TERIDIAN SEMICONDUCTOR CORP.

A Maxim Integrated Products Brand

78M6612 Split-Phase Firmware V1.0 Description Document

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Table of Contents

Figures

Tables

1 Introduction

This document describes the 78M6612 Split-Phase Firmware V1.0, which can be used with the Teridian 78M6612 power and energy measurement IC. This firmware specifically provides wideband measurements in a split-phase system. The computations are on a phase offset of 80° providing the following measurements:

- Voltage RMS (Line1, Line2)
- Current RMS (Line1, Line2)
- Active Power (Line1, Line2, aggregate)
- Apparent Power (Line1, Line2, aggregate)
- Reactive Power (Line1, Line2, aggregate)
- Power Factor (Line1, Line2)
- Line Frequency

The 78M6612 Split-Phase Firmware also provides simple methods for calibration and alarm monitoring. The serial UART interface is used for communications with the host.

1.1 Hardware Assignments

The measurement (sensor) interface for the 78M6612 must be configured as shown in Figure 1 to be compatible with the firmware build.

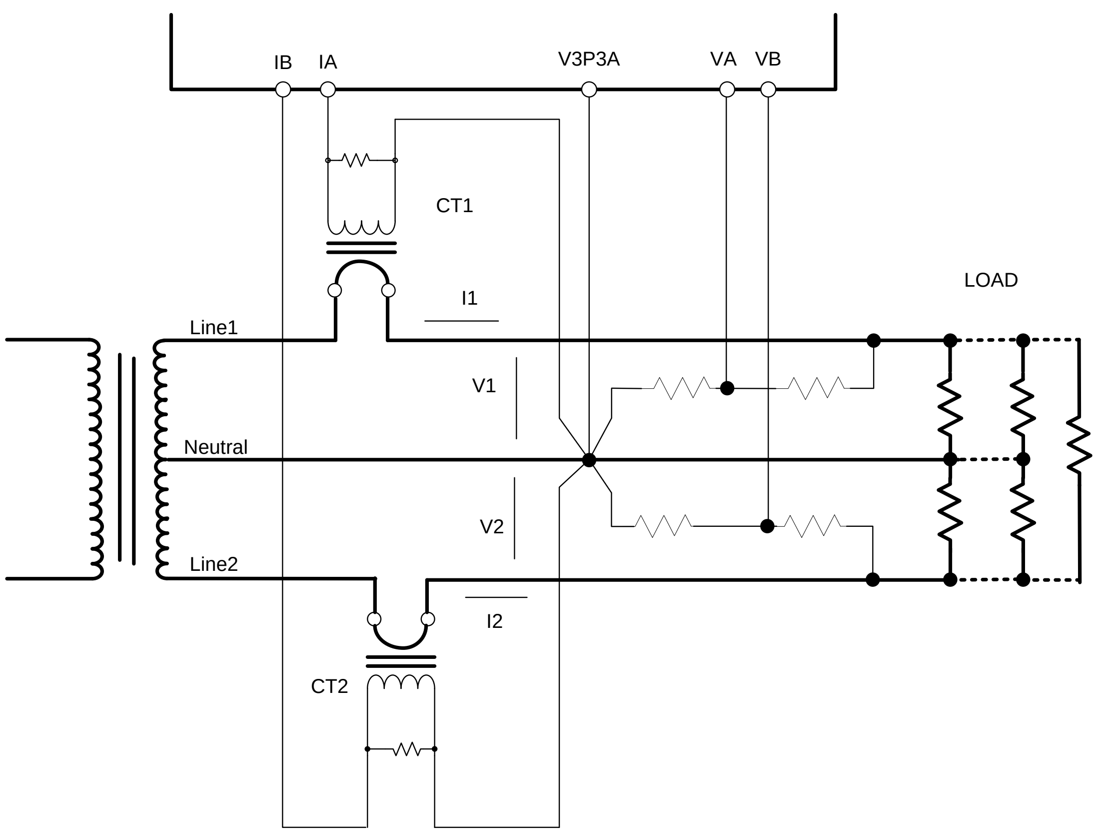

Figure 1: Simplified Connection Diagram of a Split-Phase System

All measurement results, command routines, and configuration registers are accessible through the TX and RX pins of serial 0 interface (UART0/RS232). Additional 78M6612 pins utilized by this firmware include:

- DIO20 used as a configurable status alarm output pin.
- DIO4, DIO5, and DIO8 as status outputs for Ready, Active, and Fault.
- DIO17 User Configurable Fault.
- DIO6 used as an optional pulse output.

RTC (Real Time Clock), LCD Driver, and Battery Modes are not supported by this firmware.

1.2 Sampling and Update Rates

This firmware utilizes an effective sampling rate of 3641 samples per second for each sampled input. While the CE continuously accumulates sampled data at the effective sample rate, status and measurement data updates to the MPU are less frequent. These updates include:

- Sag status is updated every Mux cycle for low-latency voltage alarm detection.
- Measurement outputs and all other alarm conditions are updated every accumulation interval which is set to 1.0 seconds for this firmware build.

1.3 Description of Wideband Measurement Equation

The 78M6612 Split-Phase Firmware provides the user with continuously updating "Wideband" measurement data (on 1 second increments by default). Wideband measurements are generally of interest when measuring in systems such as switched mode power supplies that tend to have non-sinusoidal (high harmonic) waveforms.

Table 2 lists the basic measurement equations for the Wideband methods.

Table 1: Measurement Equations Definitions

Symbol	Parameter	Wideband Equation
V	RMS Voltage	$V = \sqrt{\sum v(t)^2}$
I	RMS Current	$I = \sqrt{\sum i(t)^2}$
P	Active Power	$P = \sum (i(t) * v(t))$
Q	Reactive Power	$Q = \sqrt{(S^2 - P^2)}$
S	Apparent Power	$S = V * I$
PF	Power Factor	P/S
PA	Phase Angle	ACOS (P/S)

Figure 2 shows the data process flow for each input including the calculations. The output registers are marked in bold while some of the inputs (coefficients) are marked in blue.

