QREG* using the following equation:

$$4 \cdot PREG + QREG = \text{floor} \left( \frac{32768 \cdot 8}{1 + \Delta \cdot 10^{-6}} + 0.5 \right)$$

*PREG* and *QREG* form a single adjustment register with *QREG* providing the two LSBs. The default values of *PREG* and *QREG*, corresponding to zero adjustment, are 0x10000 and 0x0, respectively. Setting both *PREG* and *QREG* to zero is illegal and disturbs the function of the RTC.

If the crystal temperature coefficient is known, the MPU can integrate temperature and correct the RTC time as necessary, using *PREG[16:0]* and *QREG[1:0]*.

The Demo Code adjusts the oscillator clock frequency using the parameters *Y\_CAL*, *Y\_CAL1* and *Y\_CAL2*, which can be obtained by characterizing the crystal over temperature. Provided the IC substrate temperature tracks the crystal temperature, the Demo Code adjusts the oscillator within very narrow limits.

The MPU Demo Code supplied with the TERIDIAN Demo Kits has a direct interface for these coefficients and it directly controls the *PREG[16:0]* and *QREG[1:0]* registers. The Demo Code uses the coefficients in the following form:

$$CORRECTION (ppm) = \frac{Y\_CAL}{10} + T \cdot \frac{Y\_CALC}{100} + T^2 \cdot \frac{Y\_CALC2}{1000}$$

Note that the coefficients are scaled by 10, 100, and 1000 to provide more resolution.

Example: For a crystal, the deviations from nominal frequency are curve fitted to yield the coefficients  $a = 10.89$ ,  $b = 0.122$ , and  $c = -0.00714$ . The coefficients for the Demo Code then become (after rounding, since the Demo Code accepts only integers):

$$Y\_CAL = -109, Y\_CALC = 12, Y\_CALC2 = 7$$

## 2.4 SCHEMATIC INFORMATION

In this section, hints on proper schematic design are provided that will help designing circuits that are functional and sufficiently immune to EMI (electromagnetic interference).

### 2.4.1 COMPONENTS FOR THE V1 PIN

The V1 pin of the 71M6534/6534H can never be left unconnected.

A voltage divider should be used to establish that V1 is in a safe range when the meter is in mission mode (V1 must be lower than 2.9V in all cases in order to keep the hardware watchdog timer enabled). Pulling ICE\_E up to V3P3 automatically disables the hardware watchdog timer.

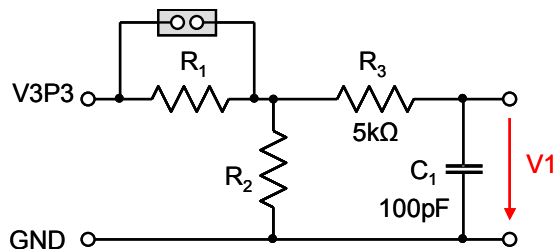


Figure 2-7: Voltage Divider for V1

On the 6534 Demo Boards this feature is implemented with resistors R83/R86/R105 and capacitor C21. See the board schematics in the Appendix for details.

### 2.4.2 RESET CIRCUIT

Even though a functional meter will not necessarily need a reset switch, the 71M6534 Demo Boards provide a reset pushbutton that can be used when prototyping and debugging software (see Figure 2-8). R1 and C1 are mounted very close to the 71M6534. In severe EMI environments R<sub>2</sub> can be removed, if the trace from the pushbutton switch to the RESETZ pin poses a problem,

For production meters, the RESET pin should be directly connected to GND.

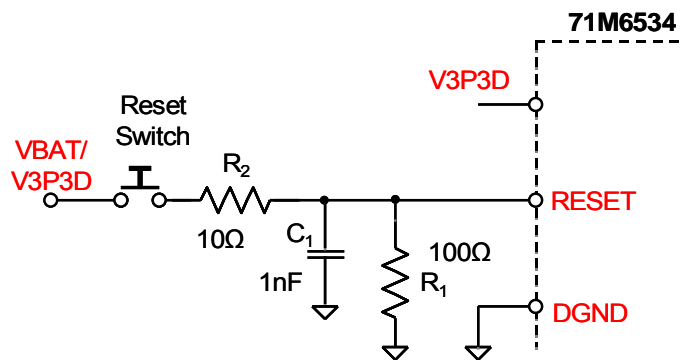


Figure 2-8: External Components for RESET

### 2.4.3 OSCILLATOR

The oscillator of the 71M6534 drives a standard 32.768kHz watch crystal (see Figure 2-9). Crystals of this type are accurate and do not require a high current oscillator circuit. The oscillator in the 71M6534 has been designed specifically to handle watch crystals and is compatible with their high impedance and limited power handling capability. The oscillator power dissipation is very low to maximize the lifetime of any battery backup device attached to the VBAT pin.

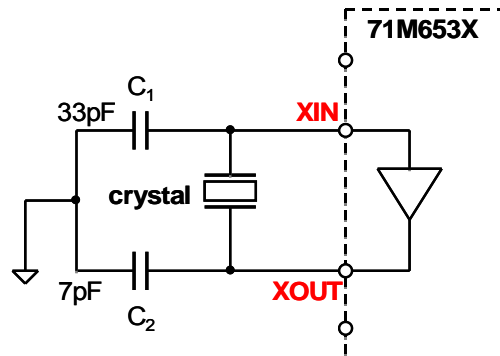


Figure 2-9: Oscillator Circuit



It is not necessary to place an external resistor across the crystal.

### 2.4.4 EEPROM

EEPROMs should be connected to the pins DIO4 and DIO5 (see Figure 2-10). These pins can be switched from regular DIO to implement an I2C interface by setting the I/O RAM register DIO\_EEX (0x2008[4]) to 1. Pull-up resistors of 10k $\Omega$  must be provided for both the SCL and SDA signals.

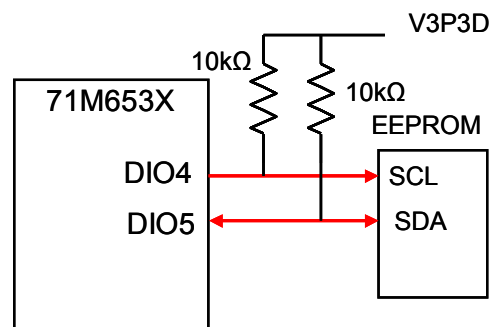


Figure 2-10: EEPROM Circuit

### 2.4.5 LCD

The 71M6534 has an on-chip LCD controller capable of controlling static or multiplexed LCDs. Figure 2-11 shows the basic connection for LCDs. Note that the LCD module itself has no power connection.

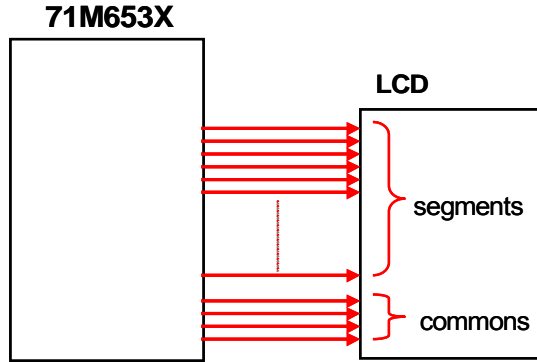


Figure 2-11: LCD Connections

### 2.4.6 OPTICAL INTERFACE

The 71M6534 IC is equipped with two pins supporting the optical interface: OPT\_TX and OPT\_RX. The OPT\_TX pin can be used to drive a visual or IR light LED with up to 20mA, a series resistor ( $R_2$  in Figure 2-12) helps limiting the current). The OPT\_RX pin can be connected to the collector of a photo-transistor, as shown in Figure 2-12.

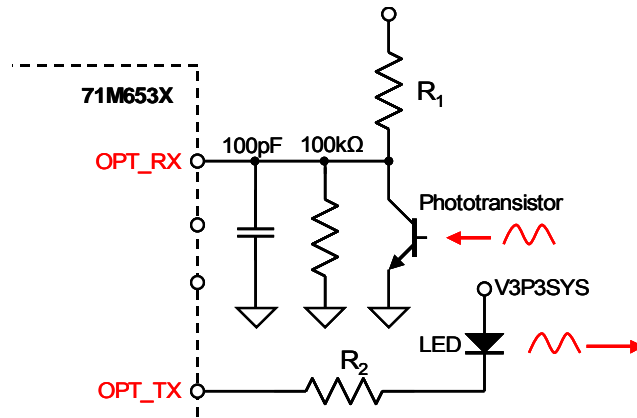


Figure 2-12: Optical Interface Block Diagram



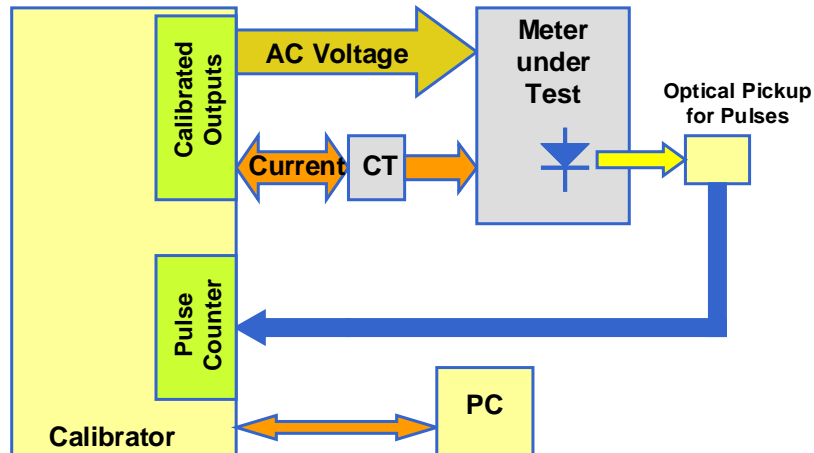
## 2.5 TESTING THE DEMO BOARD

This section will explain how the 71M6534/6534H 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.

### 2.5.1 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 2-13 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 CT or CTs that are not part of the Demo Board. The Demo Board rather receives the voltage output signals from the CT. 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  $K_h$  and the applied power.



**Figure 2-13: Meter with Calibration System**

TERIDIAN Demo Boards are not calibrated prior to shipping. However, the Demo Board pulse outputs are tested and compared to the expected pulse output. Figure 2-14 shows the screen on the controlling PC for a typical Demo Board. The number in the red field under “As Found” represents the error measured for phase A, while the number in the red field under “As Left” represents the error measured for phase B. Both numbers are given in percent. This means that for the measured Demo Board, the sum of all errors resulting from tolerances of PCB components, CTs, and 71M6534/6534H tolerances was  $-2.8\%$  and  $-3.8\%$ , a range that can easily be compensated by calibration.

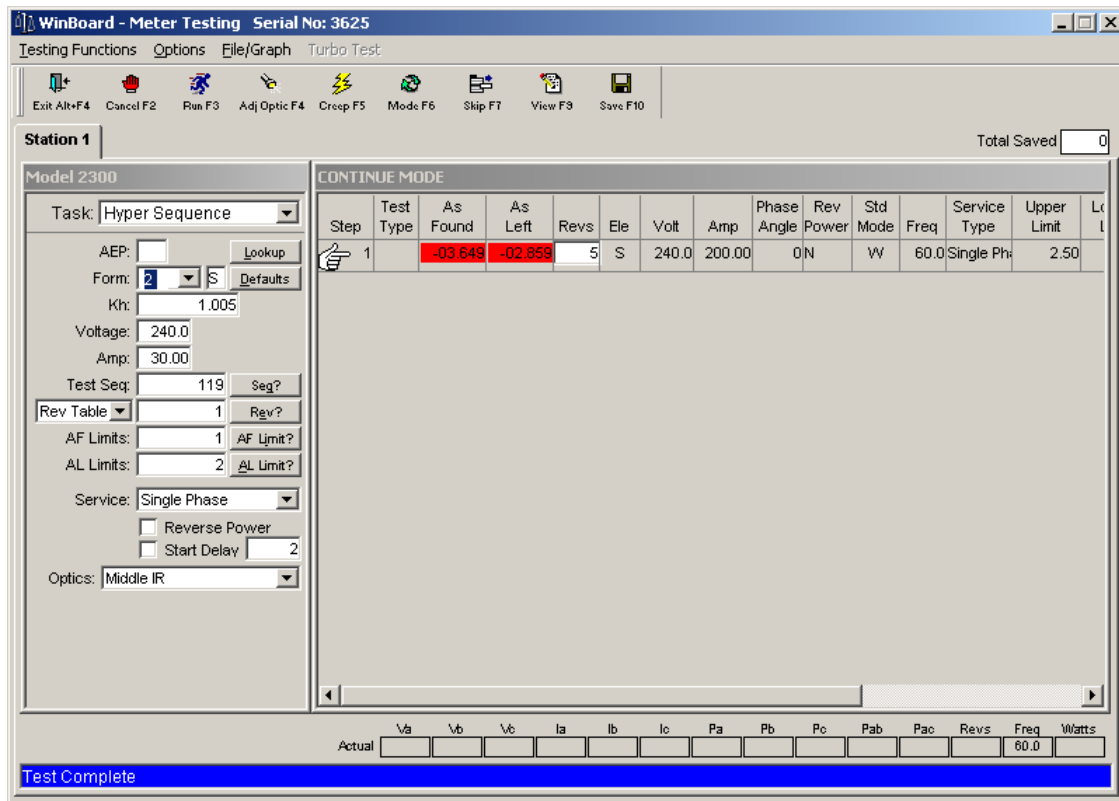


Figure 2-14: Calibration System Screen

## 2.5.2 EEPROM

Testing the EEPROM provided on the Demo Board is straightforward and can be done using the serial command line interface (CLI) of the Demo Code.

To write a string of text characters to the EEPROM and read it back, we apply the following sequence of CLI commands:

- >EEC1 Enables the EEPROM
- >EESthis is a test Writes text to the buffer
- >EET80 Writes buffer to address 80

**Written to EEPROM address 0000080 74 68 69 73 20 69 73 20 61 ....**

Response from Demo Code

- >EER80.E Reads text from the buffer

**Read from EEPROM address 0000080 74 68 69 73 20 69 73 20 61 ....**

Response from Demo Code

- >EEC0 Disables the EEPROM

### 2.5.3 RTC

Testing the RTC inside the 71M6534/6534H IC is straightforward and can be done using the serial command line interface (CLI) of the Demo Code.

To set the RTC and check the time and date, we apply the following sequence of CLI commands:

- >M10 LCD display to show calendar date
- >RTD05.09.27.3 Sets the date to 9/27/2005 (Tuesday)
- >M9 LCD display to show time of day
- >RTT10.45.00 Sets the time to 10:45:00. AM/PM distinction: 1:22:33PM = 13:22:33

### 2.5.4 HARDWARE WATCHDOG TIMER (WDT)

The hardware WDT of the 71M6534/6534H is disabled when the voltage at the V1 pin is at 3.3V (V3P3). On the Demo Boards, this is done by plugging in a jumper at TP10 between the V1 and V3P3 pins.

Conversely, removing the jumper at TP10 will enable the WDT. When the WDT is enabled, typing "W" at the command line interface will cause the Demo Board to reset.

### 2.5.5 LCD

Various tests of the LCD interface can be performed with the Demo Board, using the serial command line interface (CLI):


Setting the LCD\_EN register to 1 enables the display outputs.

| Register Name | Address [bits] | R/W | Description  |
|---------------|----------------|-----|--|
| LCD_EN        | 2021[5]        | R/W | Enables the LCD display. When disabled, VLC2, VLC1, and VLC0 are ground, as are the COM and SEG outputs. |

To access the LCD\_EN register, we apply the following CLI commands:

- >RI21\$ Reads the hex value of register 0x2021
- >25 Response from Demo Code indicating the bit 5 is set
- >RI21=5 Writes the hex value 0x05 to register 0x2021 causing the display to be switched off
- >RI21=25 Sets the LCD\_EN register back to normal

The LCD\_CLK register determines the frequency at which the COM pins change states. A slower clock means lower power consumption, but if the clock is too slow, visible flicker can occur. The default clock frequency for the 71M6534/6534H Demo Boards is 150Hz (LCD\_CLK = 01).

| Register Name | Address [bits] | R/W | Description  |
|---------------|----------------|-----|--|
| LCD_CLK[1:0]  | 2021[1:0]      | R/W | Sets the LCD clock frequency, i.e. the frequency at which SEG and COM pins change states.<br>$f_w = 32,768\text{Hz}$<br><br>00: $f_w/2^9$ , 01: $f_w/2^8$ , 10: $f_w/2^7$ , 11: $f_w/2^6$ |

To change the LCD clock frequency, we apply the following CLI commands:

- >RI21\$ Reads the hex value of register 0x2021
- >25 Response from Demo Code indicating the bit 0 is set and bit 1 is cleared.

>**RI21=24**      Writes the hex value 0x24 to register 0x2021 clearing bit 0 – LCD flicker is visible now

>**RI21=25**      Writes the original value back to *LCD\_CLK*

## 2.6 TERIDIAN APPLICATION NOTES

Please contact your local TERIDIAN sales representative for TERIDIAN Application Notes. Available application notes will be listed below in future editions of this document.


# 3

## 3 HARDWARE DESCRIPTION

### 3.1 D6534T14A2 BOARD DESCRIPTION: JUMPERS, SWITCHES AND TEST POINTS

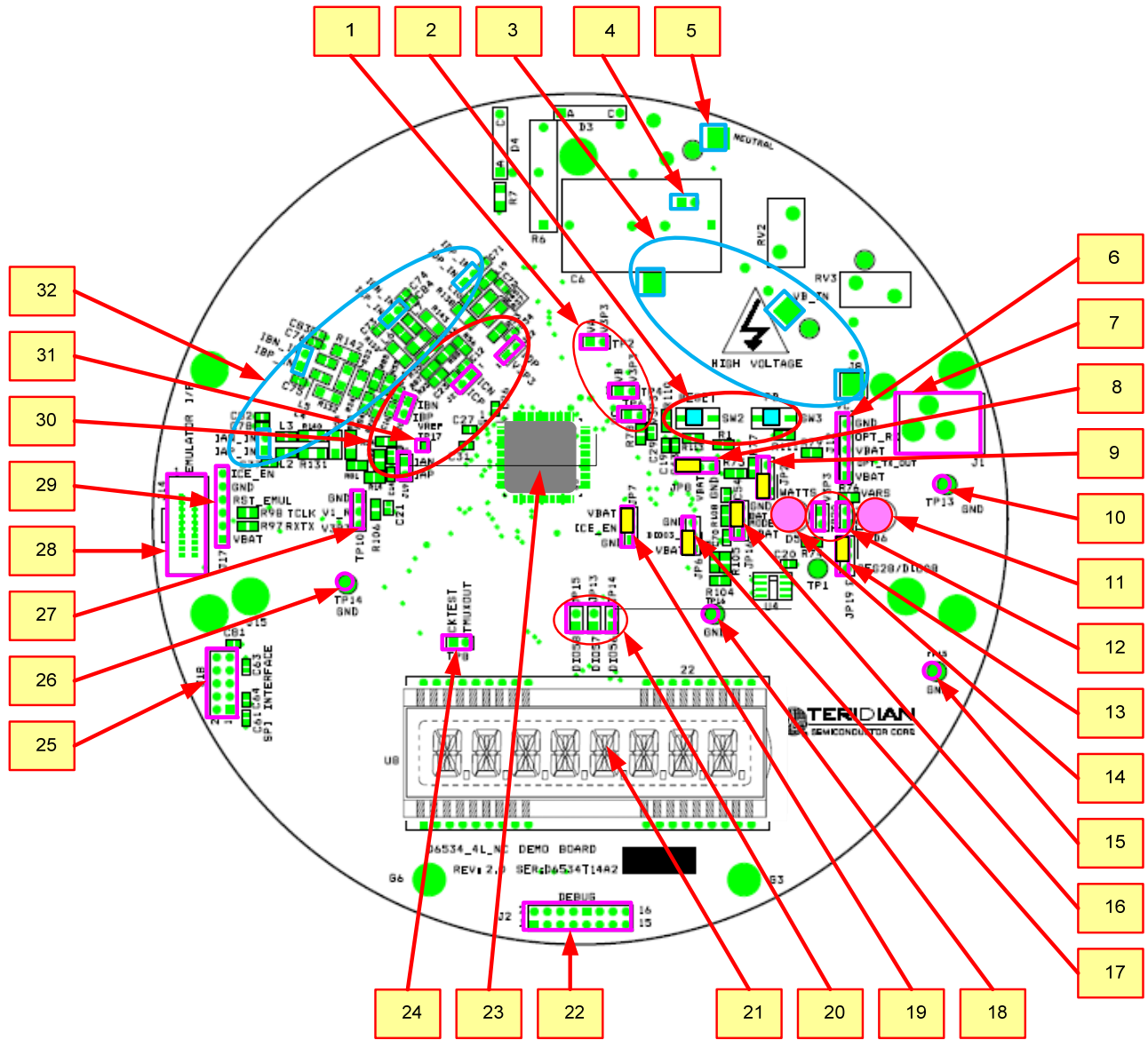
The items described in the following table refer to the flags in Figure 3-1.

Table 3-1: D6534T14A2 Demo Board Description

| Item # | Reference Designator | Name  | Description   |
|--------|----------------------|---|---|
| 1      | TP2                  | VA/V3P3   | Two-pin header test points. One pin is either the VA, VB or VC line voltage input to the IC and the other pin is V3P3A.   |
|        | TP4                  | VB/V3P3   |   |
|        | TP6                  | VC/V3P3   |   |
| 2      | SW2                  | RESET   | Chip reset switch: When the button is pressed, the RESET pin is pulled high which resets the IC into a known state.   |
|        | SW3                  | PB  | Multi-function pushbutton, used to wake-up the 71M6534 from sleep mode into brownout mode. In mission mode, this button functions to control the parameters displayed on the LCD.   |
| 3      | J4, J6, J8,          | VA_IN, VB_IN,<br>VC_IN<br> | VA_IN, VB_IN, and VC_IN are the line voltage inputs. Each point has a resistor divider that leads to the respective pin on the chip that is the voltage input to the A/D. These inputs connect to spade terminals located on the bottom of the board.<br><b>Caution: High Voltage! Do not touch these pins!</b> |
| 4      | JP1                  | PS_SEL[0]   | Two-pin header. When the jumper is installed the on-board power supply (AC signal) is used to power the demo board. When not installed, the board must be powered by an external DC supply connected to J1. <b>Normally installed.</b>  |
| 5      | J9                   | Neutral   | The neutral wire connect to the spade terminal located on the bottom of the board.  |
| 6      | J12                  | OPT_RX,<br>OPT_TX_OUT   | 5-pin header for access to the optical interface (UART1). <b>For better EMI performance, jumpers should be installed from both OPT_RX and OPT_TX_OUT to V3P3D.</b>  |
| 7      | J1                   | --  | Plug for connecting the external 5 VDC power supply   |
| 8      | JP8                  | VBAT  | Three-pin header that allows the connection of a battery. If no battery is connected to the VBAT pin, a jumper should be placed between pins 1 and 2 ( <b>default setting of the Demo Board</b> ). A battery can be connected between terminals 2 (+) and 3 (-).  |