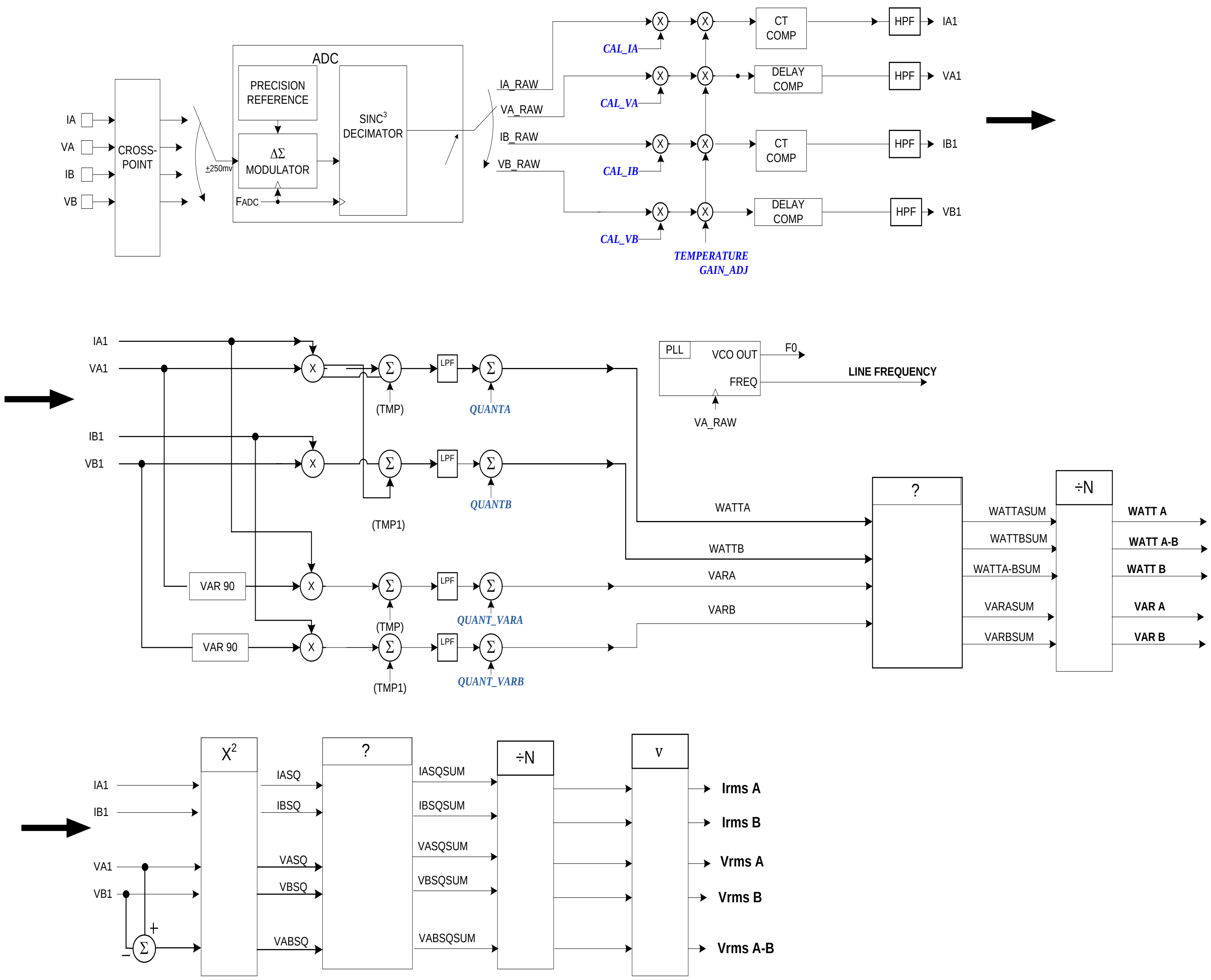

Figure 2: Data Processing Flow

2 Functional Description

This section summarizes the functional operation of the 78M6612 Split-Phase Firmware. Reference the data sheet and application notes for more information on terminologies and detailed IC operation.

2.1 Initialization and Start-up

Upon power-up, both MPU and Compute Engine (CE) cores start executing the application code from designated blocks of Flash memory. Status indicators for 'Ready' and 'Active' are available to the host via DIO pins.

2.2 AC Measurement and Monitoring

The integrated AFE and CE function as a data acquisition system, controlled by the MPU. The low-voltage analog input signals are sampled and stored in CE DRAM where they are processed by the CE. This firmware utilizes an effective sampling rate of 3641 samples per second for each individual channel. The CE, a dedicated 32-bit signal processor, performs the computations necessary to perform all the measurements. The CE calculations and processes include:

- Multiplication of each current sample with its associated voltage sample to obtain the energy per sample (when multiplied with the constant sample time).
- Frequency-insensitive delay cancellation on all channels (to compensate for the delay between samples caused by the multiplexing scheme).
- Monitoring of the input signal frequency (for frequency and phase information).
- Monitoring of the input signal amplitude (for sag detection).
- Scaling of the processed samples based on calibration coefficients.

At the end of each accumulation interval, these atomic measurements are provided to the MPU for post-processing. Alternate multiplexer cycles also gather measurements of the IC's junction temperature for additional compensation in the MPU. Post-processing functions handled by the MPU at the end of every accumulation interval include:

- Compensation for environmental variables.
- Calculation of apparent power, power factor, phase angle.
- Comparing of measurement outputs to configurable alarm thresholds.
- Scaling and formatting of output measurement data.
- Updating of all output registers (data and alarm status).

2.2.1 Alarm Monitoring

Table 3 lists the available bits of the STATUS and MASK registers. The user sets the thresholds for each alarm as well as the MASK registers to determine which bits will cause an ALARM and which alarm is output on pin DIO20. Status bits clear automatically when the alarming condition no longer exists.

Table 2: Alarm Status/Mask Registers

Bit	Name	Function
31-24		Reserved
23	REV	Line-Neutral reversed
22	CreepB	Line 2 creep
21	CreepA	Line 1 creep
20	MFault	Alarm for multi-fault event
19	ImaxT	Total current limit exceeded
18	PFmaxB	Line 2 power factor limit exceeded
17	PFminB	Line 2 power factor limit exceeded
16-15		Reserved
14	ImaxB	Line 2 rms current limit exceeded
13		Reserved
12	PFmaxA	Line 1 power factor limit exceeded
11	PFminA	Line 1 power factor limit exceeded
10-9		Reserved
8	ImaxA	Line 1 rms current limit exceeded
7	LopenA	Line 1 open
6		Reserved
5	LopenB	Line 2 open
4	VSag	Voltage sag event detected
3	Fmax	Line frequency limit exceeded
2	Fmin	Line frequency limit exceeded
1	Tmax	Temperature limit exceeded
0	Tmin	Temperature limit exceeded

2.2.2 Sag Detection

The 78M6612 Split-Phase Firmware includes the sag detection function. The sag is a momentary or permanent decrease of line voltage amplitude. The causes can be several, for example: overload, power line problems, and transients.

The sag detection can be used to monitor or record the quality of the power line or utilize the sag alarm pin to notify external devices (for example a host microprocessor) of a pending power-down. The external device can then enter a power-down mode (for example, saving data or recording the event) before a power outage.

Figure 3 shows a typical sag event.

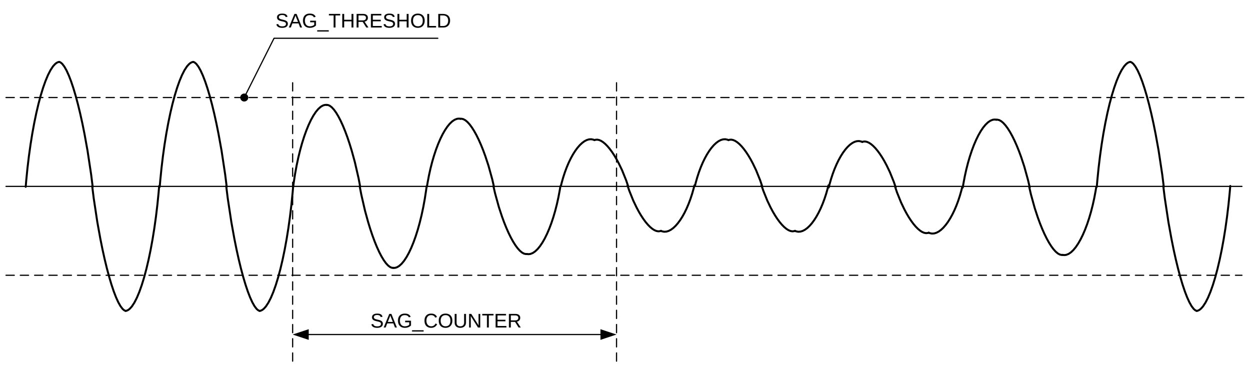

Figure 3: Typical Sag Event

The sag detection is base on a voltage threshold (SAG_THR), and a counter value (time). The counter is updated at the ADC sample rate and starts whenever the voltage is below the SAG_THR value for the VA input. The alarm bit and alarm pin are set if the counter exceeds the SAG_CNT value.

2.3 Configuration and Control

2.3.1 Input Registers

The following parameters are configurable by the user via input registers:

- Sensor range and configuration.
- Calibration targets, settings, and coefficients.
- Alarm Thresholds and Mask Settings.
- Squelch or 'CREEP' Thresholds for measurement outputs.

2.3.2 Updating Flash

The default values of all input registers can be updated by the user at run-time. The following Flash update routines save the current value of any input register as the default. Care must be taken when invoking the Flash update commands –]U or)U – as factory default parameters might be overwritten with new values.

To Update CE Variables	**To Update MPU Variables**
CE0<CR>]U<CR> CE1<CR>	CE0<CR>)U<CR> CE1<CR>

2.3.3 Sensor (Hardware) Configuration

A few parameters specific to the hardware implementation may require one time configuration. The firmware allows for parameters to be modified by the user at run-time and saved to Flash. These hardware-specific parameters include:

- VMAX and IMAX registers define the upper and lower values of the ADC range. These parameters allow the scaling of raw data to real-world values.
- The CESTATE register contains a bit that selects either single-ended voltage sensing (for non-isolated sensor configurations) or differential voltage sensing (for isolated sensor configurations).

2.3.4 Calibration

As with any measurement system, there are sets of compensation coefficients or parameters that are used to compensate for system inaccuracies. Input registers for all coefficients can be manually modified and saved to Flash. Alternatively, high-level calibration routines can be invoked. These routines automatically determine the coefficients for common parameters and save them to Flash memory. The different types of compensation parameters include:

- Voltage – Offset for voltage sense circuit.
- Current – Offset for current sense circuit.
- Phase – Voltage-to-current phase offset introduced by transformer or filters in sense circuits.
- Temperature – Offset for junction temperature at room temp.
- Temperature – Coefficients for temperature curve.
- QUANT – Fixed offsets for voltage and current at light loads

The calibration routines compensate for sensors and system inaccuracy. The new coefficients computed during calibration are stored in the on-chip flash.

In order to perform a calibration, an external voltage source and external current source (or load) are required. The calibration routines have a target voltage and current for both phases to match. The target calibration voltage and current values are specified in the registers 0xC1 and 0xC2. Calibration Tolerance is also important to be predefined, for example the coefficients are modified until the measured current or voltage is within the specified tolerance from the target value. The voltage calibration tolerance register is at address 0xC4 while the current tolerance is specified in register 0xC5.

Other settings for calibration are average counts and maximum number of iterations.
The average counts represent the number of voltage measurements (register 0xC6) or current measurements (register 0xC7) averaged and used to be compared against the target.

Figure 4 shows a split-phase calibration test setup.

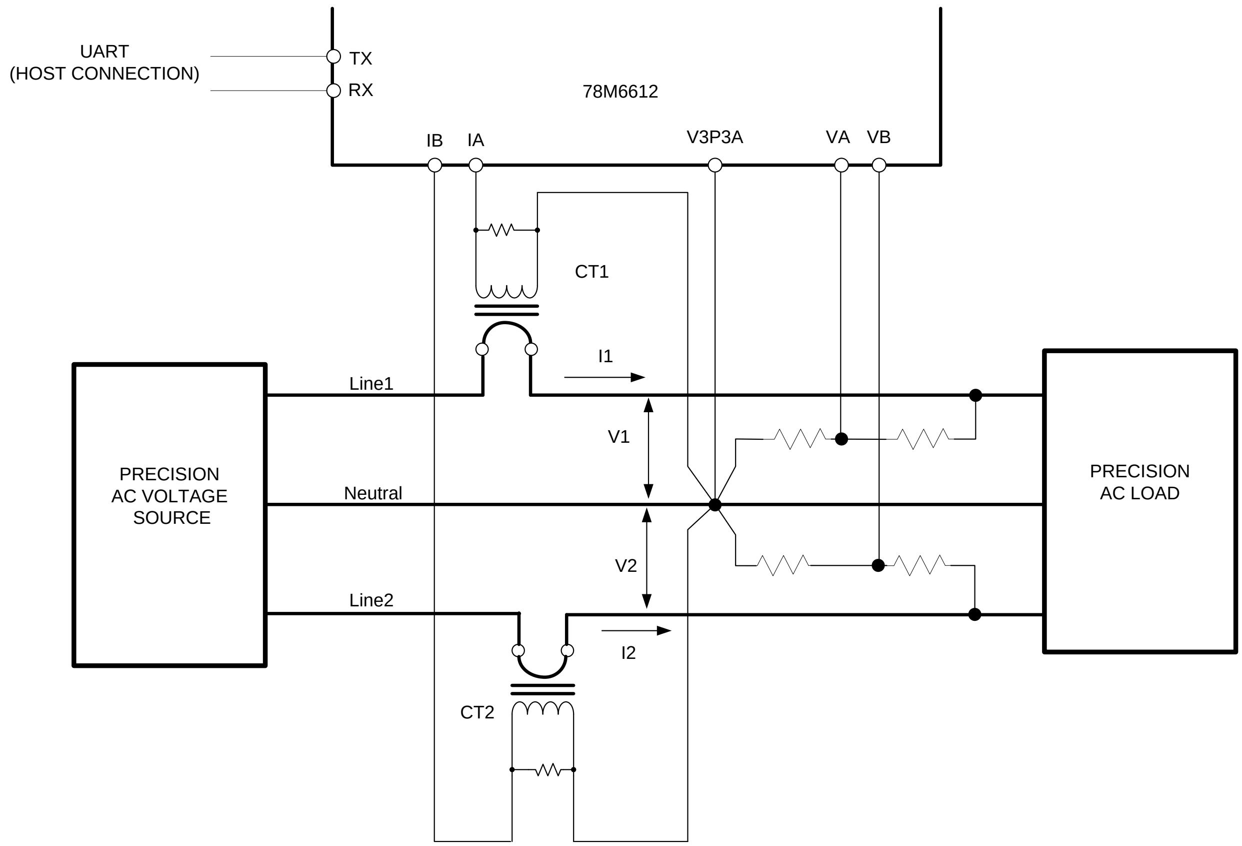

Figure 4: Split-Phase Calibration Test Setup

After turning on the relays, the voltage inputs are calibrated first and then the load currents are calibrated. The voltage calibration and current calibration each take a few seconds to complete. The Temperature calibration is done automatically during Voltage calibration. The characters following the prompt symbol **">"** are the CLI command characters. A following carriage return initiates the command.

```
>tc0
>clv
VCal OK
>cli
ICal 1 OK2 OK
```

Once the 78M6612 Split-Phase board is calibrated, it is recommended to read back and record the calibration coefficients. Should the firmware be updated in the future, the calibration coefficients can be easily restored.