| Item # | Reference Designator | Name                | Description  |
|--------|----------------------|---------------------|--|
| 9      | JP20                 | --                  | 3-pin header for selecting the output driving the VARh pulse LED. 1-2: RPULSE, 2-3: YPULSE. <b>A jumper is normally installed from pin 1 to pin 2.</b>   |
| 10     | TP13                 | GND                 | GND test point.  |
| 11     | D6                   | VAR5                | LED for VARh pulses  |
| 12     | TP20                 | --                  | 2-pin header enabling access to the selected pulse output (DIO8, DIO6, OPT_TX) and V3P3.   |
|        | TP21                 |                     | 2-pin header enabling access to the selected pulse output (DIO7, DIO9) and V3P3.   |
| 13     | JP19                 | SEG28/ DIO08        | 3-pin header for selecting the output driving the Wh pulse LED. 1-2: WPULSE or OPT_TX, 2-3: XPULSE. <b>A jumper is normally installed from pin 1 to pin 2.</b>   |
| 14     | D5                   | WATTS               | LED for Wh pulses  |
| 15     | TP15                 | GND                 | GND test point.  |
| 16     | JP16                 | BAT MODE            | 3-pin header for selection of the firmware function in battery mode. Plugging a jumper across pins 2 and 3 will select 9600bd and will also disable the battery modes. Plugging a jumper across pins 1 and 2 will select 300bd and enable battery modes. |
| 17     | JP6                  | DIO3_R              | 3-pin header allowing access to the DIO03 pin.   |
| 18     | TP16                 | GND                 | GND test point.  |
| 19     | JP7                  | ICE_EN              | 3-pin header for selection of the voltage for the ICE_E pin. <b>A jumper is normally installed between V3P3D and ICE_E</b> , enabling programming of the 71M6534.  |
| 20     | JP13, JP14, JP15     | DIO56, DIO57, DIO58 | 2-pin headers providing access to the DIO pins DIO56, DIO57, and DIO58.  |
| 21     | U8                   | --                  | LCD with eight digits and 14 segments per digit.   |
| 22     | J2                   | DEBUG               | 8X2 header providing access for the Debug Board.   |
| 23     | --                   | --                  | The 71M6534 IC in LQFP-120 package.  |
| 24     | TP8                  | CKTEST, TMUXOUT     | 2-pin header providing access to the TMUXOUT and CKTEST signals.   |
| 25     | J18                  | SPI Interface       | 2X5 header providing access to the SPI interface of the 71M6534.   |
| 26     | TP14                 | GND                 | GND test point.  |
| 27     | TP10                 | V1_R                | 3-pin header used to enable or disable the hardware watchdog timer (WDT). <b>The WDT is disabled by plugging as jumper between V1_R and V3P3 (default)</b> and enabled by plugging as jumper between V1_R and GND.                                       |
| 28     | J14                  | EMULATOR I/F        | 2x10 high-density connector port for connecting the Signum ICE ADM-51 or the TFP-2 programmer.   |
| 29     | J17                  | --                  | 6-pin header providing access to the essential signals of the emulator interface.  |
| 30     | J19                  | IAN, IAP            | 2-pin headers providing access to the current input pins of channel A, B, C and D, used in differential mode.  |
|        | J20                  | IBN, IBP            |  |
|        | J21                  | ICN, ICP            |  |
|        | J22                  | IDN, IDP            |  |
| 31     | TP17                 | VREF                | 1-pin header providing access to the VREF pin.   |

| Item # | Reference Designator | Name          | Description  |
|--------|----------------------|---------------|--|
| 32     | J3                   | IAN_IN/IAP_IN | 2-pin headers mounted on the bottom of the board for connecting current transformers (CTs) to their associated current inputs. |
|        | J5                   | IBN_IN/IBP_IN |  |
|        | J7                   | ICN_IN/ICP_IN |  |
|        | J10                  | IDN_IN/IDP_IN |  |



**Figure 3-1: D6534T14A2 Demo Board - Board Description**  
 (Default jumper settings indicated in yellow)

## 3.2 BOARD HARDWARE SPECIFICATIONS

### PCB Dimensions

- Diameter 6.5" (165.1mm)
- Thickness 0.062" (1.6mm)
- Height w/ components 2.0" (50.8mm)

### Environmental

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

### Power Supply

- Using AC Input Signal 240V...700V rms
- DC Input Voltage (powered from DC supply) 5VDC  $\pm$ 0.5V
- Supply Current 25mA typical

### Input Signal Range

- AC Voltage Signals (VA, VB, VC) 0...240V rms
- AC Current Signals (IA, IB, IC) from CT 0...0.25V p/p

### Interface Connectors

- DC Supply Jack (J1) to Wall Transformer Concentric connector, 2.5mm
- Emulator (J14) 10x2 Header, 0.05" pitch
- Input Signals Spade Terminals and 0.1" headers on PCB bottom
- Debug Board (J2) 8x2 Header, 0.1" pitch

### Functional Specification

- Program Memory 256KByte FLASH memory
- NV memory 1Mbit serial EEPROM
- Time Base Frequency 32.768kHz,  $\pm$ 20PPM at 25°C
- Time Base Temperature Coefficient -0.04PPM/°C2 (max)

### Controls and Displays

- Reset Button (SW2)
- Numeric Display 8-digit LCD, 14-segments per digit, 8mm character height, 89.0 x 17.7mm view area
- "Watts" red LED (D5)
- "VARS" red LED (D6)

### Measurement Range

- Voltage 120...700 V rms (resistor division ratio 1:3,398)
- Current 0...200A (1.7 $\Omega$  burden resistor for 2,000:1 CT)





## 4 APPENDIX

This appendix includes the following documentation, tables and drawings:

### **D6534T14A2 Demo Board Description**

- D6534T14A2 Demo Board Electrical Schematic
- D6534T14A2 Demo Board Bill of Materials
- D6534T14A2 Demo Board PCB layers (copper, silk screen, top and bottom side)

### **Debug Board Description**

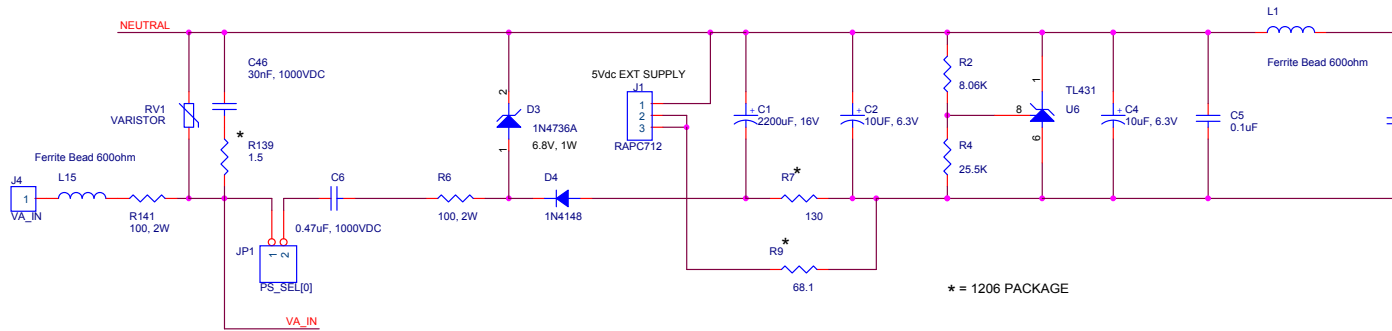
- Debug Board Electrical Schematic
- Debug Board Bill of Materials
- Debug Board PCB layers (copper, silk screen, top and bottom side)

### **71M6534H IC Description**

- 71M6534H Pin Description
- 71M6534H Pin-out

### **Formulae for Fast Calibration**

### 4.1 D6534T14A2 SCHEMATICS, PCB LAYOUT AND BOM



POWER SUPPLY SELECTION TABLE

| SELECTION                        | PS_SEL[0] (JP1) |
|----------------------------------|-----------------|
| ON BOARD SUPPLY                  | IN              |
| EXT 5Vdc SUPPLY THRU J1          | OUT             |
| EXT 5Vdc SUPPLY THRU DEBUG BOARD | OUT             |