There are four calibration coefficients: one for each voltage input and one for each current input. These four coefficients are read back using the ***]8????*** command.

```
>]8????
+11290 +11294 +16542 +16544
>_
```

3 Serial Communication

The serial communication with the 78M6612 takes place over a UART (UART0) interface. The default settings for the UART of the 78M6612, as implemented in this firmware, are given below:

Baud Rate: 38400bps
Data Bits: 8
Parity: None
Stop Bits: 1
Flow Control: Xon/Xoff

The host's serial interface port is required to implement these settings on its UART. To verify communication between the host and the 78M6612, the host must send a <CR> (carriage return) to the 78M6612. Communication is verified when the 78M6612 returns a > (greater than sign) known as the command prompt. An example is given below:

The host sends the following to the 78M6612:

<CR>

The 78M6612 sends the following back to the host:

>

3.1 CLI Interface

The Command Line Interface (CLI) provides a simple ASCII interface to access input and output registers and to invoke commands. The CLI interface connects to a HyperTerminal or any other terminal emulation SW. The CLI interface can also be used to interface to a host processor. Appendix A contains a description of the CLI commands and syntax.

4 Register Descriptions

This section describes the measurement outputs that can be obtained. The host accessing the measurement information from the 78M6612 more frequently will not result in any update in the information.

4.1 Measurement Output Registers

Table 3: MPU Outputs

Output	Location (hex)	LSB	Comment	Example
Delta Temperature	00	0.1 °C	Temperature difference from 22 °C.	If external temperature is 32 °C)00?<CR> Returns: +10.0
Line Frequency	01	0.01 Hz	Line Frequency.	If the line frequency is 60 Hz:)01?<CR> Returns: +60.00
Alarm Status	02		**Definition for Status Register** Bit 0 – Temperature limit exceeded. Bit 1 – Temperature limit exceeded. Bit 2 – Line Frequency limit exceeded. Bit 3 – Line Frequency limit exceeded. Bit 4 - Voltage sag event detected. Bit 5 – Line 2 open. Bit 6 – Reserved Bit 7 – Line 1 open. Bit 8 – Line 1 rms current limit exceeded. Bits 9:10 – Reserved Bit 11 – Line 1 power factor limit exceeded. Bit 12 – Line 1 power factor limit exceeded. Bit 13 – Reserved Bit 14 – Line 2 rms limit exceeded. Bits 15:16 – Reserved Bit 17 – Line 2 power factor limit exceeded. Bit 18 – Line 2 power factor limit exceeded. Bit 19 – Total current limit exceeded. Bit 20 – Alarm for multi-fault event. Bit 21 – Line 1 creep Bit 22 – Line 2 creep Bit 23 – Line/Neutral Reversed. Bits 24:31 – Reserved	Alarms become “1” when thresholds exceeded. Note: Additional Status Alert is Located at addr 0xBD (see Table 4) Note: When AC voltage input is less than or equal to 10 V_{RMS}, • Only MINVA alarm is active. • All measurements are forced to 0 except power factor, which is forced to 1. Note: The frequency measurement is forced to 0 as long as the SAG voltage alarm is active.
Vrms A	06	mVrms	Vrms voltage.	If the line voltage is 120 V)06?<CR> Returns: +120.000
Watts A	07	mW	Line Out A active power measurement (per second).	If 120 Watts are measured on Line Out A)07?<CR> Returns: +120.000

Output	Location (hex)	LSB	Comment	Example
Vrms B	26	mV	Vrms voltage	If the line voltage is 120 V)26?<CR> Returns: +120.000
Irms_wb A	2A	mA	Line Out A wideband rms current measurement.	If wideband current measured on Line Out A is 12 Amps)2A?<CR> Returns: +12.000
VARs_wb A	2B	mW	Line Out A wideband reactive power measurement (per second).	If wideband 120 VARs are measured on Line Out A)2B?<CR> Returns: +120.000
VAs_wb A	2C	mW	Line Out A wideband apparent power measurement (per second).	If wideband 120 VAs are measured on Line Out A)2C?<CR> Returns: +120.000
Power Factor_wb A	2D	–	Line Out A wideband power factor. The output will be between -0.950 and 1.000. Positive power factor is defined as current lagging voltage (inductive). Negative power factor is defined as voltage lagging current (capacitive).	If the wideband power factor on Line Out A is 0.95)2D?<CR> Returns: +0.950
Vrms A-B	46	mV	Vrms voltage Line-to-Line	If the line voltage is 240 V)46?<CR> Returns: +240.000
Watts B	47	mW	Line B active power measurement (per second).	If 120 Watts are measured on Line Out B)47?<CR> Returns: +120.000
Irms_wb B	6A	mArms	Line B wideband rms current measurement.	If wideband current measured on Line Out B is 12 Amps)6A?<CR> Returns: +12.000
VARs_wb B	6B	mW	Line B wideband reactive power measurement (per second).	If wideband 120 VARs are measured on Line Out B)6B?<CR> Returns: +120.000
VAs_wb B	6C	mW	Line B wideband apparent power measurement (per second).	If wideband 120 VAs are measured on Line Out B)6C?<CR> Returns: +120.000

Output	Location (hex)	LSB	Comment	Example
Power Factor_wb B	6D	–	Line B wideband power factor. The output will be between -0.950 and 1.000. Positive power factor is defined as current lagging voltage (inductive). Negative power factor is defined as voltage lagging current (capacitive).	If the wideband power factor on Line Out B is 0.95)6D?<CR> Returns: +0.950
Watts A-B	80	mW	Active power measurement (per second) aggregate. Line A and Line B	If 120 Watts are measured on both outlets)80?<CR> Returns: +120.000
Irms A-B	93	mArms	wideband Irms current measurement aggregate. Line A and Line B	If wideband current measured on both outlets is 12 Amps)93?<CR> Returns: +12.000
VARs_wb T	94	mW	wideband reactive power measurement aggregate. Line A and Line B	If wideband 120 VARs are measured on both outlets)94?<CR> Returns: +120.000
VAs_wb T	95	mW	wideband apparent power measurement aggregate. Line A and Line B	If wideband 120 VAs are measured on both outlets)95?<CR> Returns: +120.000

4.2 Configuration Input Registers

4.2.1 MPU Parameters

Table 4: MPU Parameters

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
VMAX A	A0	mVrms	+471.500	External rms voltage corresponding to 250 mVpk at the VA input of the 78M6612. It must be set high enough to account for overvoltages. Usually set to 471.500 V (471.500d).	If only using a 120V system, the user can set VMAX A to about 2x the maximum voltage for added resolution. Set VMAX A to 270V:)A0=+270.000<CR>
IMAX A	A2	mArms	+52.000	External rms current corresponding to 250 mVpk at the IA input of the 78M6612.	The default is set to 52 Amps for overhead. For added margin, in a system using current shunts IMAX could be changed as follows: IMAX= (Vpk/√2)/R_{shunt} For a 4 mΩ current shunt IMAX=44.19 Amps To set IMAX A:)A2=+44.190<CR>
IMAX B	A4	mArms	+52.000	External rms current corresponding to 250 mVpk at the IB input of the 78M6612.	The default is set to 52 Amps for overhead. For added margin, in a system using current shunts IMAX could be changed as follows: IMAX= (Vpk/√2)/R_{shunt} For a 4 mΩ current shunt IMAX=44.19 Amps)A4=+44.190<CR>
Reserved	B0 - BC		0	Reserved	Reserved
Additional Status	BD	–	1	Bit 0 – Reserved. Bit 1 – WPULSE Disable. Bit 2 – VCal Failure. Bit 3 – ICal1 Failure. Bit 4 – WCal1 Failure. Bit 5 – ICal2 Failure Bit 6 – WCal2 Failure	
Unused	BE	–			
Reserved	C0	–	0	Reserved	Reserved
Calibration Voltage	C1	mVrms	+120.000	Target line voltage (rms) used for calibration.	If the target line voltage for calibration is 220V, enter the following: >)C1=+220<CR>
Calibration Current	C2	mArms	+1.000	Target load current (rms) used for calibration.	If the target load current for calibration is 2A, enter the following: >)C2=+2<CR>

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Tolerance on Voltage	C4	mVrms	+0.010	Measured value to fall within this set tolerance of the target value (Calibration Voltage entry) for the calibration to be complete.	If the tolerance to the target voltage is desired to be more coarse, to within 0.1V, the user can enter the following: >)C4=+0.100<CR>
Tolerance on Current	C5	mArms	+0.010	Measured value to fall within this set tolerance of the target value (Calibration Current entry) for the calibration to be complete.	If the tolerance to the target current is desired to be more coarse, to within 0.1A, the user can enter the following: >)C5=+0.100<CR>
Average Count for Voltage	C6	1	+3	Number of voltage measurements taken and averaged to be compared to the target value (Calibration Voltage entry).	If the amount of averaging for the voltage measurement is desired to increase to 10 enter the following: >)C6=+10<CR>
Average Count for Current	C7	1	+3	Number of current measurements taken and averaged to be compared to the target value (Calibration Current entry).	If the amount of averaging for the current measurement is desired to increase to 10 enter the following: >)C7=+10<CR>
Max Iteration for Voltage	C8	1	+10	Number of attempts to reach the target value (Calibration Voltage entry) within the programmed tolerance.	If maximum number of iterations to be tried for obtaining the target value of voltage within the set tolerance (at C4) is to be reduced to 5, then enter: >)C8=+5<CR>
Max Iteration for Current	C9	1	+10	Number of attempts to reach the target value (Calibration Voltage entry) within the programmed tolerance.	If maximum number of iterations to be tried for obtaining the target value of power within the set tolerance (at C5) is to be reduced to 5, then enter: >)C9=+5<CR>
Tolerance on Watts	CA	mW	+0.010	Measured value to fall within this set tolerance of the target value (Calibration Voltage multiplied by the calibration current entries) for the calibration to be complete.	If the tolerance to the target power is desired to be more coarse, to within 0.1W, the user can enter the following: >)CA=+0.100<CR>
Average Count for Watts	CB	1	+3	Measured value to fall within this set tolerance of the target value (Calibration Voltage multiplied by the calibration current entries) for the calibration to be complete.	If the amount of averaging for the power measurement is desired to increase to 10 enter the following: >)CB=+10<CR>
Max Iteration for Watts	CC	1	+10	Number of attempts to reach the target value (Calibration Voltage multiplied by the calibration current entries) within the programmed tolerance.	If maximum number of iterations to be tried for obtaining the target value of power within the set tolerance (at CA) is to be reduced to 5, then enter: >)CC=+5<CR>

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Calibration WRATE	CD	1	+4860	Entry for WRATE during the calibration step only. After calibration, WRATE returns to the value entered in]0F.	
Calibration Temperature	CE	0.1°C	+22.0	Target nominal temperature for calibration.	If the user desires the target nominal temperature to be 25°C, then set as follows: >)CE=+25.0<CR>
Calibration Watts	CF	mW	120.000	Target Watts used for calibration.	If the target Watts for calibration is 240, enter the following: >)CF=+240.000<CR>
Temp Alarm Min Threshold	D0	0.1°C	+0.0°C	Minimum Temperature Alarm Threshold. A temperature below this threshold will set the alarm (bit 0 of the Alarm Status Register).	If the minimum temperature threshold is to be change to 10°C then set as follows: >)D0=+10.0
Temp Alarm Max Threshold	D1	0.1°C	+70°C	Maximum Temperature Alarm Threshold. A temperature above this threshold will set the alarm (bit 1 of the Alarm Status Register).	If the maximum temperature threshold is to be change to 50°C then set as follows: >)D1=+50.0
Frequency Minimum Threshold	D2	0.1Hz	+59.0	Minimum Frequency Alarm Threshold. A frequency below this threshold will set the alarm (bit 2 of the Alarm Status Register).	If the minimum frequency threshold is to be changed to 59.5 Hz then enter the following: >)D2=+59.5
Frequency Maximum Threshold	D3	0.1Hz	+61.0	Maximum Frequency Alarm Threshold. A frequency above this threshold will set the alarm (bit 3 of the Alarm Status Register).	If the maximum frequency threshold is to be changed to 60.5 Hz then enter the following: >)D2=+60.5
SAG Voltage Alarm Threshold	D4	mVpk	+80.0	Sets an alarm (bit 4 of the Alarm Status Register) if voltage drops below the SAG threshold.	
Min Voltage Alarm Threshold	D5	mVrms	+100.000	Minimum voltage level selected to flag user (bit 5 of the Alarm Status Register).	To change the minimum voltage threshold from the 40 Volt default to 80 Volts:)D5=+80.000<CR>
Peak Voltage Alarm Threshold	D6	mVrms	+140.000	Peak voltage setting that user wishes to flag (bit 6 of the Alarm Status Register).	To change the peak voltage threshold from the default 407.3 Volts to 280 Volts:)D6=+280.000<CR>
Unused	D7-D8	–			

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Peak IA_wb Alarm Threshold	D9	mArms	+15.000	Maximum Wideband Current measured on the IA channel above which a flag must set (bit 8 of the Alarm Status Register).	If the peak wideband current threshold on Line Out A is to be changed from the default value of 15 Amps to 30 Amps then set as follows:)D9=+30.000<CR>
PFA_wb_Neg Threshold	DC	–	-0.700	Wideband Power Factor Negative Threshold for Line Out A. A less negative wideband power factor than this threshold will set an alarm (bit 11 of the Alarm Status Register). Only available if)F2 bit 2 is set to 1.	If the negative wideband power factor threshold on Line Out A is to be changed from the default to -0.6 then set as follows:)DC=-0.600<CR>
PFA_wb_Pos Threshold	DD	–	+0.700	Wideband Power Factor Positive Threshold for Line Out A. A positive wideband power factor less than this threshold will set an alarm (bit 12 of the Alarm Status Register).	If the positive wideband power factor threshold on Line Out A is to be changed from the default to +0.6 then set as follows:)DD=+0.600<CR>
Peak IB_wb Alarm Threshold	DF	mArms	+15.000	Maximum Wideband Current measured on the IB channel above which a flag must set (bit 14 of the Alarm Status Register).	If the peak wideband current threshold on Line Out B is to be changed from the default value of 15 Amps to 30 Amps then set as follows:)DF=+30.000<CR>
PFB_wb_Neg Threshold	E2	–	-0.700	Wideband Power Factor Negative Threshold for Line Out B. A less negative wideband power factor than this threshold will set an alarm (bit 17 of the Alarm Status Register). Only available if)F2 bit 2 is set to 1.	If the negative wideband power factor threshold on Line Out B is to be changed from the default to -0.6 then set as follows:)E2=-0.600<CR>
PFB_wb_Pos Threshold	E3	–	+0.700	Wideband Power Factor Positive Threshold for Line Out B. A positive wideband power factor less than this threshold will set an alarm (bit 18 of the Alarm Status Register).	If the positive wideband power factor threshold on Line Out B is to be changed from the default to +0.6 then set as follows:)E3=+0.600<CR>
Alarm Mask_Reg	E6	–	9C597F	Alarm mask for bits in the Alarm Status register. A "0" masks the bit.	
Alarm Mask_Reg	E7	–	9C597F		