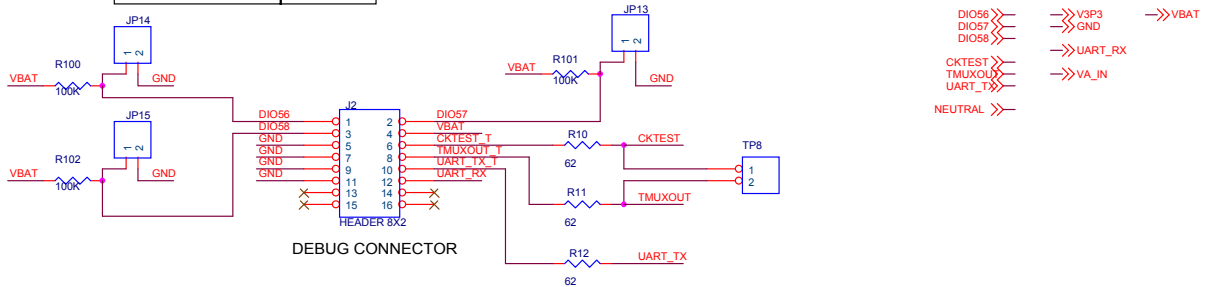


Figure 4-1: TERIDIAN D6534T14A2 Demo Board: Electrical Schematic 1/3

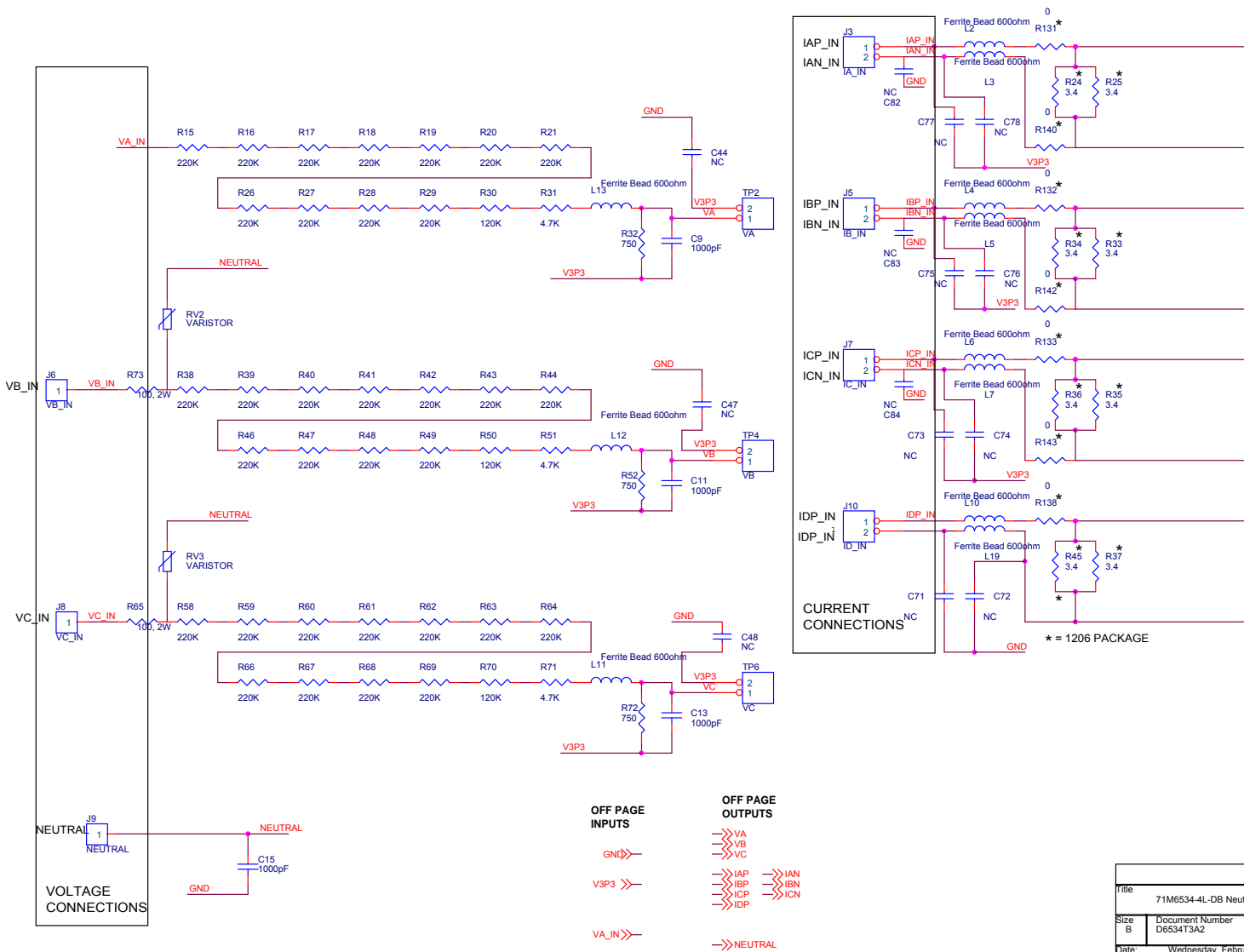


Figure 4-2: TERIDIAN D6534T14A2 Demo Board: Electrical Schematic 2/3

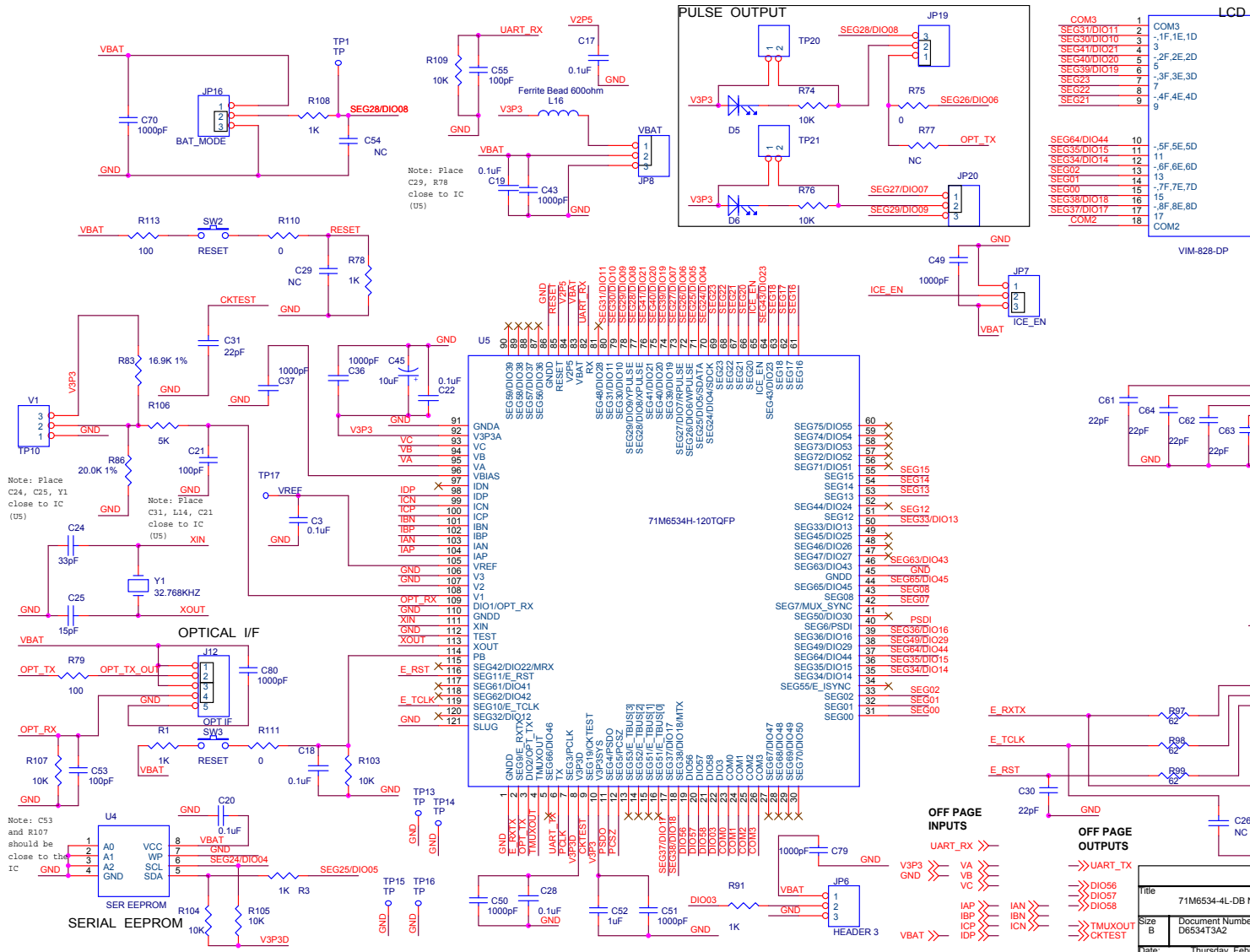


Figure 4-3: TERIDIAN D6534T14A2 Demo Board: Electrical Schematic 3/3

| Item | Q  | Reference  | Part                  | PCB Footprint | Digi-Key/Mouser Part Number | Part Number             | Manufacturer      |
|------|----|--|-----------------------|---------------|-----------------------------|-------------------------|-------------------|
| 1    | 1  | C1   | 2200uF                | radial        | P5143-ND                    | ECA-1CM222              | Panasonic         |
| 2    | 3  | C2,C4,C45  | 10uF                  | RC1812        | 478-1672-1-ND               | TAJB106K010R            | AVX               |
| 3    | 8  | C5,C17-C20,C22,C28,C29   | 0.1uF                 | RC0603        | 445-1314-1-ND               | C1608X7R1H104K          | TDK               |
| 4    | 1  | C6   | 0.47uF                |               | B1918-ND                    | 2222 383 30474          | Vishay            |
| 5    | 33 | C8-C16,C23,C33-C36,C40-C44,C47-C51,C56-C59,C69,C70,C79,C80,C81 | 1000pF                | RC0603        | 445-1298-1-ND               | C1608X7R2A102K          | TDK               |
| 6    | 11 | C21,C32,C54,C71-C78  | NC                    | RC0603        |                             |                         |                   |
| 7    | 1  | C24  | 33pF                  | RC0603        | 445-1275-1-ND               | C1608C0G1H330J          | TDK               |
| 8    | 1  | C25  | 7pF                   | RC0603        | 490-3564-1-ND               | GQM1885C1H7R0CB01D      | Murata            |
| 9    | 13 | C26,C27,C30,C31,C60-C68  | 22pF                  | RC0603        | 445-1273-1-ND               | C1608C0G1H220J          | TDK               |
| 10   | 1  | C46  | 0.03uF                | axial         | 75-125LS30-R                | 125LS30-R               | Vishay            |
| 11   | 1  | C52  | 1uF                   | RC0603        | PCC2224CT-ND                | ECJ-1VB1C105K           | Panasonic         |
| 12   | 2  | C53,C55  | 100pF                 | RC0603        | 445-1281-1-ND               | C1608C0G1H101J          | TDK               |
| 13   | 1  | D1   | UCLAMP3301D           | SOD-323       | --                          | UCLAMP3301D.TCT         | SEMTECH           |
| 14   | 1  | D3   | 6.8V ZENER            | D041          | 1N4736ADICT-ND              | 1N4736A-T               | DIODES            |
| 15   | 1  | D4   | Switching Diode       | D035          | 1N4148DICT-ND               | 1N4148-T                | DIODES            |
| 16   | 2  | D5,D6  | LED                   | radial        | 404-1104-ND                 | H-3000L                 | Stanley           |
| 17   | 1  | D8   | NC                    | SOD-323       |                             |                         |                   |
| 18   | 1  | J1   | DC jack (2.5mm)       | RAPC712       | 502-RAPC712X                | RAPC712X                | Switchcraft       |
| 19   | 1  | J2   | HEADER 8X2            | 8X2PIN        | S2011E-36-ND                | PZC36DAAN               | Sullins           |
| 20   |    | J3,J5,J7,J10,J16   | HEADER 2              | 2X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 21   | 4  | J4,J6,J8,J9  | Spade Terminal        |               | A24747CT-ND                 | 62395-1                 | AMP               |
| 22   | 1  | J12  | HEADER 5              | 5X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 23   | 1  | J13,J19-J22  | HEADER 4              | 4X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 24   | 1  | J14  | 10X2 CONNECTOR, 0.05" |               | 571-5-104068-1              | 5-104068-1              | AMP               |
| 25   | 1  | J17  | HEADER 6              | 6X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 26   | 1  | J18  | HEADER 5X2            | 5X2PIN        | S2011E-36-ND                | PZC36DAAN               | Sullins           |
| 27   | 6  | JP1,JP13,JP14,JP15,JP17,JP18                                   | HEADER 2              | 2X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 28   | 5  | JP6,JP7,JP8,JP16,JP19,JP20                                     | HEADER 3              | 3X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 29   | 1  | JP12   | HEADER 9              | 9X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 30   | 16 | L1-L13,L15,L16,L19   | Ferrite bead, 600 Ohm | RC0805        | 445-1556-1-ND               | MM22012S601A            | TDK               |
| 31   | 3  | RV1,RV2,RV3  | VARISTOR              | radial        | 594-2381-594-55116          | 238159455116            | Vishay            |
| 32   | 1  | R2   | 8.06K, 1%             | RC0805        | 311-8.06KCRCT-ND            | RC0805FR-078060KL       | Yageo             |
| 33   | 1  | R4   | 25.5K, 1%             | RC0805        | 311-25.5KCRCT-ND            | RC08052FR-072552L       | Yageo             |
| 34   | 4  | R6,R65,R73,R141  | 100, 2W               | axial         | 100W-2-ND                   | RSF200JB-100R           | Yageo             |
| 35   | 1  | R7   | 130, 1%               | RC1206        | 311-130FRCT-ND              | RC1206FR-071300L        | Yageo             |
| 36   | 1  | R9   | 68, 1%                | RC1206        | 311-68.0FRCT-ND             | RC1206FR-0768R0L        | Yageo             |
| 37   | 11 | R10,R11,R12,R90,R92,R93,R95,R96,R97,R98,R99                    | 62                    | RC0805        | P62ACT-ND                   | ERJ-6GEYJ620V           | Panasonic         |
| 38   | 12 | R14,R22,R23,R32,R52-R57,R72,R135                               | 750, 1%               | RC0805        | P750CCT-ND                  | ERJ-6ENF7500V           | Panasonic         |
| 39   | 33 | R15-R21,R26-R29,R38-R44,R46-R49,R58-R64,R66-R69                | 220K, 1%              | RC0805        | 311-220KCRCT-ND             | RC0805FR-07220KL        | Yageo             |
| 40   | 10 | R24,R25,R33-R37,R45,R136,R137                                  | 3.4, 1%               | RC1206        | 311-3.40FRCT-ND             | RC1206FR-073R40L        | Yageo             |
| 41   | 3  | R30,R50,R70  | 120K, 1%              | RC0805        | 311-120KCRCT-ND             | RC0805FR-071203L        | Yageo             |
| 42   | 3  | R31,R51,R71  | 4.70K, 1%             | RC0805        | 311-4.70KCRCT-ND            | RC0805FR-074701L        | Yageo             |
| 43   | 9  | R74,R76,R80,R103,R104,R105,R106,R107,R109                      | 10K                   | RC0805        | P10KACT-ND                  | ERJ-6GEYJ103V           | Panasonic         |
| 44   | 2  | R75,R94  | 0                     | RC0805        | P0.0ACT-ND                  | ERJ-6GEY0R00V           | Panasonic         |
| 45   | 1  | R77  | NC                    | RC0805        |                             |                         |                   |
| 46   | 4  | R78,R91,R108,R111  | 1K                    | RC0805        | P1.0KACT-ND                 | ERJ-6GEYJ102V           | Panasonic         |
| 47   | 10 | R79,R81,R82,R84,R85,R87,R88,R89,R110,R112                      | 100                   | RC0805        | P100ACT-ND                  | ERJ-6GEYJ101J           | Panasonic         |
| 48   | 1  | R83  | 16.9K, 1%             | RC0805        | P16.9KCT-ND                 | ERJ-6ENF1692V           | Panasonic         |
| 49   | 1  | R86  | 20.0K, 1%             | RC0805        | P20.0KCT-ND                 | ERJ-6ENF2002V           | Panasonic         |
| 50   | 3  | R100,R101,R102   | 100K                  | RC0805        | P100KACT-ND                 | ERJ-6GEYJ104V           | Panasonic         |
| 51   | 8  | R131,R132,R133,R134,R140,R142,R143,R144                        | 0                     | RC1206        | P0.0ECT-ND                  | ERJ-8GEY0R00V           | Panasonic         |
| 52   | 1  | R139   | 1.5                   | RC1206        | P1.5ECT-ND                  | ERJ-8GEYJ1R5V           | Panasonic         |
| 53   | 1  | SW2,SW3  | SWITCH                |               | P8051SCT-ND                 | EVQ-PJX05M              | Panasonic         |
| 54   | 8  | TP2-TP4,TP6-TP8,TP20,TP21                                      | TP                    | 2X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 55   | 1  | TP10   | TP                    | 3X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 56   | 4  | TP13-TP16  | Test Point            |               | 5011K-ND                    | 5011                    | Keystone 1)       |
| 57   | 1  | TP17   | TP                    | 1X1PIN        | S1011E-36-ND                | PZC36SAAN               | Sullins           |
| 58   | 5  | U1,U2,U3,U7,U9   | BAV99DW               | SOT363        | BAV99DW-FDICT-ND            | BAV99DW-7-F             | DIODES            |
| 59   | 1  | U4   | SER EEPROM            | SO8           | AT24C256BN-10SU-1.8-ND      | AT24C256BN-10SU-1.8     | ATMEL             |
| 60   | 1  | U5   | 71M6534               | 120TQFP       | --                          | 71M6534-IGT             | TERIDIAN          |
| 61   | 1  | at U5  | 120TQFP Socket        | 120TQFP       | --                          | IC149-120-143-B5        | Yamaichi          |
| 62   | 1  | U6   | REGULATOR, 1%         | SO8           | 296-1288-1-ND               | TL431AIDR               | Texas Instruments |
| 63   | 1  | U8   | LCD                   |               | 153-1110-ND                 | VIM-828-DP5.7-6-RC-S-LV | VARITRONIX 2)     |
| 64   | 1  | Y1   | 32.768kHz             |               | XC1195CT-ND                 | ECS-327-12.5-17X-TR     | ECS               |