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Clear Control and Power Factor Polarity	F2	–	0	Clear Control and Power Factor Polarity Register: Bit 2 – Power Factor Polarity 0 = Power Factor is positive only. Negative alarm thresholds and alarms are not enabled. 1 = Power factor can be positive or negative. Bit1 – Clears Counts Bit 0 – Clears Accumulators.	

4.2.2 CE Parameters

The user does not typically need to alter the calibration parameters as they are automatically set by Calibration Commands.

Table 5: CE Parameters

CE Parameter	Location (hex)	LSB	Default	Comment	Example
CAL IA	08	16384 is the default and is a gain of 1. 32767 is max giving a gain of 2.	+13873	Gain constant for IA input.	If current on channel A is low by 1% scale the nominal number, 16384 by 1/(1-0.01). Number to be entered would be 16549:]08=+16549<CR> If current on channel A is high by 1% scale the nominal number, 16384 by 1/(1+0.01). Number to be entered would be 16222:]08=+16222<CR>
CAL IB	09	16384 is the default and is a gain of 1. 32767 is max giving a gain of 2.	+13873	Gain constant for IB input.	If current on channel B is low by 1% scale the nominal number, 16384 by 1/(1-0.01). Number to be entered would be 16549:]09=+16549<CR> If current on channel A is high by 1% scale the nominal number, 16384 by 1/(1+0.01). Number to be entered would be 16222:]09=+16222<CR>
CAL VA	0A	16384 is the default and is a gain of 1. 32767 is max giving a gain of 2.	+13024	Gain constant for VA input.	If voltage on channel A is low by 1% scale the nominal number, 16384 by 1/(1-0.01). Number to be entered would be 16549:]0A=+16549<CR> If current on channel A is high by 1% scale the nominal number, 16384 by 1/(1+0.01). Number to be entered would be 16222:]0A=+16222<CR>
CAL VB	0B	16384 is the default and is a gain of 1. 32767 is max giving a gain of 2.	+13024	Gain constant for VB input.	If voltage on channel B is low by 1% scale the nominal number, 16384 by 1/(1-0.01). Number to be entered would be 16549:]0B=+16549<CR> If current on channel A is high by 1% scale the nominal number, 16384 by 1/(1+0.01). Number to be entered would be 16222:]0B=+16222<CR>
PHASE_ADJ_IA	0C	-16384 ≤ PHASE_ADJ_IA ≤ +16384	0	Line Out A Phase adjustment =15 * PHASE_ADJ_IA * 2^{-14} (degrees)	No adjustment should be necessary when using current shunts.
PHASE_ADJ_IB	0D	-16384 ≤ PHASE_ADJ_IB ≤ +16384	0	Line Out B Phase adjustment =15 * PHASE_ADJ_IB * 2^{-14} (degrees)	No adjustment should be necessary when using current shunts.

CE Parameter	Location (hex)	LSB	Default	Comment	Example
CESTATE	0E		5005h	SAG CNT Bits 15:8 – determines the consecutive voltage samples below SAG_Threshold before a sag alarm is declared. 255 is the maximum value. Pulse Selection (PULSEL) Bit 4 0 – chooses Line Out A (IA input) for pulse generation 1 – chooses Line Out B (IB input) for pulse generation. Reserved Bit 3 Voltage Sensor Configuration Bit 2 0 – Isolated mode uses VA-VB for Voltage 1 – Non-isolated mode uses VA for voltage; V3P3 must be tied to NTRL; VB can be tied to EGND for reversal detection Pulse gain factor Bits 1 and 0 00 – 6x 01 – (6/64)x 10 – 96x 11 – 1.5x	]0E=5005 Selects at least 80 (50h) consecutive voltage samples below SAG_Threshold before SAG alarm. Select Line Out A as pulse source. Selects VA (non-isolated mode) for Voltage of both Outlets 1 and 2. Selects Pulse Gain Factor equal to 6/64.
WRATE	0F	Kh = VMAX A * IMAX A / (WRATE * X) 1.6826E+01 WattSec	+4860	Controls the number of pulses that are generated per measured Wh and VARh measurements.	]0F=+4860 Kh = 0.32 * Wh / pulse with X = 6/64, VMAX =600 V and IMAX = 52 A
Reserved	10			Reserved	
SAG Threshold	11	VMAX A *4.2551E-07 (Vpk)	+313350	The voltage threshold for SAG warnings. The default value is 80 Vpk if VMAX = 600 V.	]11=+313350 80 Vpk SAG Threshold.

CE Parameter	Location (hex)	LSB	Default	Comment	Example
QUANTA	12	VMAX A * IMAX A * 1.8541E-10 (Watt)	0	Compensation added to the Watt calculation for Line Out A. Used for compensation at low current levels. Keep below 10000d.	
QUANTB	13	VMAX A * IMAX B * 1.8541E-10 (Watt)	0	Compensation added to the Watt calculation for Line Out B. Used for compensation at low current levels. Keep below 10000d.	
QUANT VAR A	14	VMAX A * IMAX A * 1.8541E-10 (Watt)	0	Compensation added to the VAR calculation for Line Out A. Used for compensation at low current levels. Keep below 10000d.	
QUANT VAR B	15	VMAX A * IMAX B * 1.8541E-10 (Watt)	0	Compensation added to the VAR calculation for Line Out B. Used for compensation at low current levels. Keep below 10000d.	
QUANT IA	16	$(IMAX\ A)^2$ * 4.6351E-11 (A^2)	0	IA input compensation added for input noise and truncation in the squaring calculation for I^2. Used for compensation at low current levels. Keep below 10000d.	
QUANT IB	17	$(IMAX\ B)^2$ * 4.6351E-11 (A^2)	0	IA input compensation added for input noise and truncation in the squaring calculation for I^2. Used for compensation at low current levels. Keep below 10000d.	
Reserved	18	–	–	Reserved	Reserved