Table 4-1: D6534T14A2 Demo Board: Bill of Material

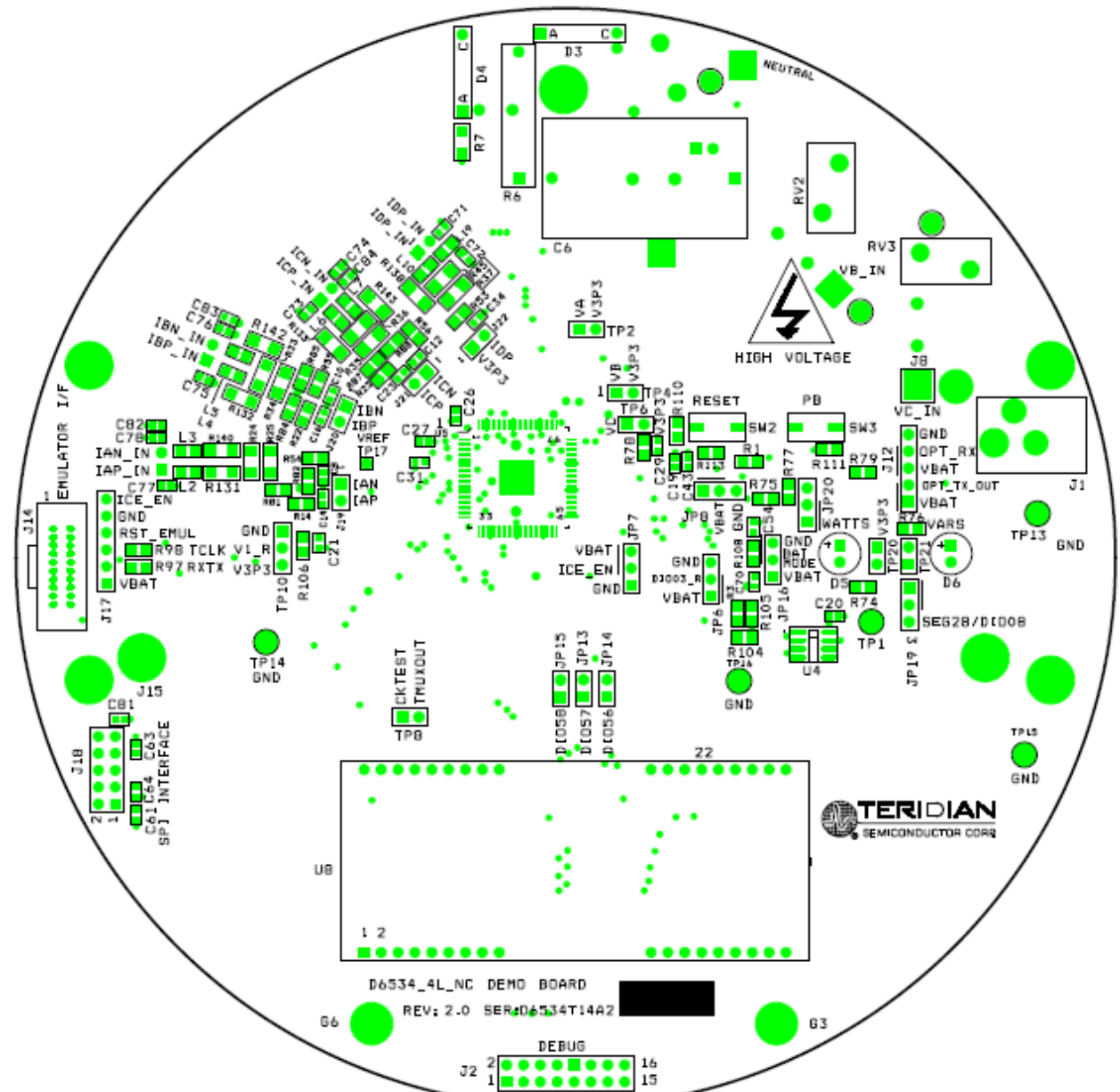


Figure 4-4: TERIDIAN D6534T14A2 Demo Board: Top View

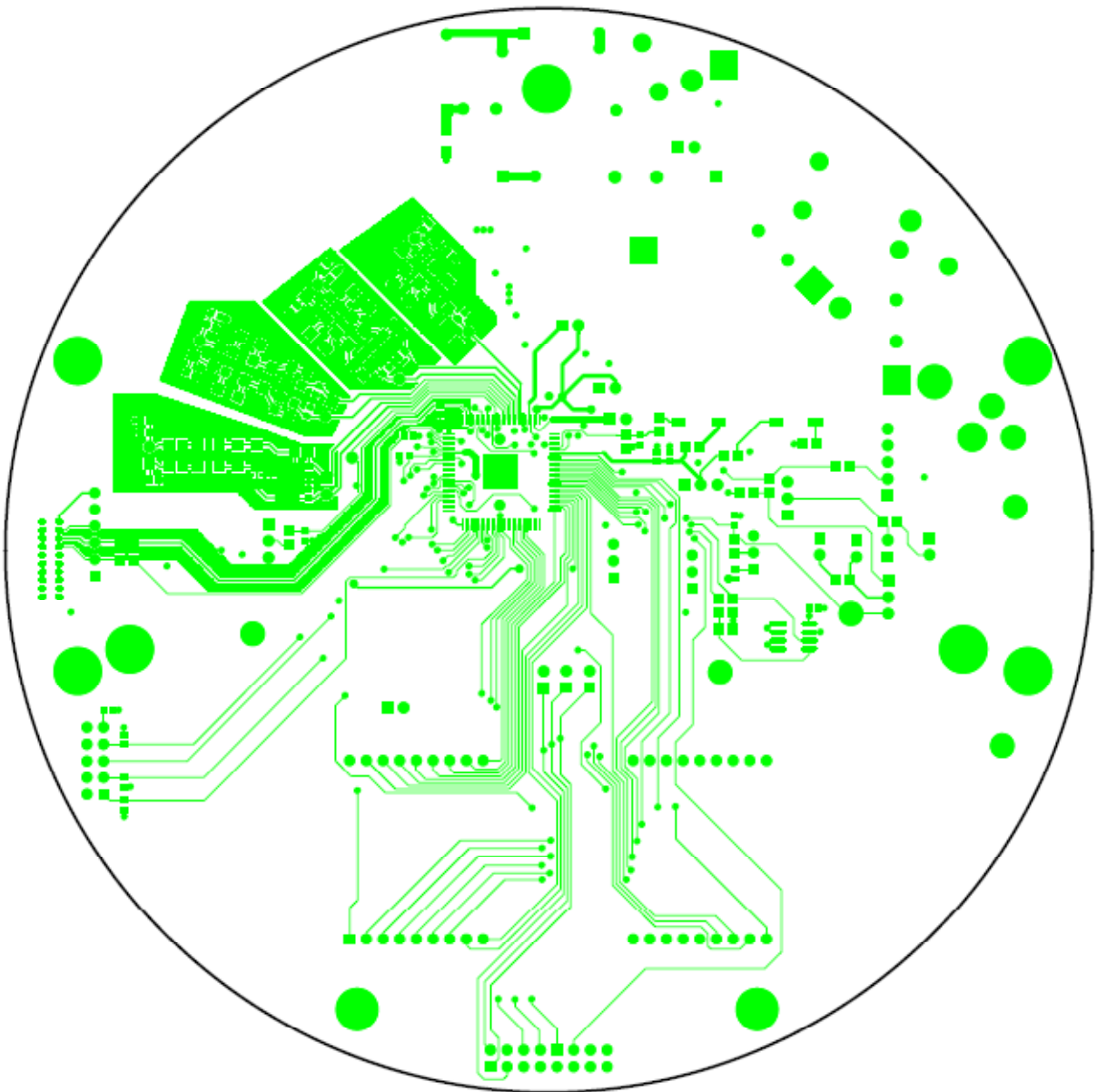


Figure 4-5: TERIDIAN D6534T14A2 Demo Board: Top Copper Layer

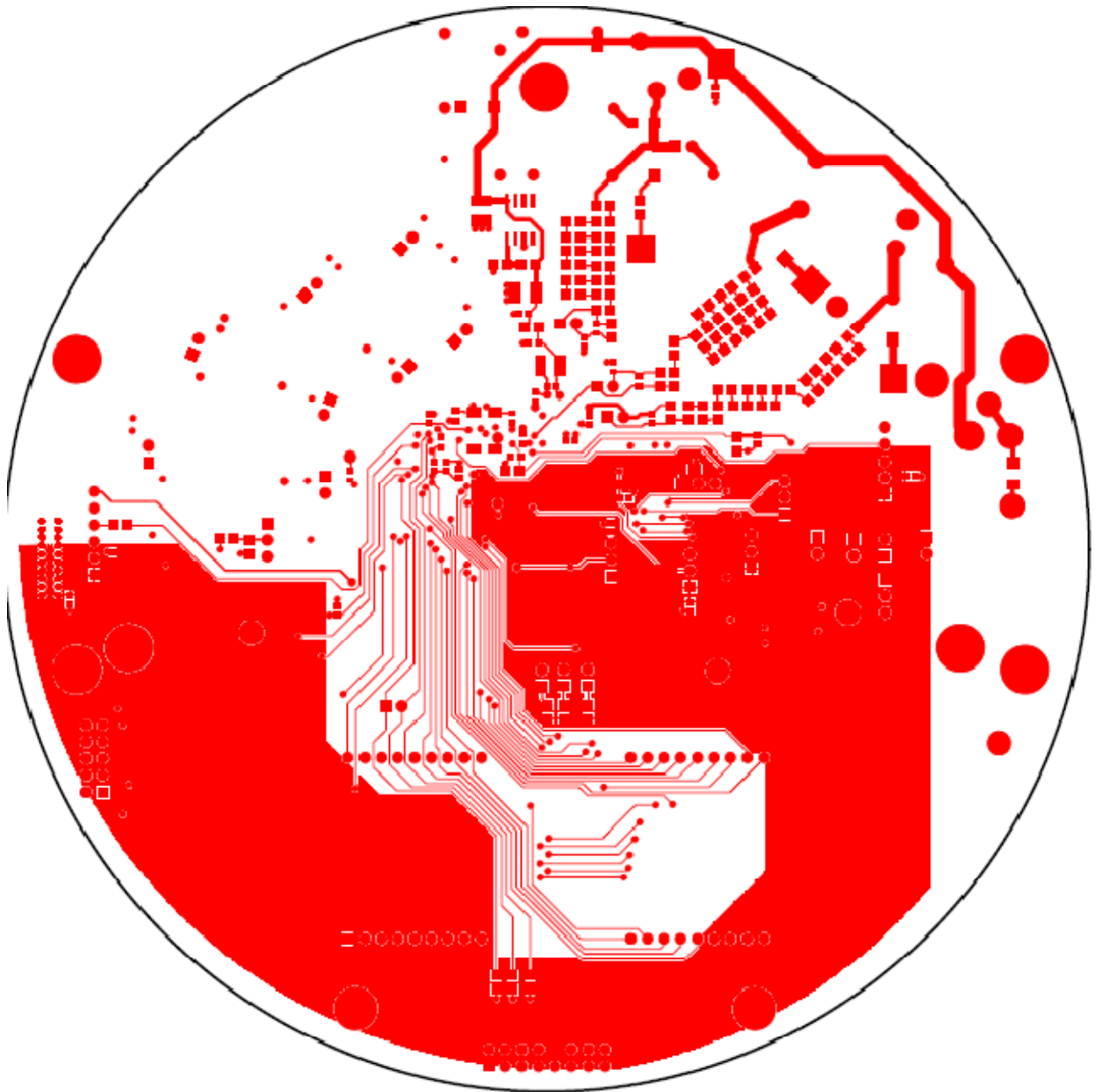


Figure 4-6: TERIDIAN D6534T14A2 Demo Board: Bottom Copper Layer



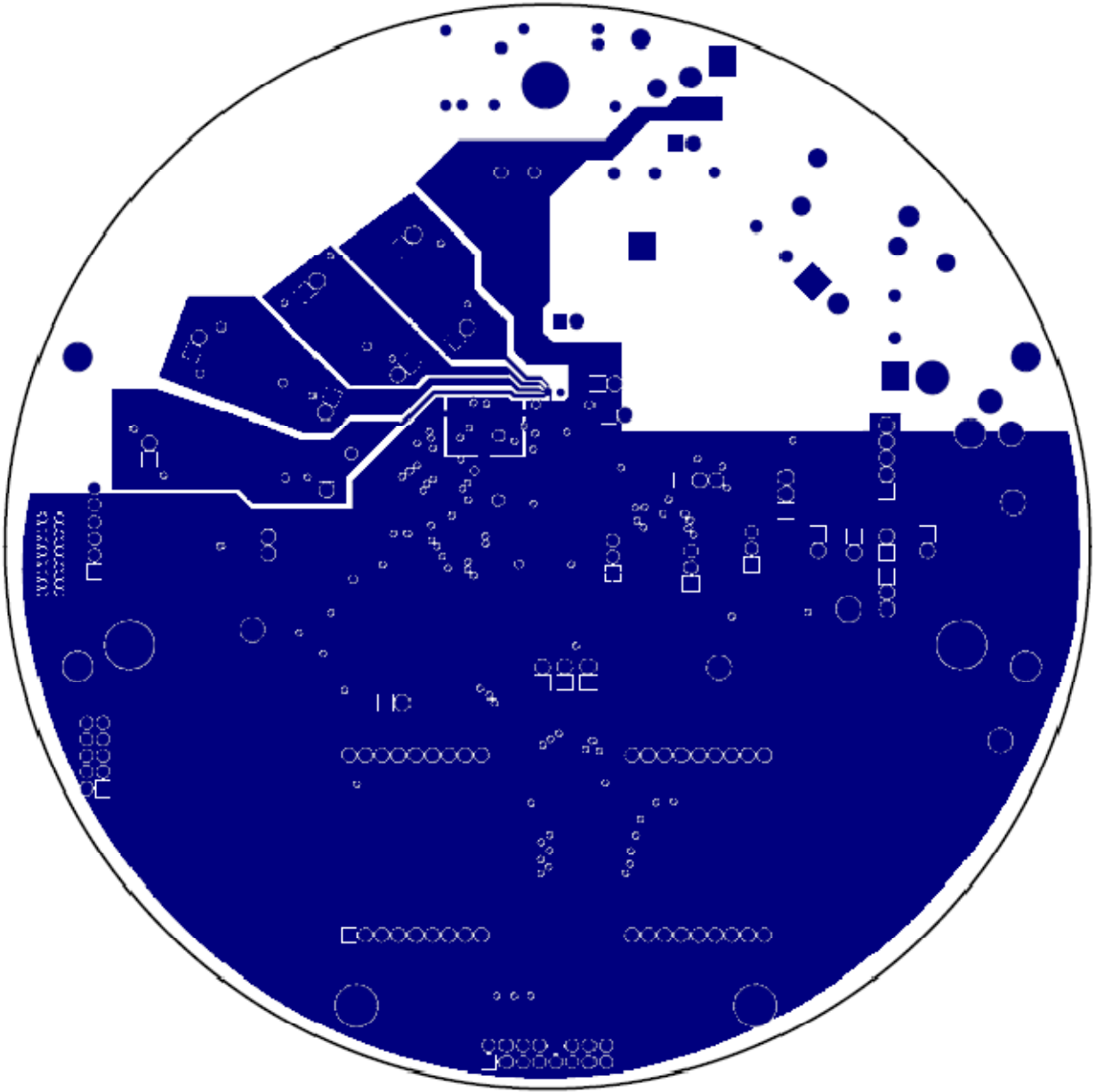


Figure 4-7: TERIDIAN D6534T14A2 Demo Board: Ground Layer

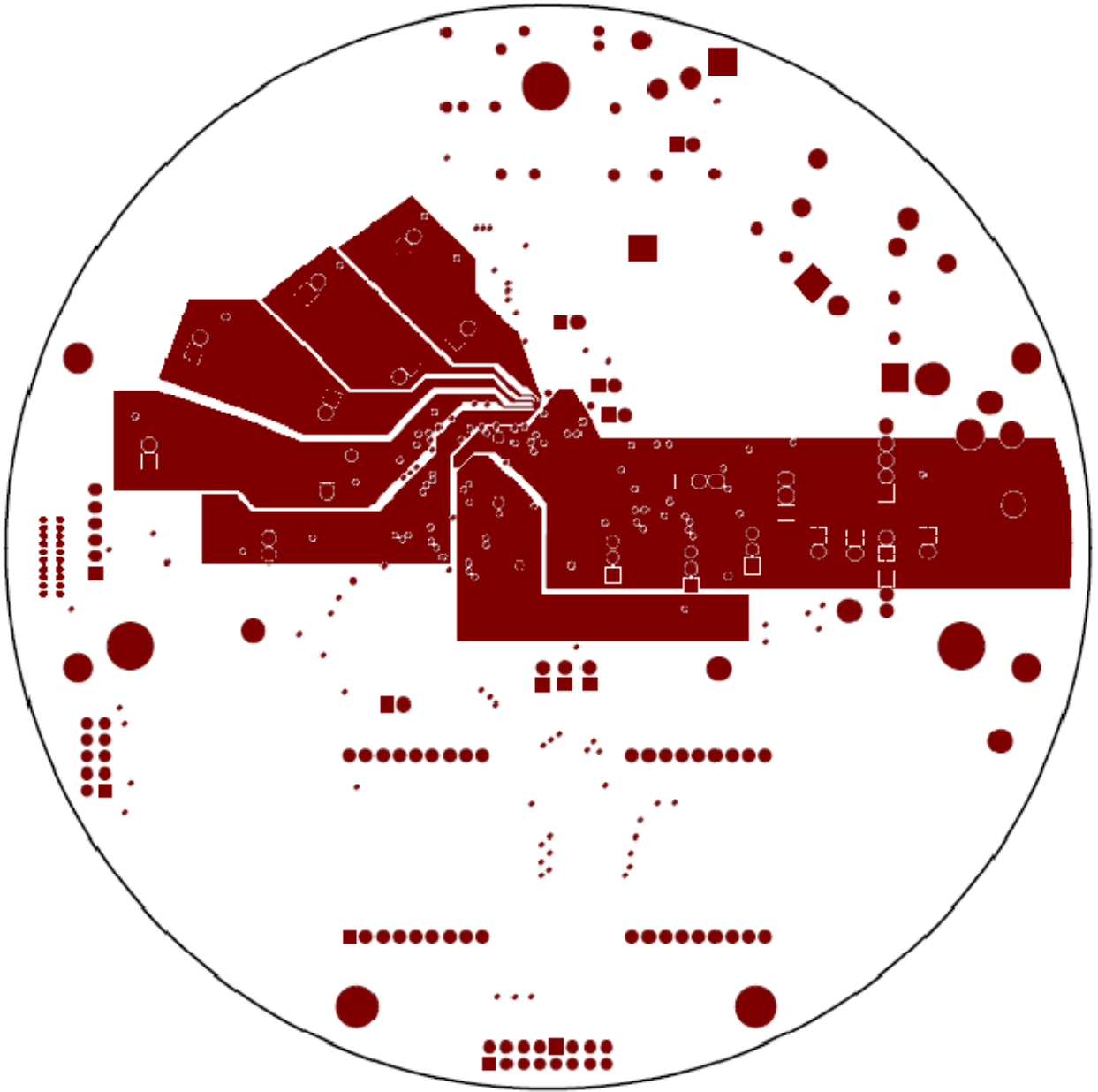


Figure 4-8: TERIDIAN D6534T14A2 Demo Board: V3P3 Layer



## 4.2 DEBUG BOARD DESCRIPTION

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

Table 4-2: Debug Board: Bill of Material

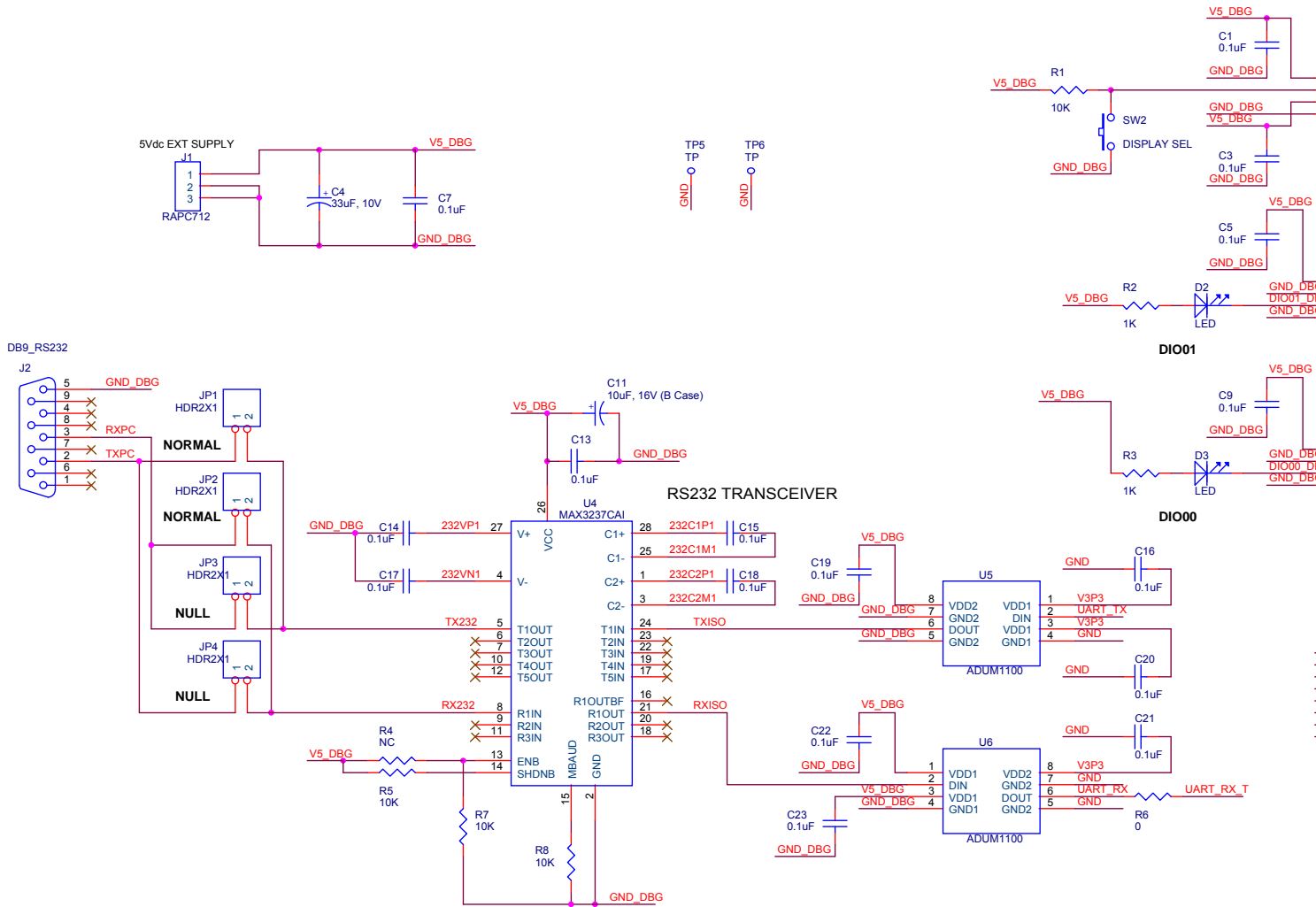


Figure 4-10: Debug Board: Electrical Schematic

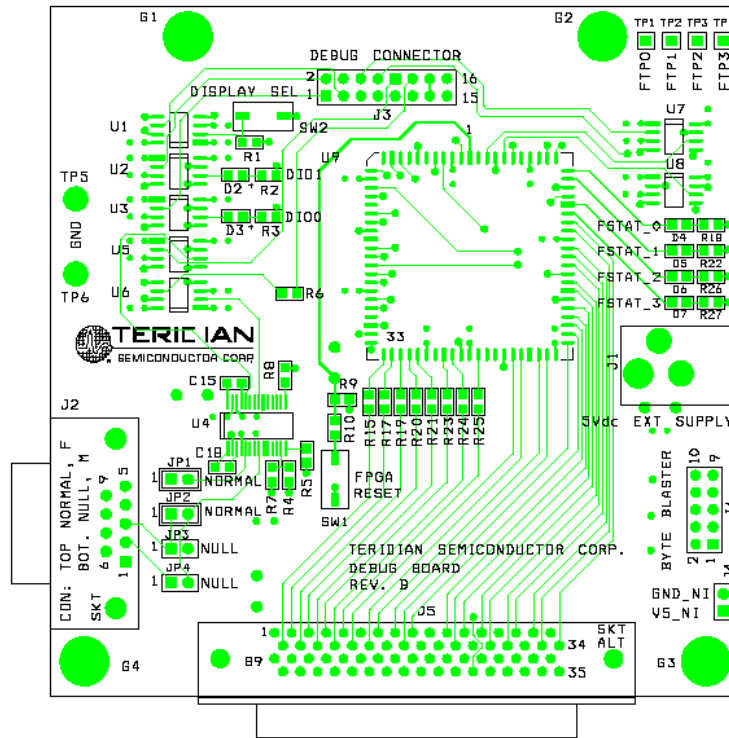


Figure 4-11: Debug Board: Top View

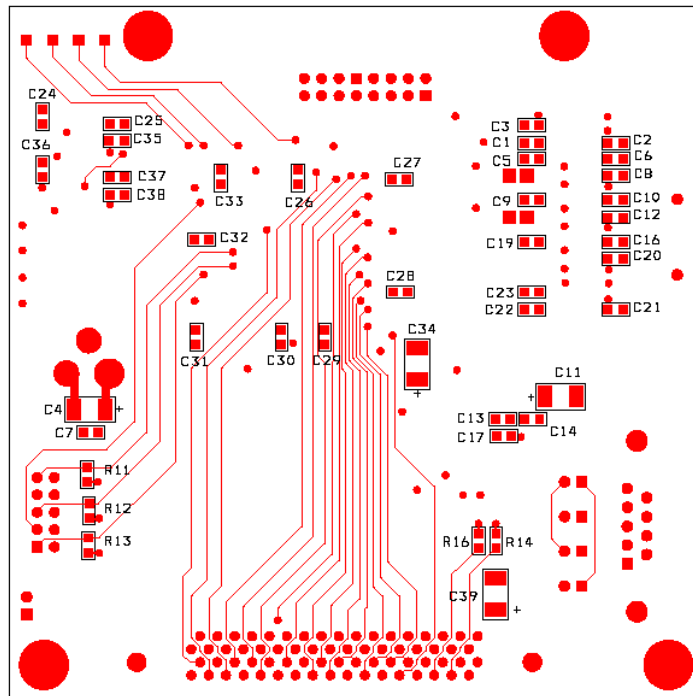


Figure 4-12: Debug Board: Bottom View

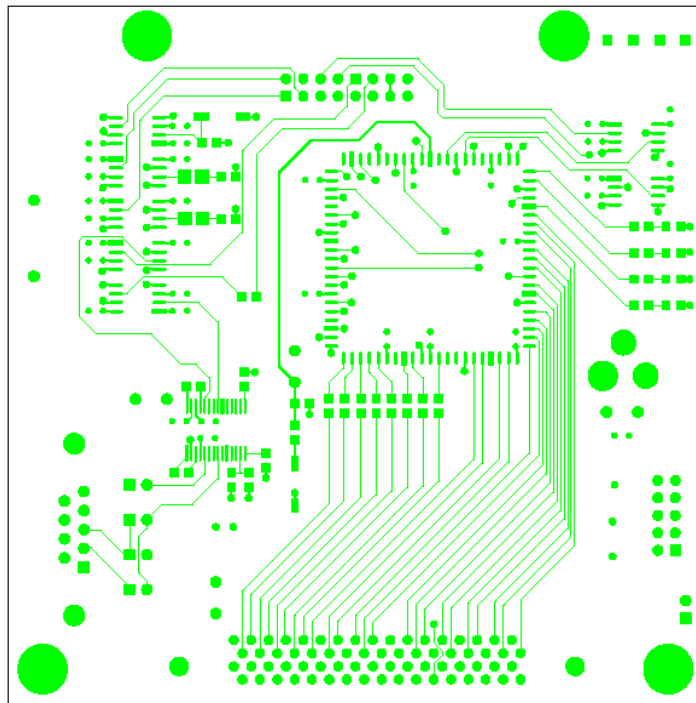


Figure 4-13: Debug Board: Top Signal Layer

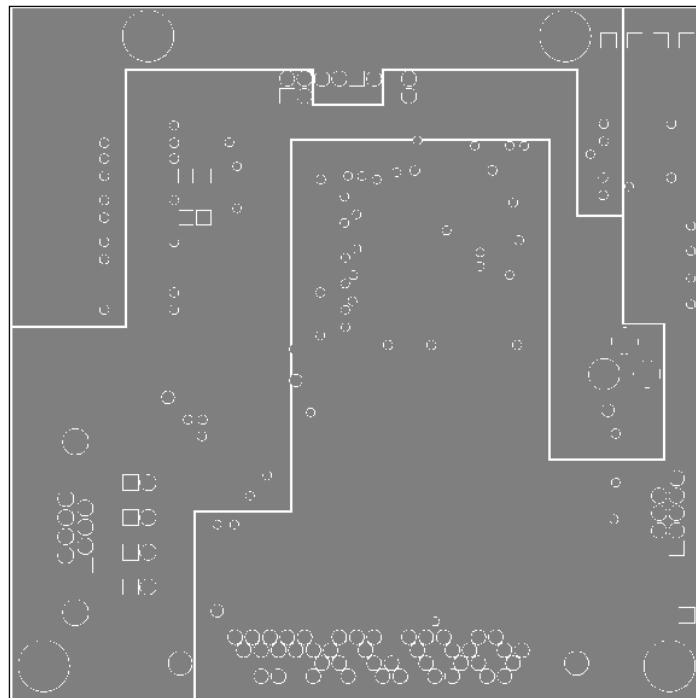


Figure 4-14: Debug Board: Middle Layer 1 (Ground Plane)

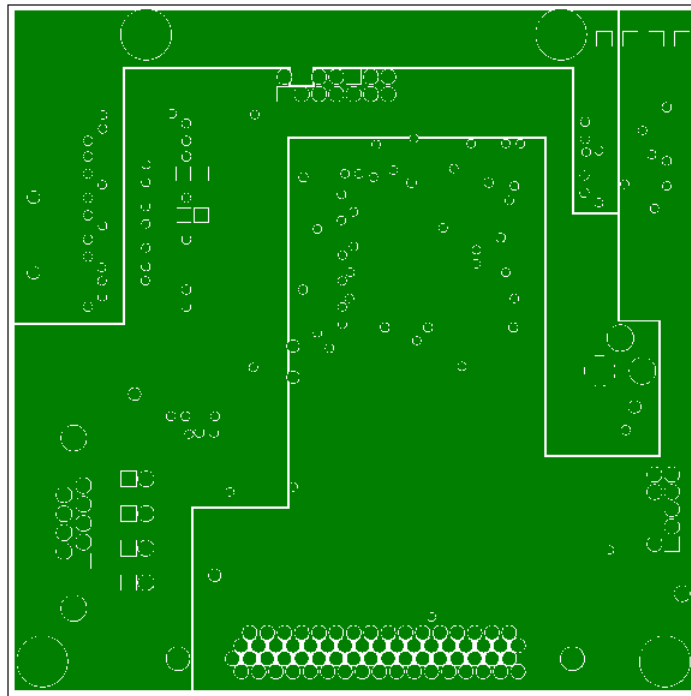


Figure 4-15: Debug Board: Middle Layer 2 (Supply Plane)