CE Parameter	Location (hex)	LSB	Default	Comment	Example
Gain Adjust	19	16384 is the default and is a gain of 1.	+16384	32767 is max giving a gain of 2.	To increase all channels equally by 1% scale the nominal number, 16384 by 1/(1-0.01). Number to be entered would be 16549:]19=+16549<CR> To decrease all channels 1% scale the nominal number, 16384 by 1/(1+0.01). Number to be entered would be 16222:]19=+16222<CR>
Reserved	1A	–	–	Reserved	Reserved
Reserved	1B	–	–	Reserved	Reserved

4.3 Address Content Summary

Table 6: MPU Output Summary Chart

	Address	Output
Measurement Data	00	Delta Temp
	01	Line Frequency
	02	Alarm Status
	06	Volts A
	07	Watts A
	26	Volts B
	2A	Current A
	2B	VAR A
	2C	VA A
	2D	Power Factor A
	46	Volts A-B
	47	Watts B
	6A	Current B
	6B	VAR B
	6C	VA B
	6D	Power Factor B
	80	Watts A-B
	93	Current A-B
	94	VAR A-B
	95	VA A-B

Table 7: MPU Input Summary Chart

Voltage	A0	Vmax
Current	A2	Imax (A)
	A4	Imax (B)
Status	BD	Alarms
Unused	BE	Unused
Reserved	C0	Reserved
Quick Calibration Parameters	C1	Calibration Voltage (Target)
	C2	Calibration Current (Target)
	C4	Tolerance on Voltage Calibration
	C5	Tolerance on Current Calibration
	C6	Average Count for Voltage
	C7	Average Count for Current
	C8	Max Iterations for Voltage
	C9	Max Iterations for Current
	CA	Tolerance on Watts Calibration
	CB	Average Count for Watts
	CC	Max Iterations for Watts
	CD	Calibration WRATE
	CE	Calibration Temperature
	CF	Calibration Watts (Target)
Temperature	D0	Min Temperature Alarm Threshold
	D1	Max Temperature Alarm Threshold
Frequency	D2	Min Frequency Alarm Threshold
	D3	Max Frequency Alarm Threshold
Alarms	D4	SAG Voltage Alarm Threshold
	D5	Min Voltage Alarm Threshold
	D6	Max Voltage Alarm Threshold
Unused	D7-D8	Unused
Alarm	D9	Max Current Alarm Threshold
Power Factor	DA-DB	Unused
	DC	Power Factor Alarm - Threshold
	DD	Power Factor Alarm + Threshold
Unused	DE	Unused
Alarm	DF	Max Current Alarm Threshold
Unused	E0-E1	Unused
Power Factor	E2	Power Factor - Threshold
	E3	Power Factor + Threshold
Alarm Mask for Status Regs	E6	Alarm Mask for Status
Alarm Mask for Alarm DI/O	E7	Alarm Mask for Alarm DIO
Unused	F1	Unused
Clear Control	F2	Accumulator and Counter Clear. Power Factor Polarity

Power Factor	DA	Unused
	DB	Unused
	DC	Power Factor Alarm - Threshold
	DD	Power Factor Alarm + Threshold
Unused	DE-DF	Unused
Unused	E0 – E5	Unused
Alarm Mask for Status Regs	E6	Alarm Mask for Status
Alarm Mask for Alarm DI/O	E7	Alarm Mask for Alarm DIO
Unused	F1	Unused
Clear Control	F2	Accumulator and Counter Clear. Power Factor Polarity

Table 8: CE Input Summary Chart

Calibration	08	Calibration Gain IA
	09	Unused
	0A	Calibration Gain VA
	0B	Unused
Phase Compensation	0C	Phase Adjust IA
	0D	Unused
CE Configuration	0E	CE State
Pulse Rate	0F	WRATE
	10	Reserved
SAG Threshold	11	SAG Threshold
Quantization Corrections	12	Quantization offset Watts Line A
	13	Quantization offset Watts Line B
	14	Quantization offset VAR A
	15	Quantization offset VAR B
	16	Quantization offset IA
	17	Quantization offset IB
	18	Reserved
Gain Adjust	19	Temperature Gain Adjust

5 Contact Information

For more information about Maxim products or to check the availability of the 78M6612, contact technical support at www.maxim-ic.com/support.

Revision History

Revision	Date	Description
1.0	5/24/2011	First publication.

Appendix A – Command Line Interface (CLI)

The Firmware includes an interface to the user or host called Command Line Interface (CLI). This interface facilitates communication via UART between the 78M6612 and the host processor. The CLI provides a simple ASCII interface to access input and output registers and to invoke commands. The CLI interface connects to a HyperTerminal or any other terminal emulation SW. The CLI interface can also be used to interface to a host processor.

A.1 Identification and Information Commands

The I command is used to identify the revisions of Demo Code and the contained CE code. The host sends the I command to the 78M6612 as follows:

>I<CR>

The 78M6612 will reply to the host the following:

MAX 78M6612 SPL S2+3 URT v114c, Feb 15 2011(c)2010 Maxim Integrated Products.
All Rights Reserved
>

A.2 Reset Commands

A soft reset of the 78M6612 can be performed by using the Z command. The soft reset restarts code execution at addr 0000 but does not alter flash contents. To issue a soft reset to the 78M6612, the host sends the following:

>Z<CR>

The W command acts like a hardware reset. Any accumulators in XRAM will retain their values.

Z	**Reset**	
Description:	Allows the user to cause soft resets.	
Usage:	Z	Soft reset.
	W	Simulates watchdog reset.

A.3 MPU Register Access Command

All the measurement calculations are stored in the MPU data range of the 78M6612. The host requests measurement information using the MPU data access command which is a right parenthesis

)

To request information, the host sends the MPU data access command, the address (in hex) which is requested, the format in which the data is desired (Hex or Decimal) and a carriage return. The contents of the addresses that would be requested by the host are contained in Section 4.

A.3.1 Individual Address Read

The host can request the information in hex or decimal format. In an address read command, the character $ requests the information to be returned in hex format. While the character ?, requests information to be returned in decimal. When requesting information in decimal, the data is preceded by a + or a -.

An example of a command requesting the measurement result in decimal is as follows:

>)28?<CR>

An example of a command requesting the measurement value in hex is as follows:

>)28$<CR>

A.3.2 Consecutive Address Read

The host can request information from consecutive addresses by adding additional ? for decimal or additional $ for hex.

An example of requests for the contents in decimal of ten consecutive addresses starting with 0x32 is:

>)32??????????<CR>

An example of requests for the contents in hex of ten consecutive addresses starting with 0x32 would be:

>)32$$$$$$$$$$<CR>

Note: The number of characters per line is limited to no more than 60.

A.3.3 Block Reads

The block read command can also be used to read consecutive registers.

For decimal format:
)startaddress:endaddress?

For hexadecimal format:
)startaddress:endaddress$

An example block read command in decimal format:

>)20:3D?<CR>

A.3.4 Concatenated Reads

Multiple commands can also be added on a single line. Requesting information in decimal from two locations and the block command from above are given below:

>)32?)35?)20:2E?<CR>

Note: The number of characters per line is limited to no more than 60.

A.3.5 Individual Address Write Commands

To modify the contents of an individual MPU Input Register, append the = character and the value to a read command.

)saddr=n<CR>

A.3.6 Update Command for MPU Inputs

The U command is used for updating default values of the MPU Data permanently in the flash. Before issuing the U command, CE must first be turned off by the disable CE command.