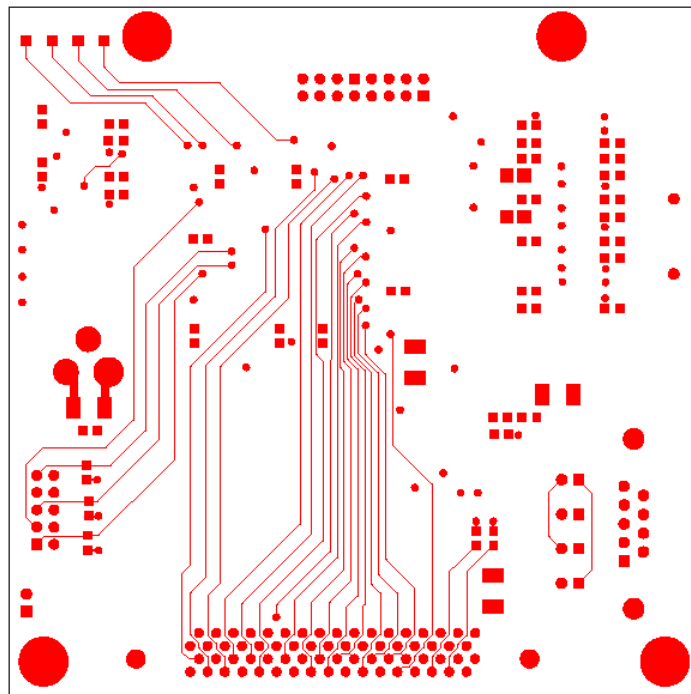


Figure 4-16: Debug Board: Bottom Trace Layer



## 4.3 71M6534H IC DESCRIPTION

### Power/Ground Pins:

| 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 3.3V power supply should be connected to this pin. It must be the same voltage as V3P3SYS.   |
| V3P3SYS | P    | System 3.3V supply. This pin should be connected to a 3.3V power supply.  |
| V3P3D   | O    | Auxiliary voltage output of the chip, controlled by the internal 3.3V selection switch. In mission mode, this pin is internally connected to V3P3SYS. In BROWNOUT mode, it is internally connected to VBAT. This pin is floating in LCD and sleep mode. |
| VBAT    | P    | Battery backup power supply. A battery or super-capacitor is to be connected between VBAT and GNDD. If no battery is used, connect VBAT to V3P3SYS.   |
| V2P5    | O    | Output of the internal 2.5V regulator. A 0.1 $\mu$ F capacitor to GNDA should be connected to this pin.   |

### Analog Pins:

| 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. In single-ended mode, the IXN pin should be tied to V3P3A.  |
| 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.  |
| V1                                     | I    | Comparator Input: This pin is a voltage input to the internal comparator. The voltage applied to the pin is compared to the internal VBIAS voltage (1.6V). If the input voltage is above VBIAS, the comparator output will be high (1). If the comparator output is low, a voltage fault will occur. A series 5k $\Omega$ resistor should be connected from V1 to the resistor divider. |
| V2, V3                                 | I    | Comparator Inputs: These pins are voltage inputs to internal comparators. The voltage applied to these pins is compared to the internal BIAS voltage of 1.6V. If the input voltage is above VBIAS, the comparator outputs will be high (1).   |
| VBIAS                                  | O    | Low impedance output for use in biasing current sensors and voltage dividers.   |
| VREF                                   | O    | Voltage Reference for the ADC. This pin should be left open.  |
| XIN<br>XOUT                            | I    | Crystal Inputs: A 32kHz crystal should be connected across these pins. Typically, a 33pF capacitor is also connected from XIN to GNDA and a 15pF capacitor is connected from XOUT to GNDA. It is important to minimize the capacitance between these pins. See the crystal manufacturer datasheet for details.  |



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

**Digital Pins:**

| Name   | Type | Description   |
|--|------|---|
| COM3, COM2,<br>COM1, COM0  | O    | LCD Common Outputs: These 4 pins provide the select signals for the LCD display.  |
| SEG0...SEG2,<br>SEG7, SEG8,<br>SEG12...SEG18,<br>SEG20...SEG23   | O    | Dedicated LCD Segment Output.   |
| SEG24/DIO4<br>...<br>SEG50/DIO30                                 | I/O  | Multi-use pins, configurable as either LCD SEG driver or DIO. (DIO4 = SCK, DIO5 = SDA when configured as EEPROM interface, WPULSE = DIO6, VARPULSE = DIO7 when configured as pulse outputs)   |
| SEG55/E_<br>ISYNC_BRKRQ  | I/O  | Multiuse pin, configurable as either LCD SEG driver or Emulator Handshake.  |
| SEG54/E_TBUS3<br>SEG53/E_TBUS2<br>SEG52/E_TBUS1<br>SEG51/E_TBUS0 | I/O  | Multiuse pins, configurable as either LCD SEG driver or Emulator Trace Bus.   |
| SEG56/DIO36<br>...<br>SEG75/DIO55                                | I/O  | Multi-use pins, configurable as either LCD SEG driver or DIO.   |
| SEG3/PCLK<br>SEG4/PSDO<br>SEG5/PCSZ<br>SEG6/PSDI                 | I/O  | Multi-use pins, configurable as either LCD SEG driver or SPI PORT.  |
| DIO3, DIO56<br>DIO57, DIO58                                      | I/O  | Dedicated DIO pins.   |
| E_RXTX/SEG9  | I/O  | Multi-use pins, configurable as either emulator port pins (when ICE_E pulled high) or LCD SEG drivers (when ICE_E tied to GND).   |
| E_RST/SEG11  | I/O  |   |
| E_TCLK/SEG10   | O    |   |
| ICE_E  | I    | ICE enable. When zero, E_RST, E_TCLK, and E_RXTX become SEG32, SEG33, and SEG38 respectively. For production units, this pin should be pulled to GND to disable the emulator port.  |
| CKTEST/SEG19   | O    | Multi-use pin, configurable as either Clock PLL output or LCD segment driver. Can be enabled and disabled by <i>CKOUT_EN</i> .  |
| TMUXOUT  | O    | Digital output test multiplexer. Controlled by <i>DMUX[3:0]</i> .   |
| OPT_RX/DIO1  | I/O  | Multi-use pin, configurable as either Optical Receive Input or general DIO. When configured as OPT_RX, this pin receives a signal from an external photo-detector used in an IR serial interface.   |
| OPT_TX/DIO2  | I/O  | Multi-use pin, configurable as Optical LED Transmit Output, WPULSE, RPULSE, or general DIO. When configured as OPT_TX, this pin is capable of directly driving an LED for transmitting data in an IR serial interface.  |
| 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 30µA (nominal) current source pull-down. No external reset circuitry is necessary. |

Digital Pins (Continued):

| Name | Type | Description   |
|------|------|---|
| RX   | I    | UART input.   |
| TX   | O    | UART output.  |
| TEST | I    | Enables Production Test. Must be grounded in normal operation.  |
| PB   | I    | Push button input. Should be at GND when not active. A rising edge sets the <i>IE_PB</i> flag. It also causes the part to wake up if it is in SLEEP or LCD mode. PB does not have an internal pull-up or pull-down. |



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

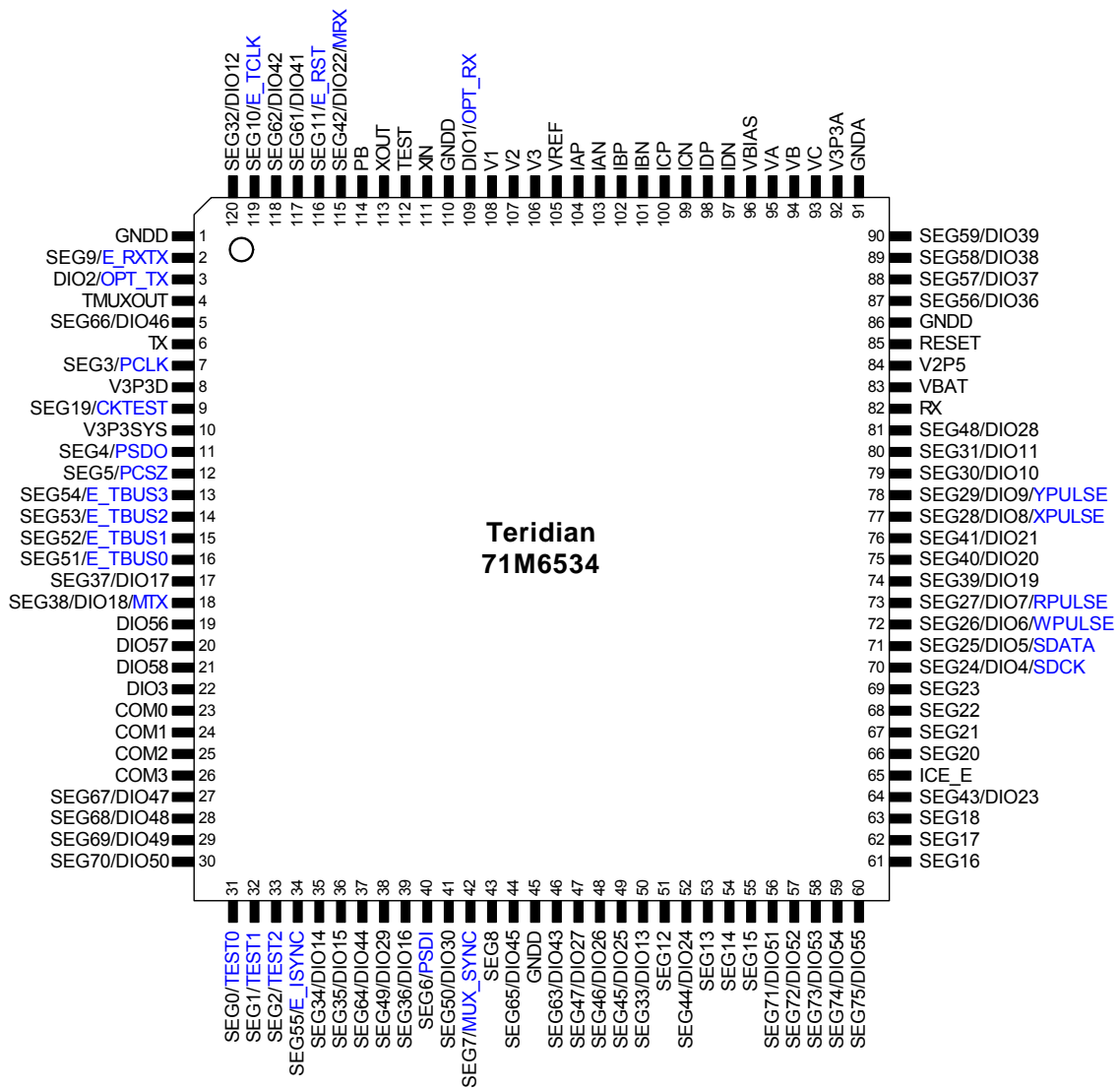


Figure 4-17: TERIDIAN 71M6534H epLQFP100: Pinout (top view)

## 4.4 FORMULAE FOR FAST CALIBRATION

A method for non-trigonometric derivation of the factors for the fast calibration is shown below.

The phase angle  $\phi$  is calculated as follows:

$$\tan \phi = \frac{-VARh_{measured}}{Wh_{measured}}$$

The value  $\frac{-VARh_{measured}}{Wh_{measured}}$  for  $\tan(\phi)$  can be used directly without calculating trigonometric values when determining the values for  $PHAD\_n$ . We simplify the rather complex term for  $PHADJ\_n$

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

introduced in Calibration Theory section by substituting the constant parts of it with the variables a, b, and c:

$$a = 1 + (1 - 2^{-9})^2 - 2(1 - 2^{-9}) \cdot \cos(2\pi f_0 T)$$

$$b = (1 - 2^{-9}) \sin(2\pi f_0 T)$$

$$c = 1 - (1 - 2^{-9}) \cos(2\pi f_0 T)$$

Now we can calculate a, b, and c for 50Hz and for 60Hz, and then insert the values back into the original equation for  $PHADJ$ , while at the same time writing 1048576 for  $2^{20}$ :

$$PHADJ\_n = 1048576 \frac{0.02229 \frac{-VARh_{measured}}{Wh_{measured}}}{0.1487 - 0.0131 \frac{-VARh_{measured}}{Wh_{measured}}} \quad (\text{for 60Hz metering})$$

$$PHADJ\_n = 1048576 \frac{0.0155 \frac{-VARh_{measured}}{Wh_{measured}}}{0.1241 - 0.09695 \frac{-VARh_{measured}}{Wh_{measured}}} \quad (\text{for 50Hz metering})$$

For the voltage, the ratio of the applied and measured RMS voltages determines the calibration factor:

$$CAL\_VA = 16384 \frac{V_{applied}}{V_{measured}}$$

For the current calibration we have to realize that the meter's signal is the vector sum of the real ( $Wh$ ) and imaginary ( $VARh$ ) parts of the energy.  $i_{gain}$ , the current gain, must be scaled to eliminate power errors and rotated in the complex plane to eliminate phase error. Let  $\varphi$  be the phase adjust angle.

A vector is rotated by multiplying by a 2x2 matrix:

$$\cos(\varphi) \quad -\sin(\varphi)$$

$$\sin(\varphi) \quad \cos(\varphi)$$

The linear adjustment vector is:

$$\frac{Wh_{applied}}{Wh_{measured} \cdot V_{gain}} \quad \frac{VARh_{applied}}{VARh_{measured} \cdot V_{gain}}$$

$i_{gain}$  is the real part of multiplying the rotation matrix by the linear adjustment vector.:

$$i_{gain} = \cos(\varphi) \frac{Wh_{applied}}{Wh_{measured} \cdot V_{gain}} + \sin(\varphi) \frac{VARh_{applied}}{VARh_{measured} \cdot V_{gain}}$$

The term after the + sign is negligible, since the applied reactive energy is near zero, so  $i_{gain}$  becomes:

$$i_{gain} = \cos(\varphi) \frac{Wh_{applied}}{Wh_{measured} \cdot V_{gain}}$$

Furthermore,

$$\cos(\varphi) = \frac{Wh_{measured}}{VAh_{measured}}$$

which simplifies the equation for  $i_{gain}$  to

$$i_{gain} = \frac{Wh_{applied}}{VAh_{measured} \cdot V_{gain}}$$

$VAh_{measured}$  is easy to calculate from  $Wh_{measured}$  and  $VARh_{measured}$ , and it turns out to have good linearity and repeatability due to the signal processing performed in the 71M65XX chip.

$$VAh_{measured} = \sqrt{Wh_{measured}^2 + VARh_{measured}^2}$$

The CE uses the value 16384 for unity gain. We can then substitute:

$$CAL\_IA = \frac{16384 \cdot Wh_{applied}}{VAh_{measured} \cdot V_{gain}}$$

#### 4.4.1 REVISION HISTORY

| Revision # | Date       | Description  |
|------------|------------|--|
| 1.0        | 10/16/2007 | Document Creation for D6534T14A1 board   |
| 1.1        | 11/27/2008 | Updated schematics and values used for capacitors at XIN/XOUT pins.                                      |
| 2.0        | 5/28/2008  | Updated document to match board revision 2 (D6534T14A2): Schematics, BOM, board description, and layout. |

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