CE0<CR>
)U<CR>
CE1<CR>

A.3.7 Repeat Command

The repeat command can be useful for monitoring measurements and is efficient in demands from the host.

If the Host requests data from MPU input registers with the following command string:

>)21??<CR>

The host can execute the same data request without issuing another command by using the repeat command as follows:

>, (no carriage return needed for the repeat command)

The host only needs to send one character rather than an entire string.

	Auxiliary	
Description:	Various	
Commands:	,	Typing a comma (“,”) repeats the command issued from the previous command line.
	/	The slash (“/”) is used to separate comments from commands when sending macro text files via the serial interface. All characters in a line after the slash are ignored.

A.3.8 MPU/XDATA Access Commands Summary

)	**MPU Data Access**	
Description:	Allows user to read from and write to MPU data space.	
Usage:	) {Starting MPU Data Address} {option}…{option}<CR>	
Command Combinations:	)saddr? <CR>	Read the register in decimal.
	)saddr?? <CR>	Read two consecutive registers in decimal.
	)saddr???<CR>	Read three consecutive registers in decimal.
	)saddr:eaddr?	Block read command in decimal format. Read consecutive registers starting with starting address saddr and ending with address eaddr. Results given in decimal.
	)saddr$<CR>	Read the register word in hex.
	)saddr$$ <CR>	Read two consecutive register words in hex.
	)saddr$$$<CR>	Read three consecutive register words in hex.
	)saddr:eaddr$	Block read command in hex format. Read consecutive registers starting with starting address saddr and ending with address eaddr. Results given in hex.
	)saddr=n<CR>	Write the value n to address saddr in hex format.
	)saddr=n=m<CR>	Write the values n and m to two consecutive addresses starting at saddr in hex format.
	)saddr=+n<CR>	Write the value n to address saddr in decimal format.
	)saddr=+n=+m<CR>	Write the values n and m to two consecutive addresses starting at saddr in decimal format.
Examples:	)28$<CR>	Reads data word 0x28 in hex format.
	)28$$<CR>	Reads data words 0x28, 0x29 in hex format.
	)28$$$<CR>	Reads data words 0x28, 0x29, 0x2A in hex format.
	)28:4D$	Read data words in hex.
	)28?<CR>	Reads data word 0x28 in decimal format.
	)28??<CR>	Reads data words 0x28, 0x29 in decimal format.
	)28???<CR>	Reads data words 0x28, 0x29, 0x2A in decimal format.
	)28:4D?	Read data words in decimal.
	)24=12345678<CR>	Writes word @ 0x24 in hex format.
	)24=12345678=9876ABCD<CR>	Writes two words starting @ 0x24 in hex format.
	)24=+123<CR>	Writes word @ 0x04 in decimal format.
	)24=+123=+334<CR>	Writes two words starting @ 0x24 in decimal format.

MPU or XDATA space is the address range for the MPU XRAM (0x00 to 0x7F). Addresses from 0x80 to FF wrap to 0x00 to 0x7F. The MPU registers differ in size, LSBs and format.

A.4 I/O RAM (Configuration RAM) Commands

The RI command is used for altering the I/O RAM contents. This is usually not necessary as the FW defaults these settings appropriately. One allowable case where the RI command could be used would be to change the accumulation interval for reported measurements. The default accumulation interval is 1 second (999.75 ms). To reduce the accumulation interval to 0.5 seconds, enter the following via the UART:

RI1=+30<CR>

A.5 Calibration Commands

The 78M6612 Split-Phase Firmware includes two types of built-in calibration routines. The first type provides complete calibration. The second group, called atomic calibration commands, provides calibration for individual portions of the IC.

A.5.1 Complete Calibration Command

The CAL command provides single-command calibration. To use this command, a precision voltage source and a precision current source are required

Enter the following:

>CAL<CR>

The response is:

TCal OK
VCal OK
ICal 0 OK
>

The device calibrates the temperature (reads CE register 71, enters it into MPU register C0, and saves to flash), calibrates the voltage (adjusts CAL VA and saves them to flash), and finally calibrates the current (adjusts CAL IA register and saves to flash).CAL Command

A.5.2 Atomic Calibration Commands

The atomic calibration commands provide individual calibration of voltage, current, power, and temperature. A sequence of these commands results in a fully calibrated unit. The following table provides a summary of the atomic calibration commands.

CLxx	**Atomic Calibration Commands**	
Description:	Allows the user to Calibrate individual sections of the IC.	
Usage:	CLV	Calibrates voltage only.
	CLI1	Calibrate current only.
	CLT	Calibrate temperature only.

A.5.2.1 CLV Command

An example of an atomic calibration command would be to calibrate voltage with the CLV command. The CLV command calibrates voltage to the target value and tolerance and saves the coefficients to flash. The CLV command example is given below:

>CLV<CR>

The response is:

VCal OK
>

A.5.2.2 CLI Command

The user can then calibrate the current using the CLI1 command. The CLI1 command calibrates the current to the target value and tolerance and saves the coefficients to flash. The CLI1 command example is given below:

>CLI1<CR>

The response is:

ICal 0 OK
>

A.5.2.3 CLT Command

The CLT command is used for the temperature calibration. With this command, the contents of CE register 71 are read and entered into MPU register C0 and the contents are saved to flash. The CLT command example is given below:

>CLT<CR>

The response is:

TCal OK
>

A.6 CE Commands

The commands that follow are included for reference only.

The CE is the main signal processing unit in the 78M6612. The commands and user writes to the CE data space are mainly for calibration purposes. For the advanced user, details of CE data access commands are described. The commands similar to the MPU access except that the host requests access to information from the CE data space using the CE data access command which is a right bracket:

]

To request information, the host sends the CE data access command, the address (in hex) which is requested, the format in which the data is desired (hex or decimal) and a carriage return. The contents of the addresses that would be requested by the host are contained in Section 4.

The host can request the information in hex or decimal format. $ requests information in hex and ? requests information in decimal.

A.6.1 Single Register CE Access

An example of a command requesting the calibration constant for current (located at address 0x28) in decimal is as follows:

>]28?<CR>

An example of a command requesting the calibration constant for current (located at address 0x28) in hex is as follows:

>]28$<CR>

A.6.2 Consecutive CE Reads

The host can request information form consecutive addresses by adding additional ? for decimal or additional $ for hex.

An example of requests for the contents in decimal of ten consecutive addresses starting with 0x28 would be:

>]28??????????<CR>

An example of requests for the contents in hex of ten consecutive addresses starting with 0x28 would be:

>]28$$$$$$$$$$<CR>

Note: The number of characters per line is limited to no more than 60.

A.6.3 CE Register Write

If the cal coefficient for the IA current input is changed:

>]08=FFFFC9B0<CR>

A.6.4 Turn Off CE Command

The CE must first be turned off using the CE0 command:

>CE0<CR>

A.6.5 U Command

The U command is now issued to change the default value set above as follows:

>]U<CR>

A.6.6 Turn On CE Command

The CE must then be turned on using the CE1 command:

>CE1<CR>

The default value for the CAL IA coefficient is now changed in the CE Data space and is updated in Flash.

Additional examples are provided in the table that follows:

]	**CE Data Access**	
Description:	Allows user to read from and write to CE data space.	
Usage:	] {Starting CE Data Address}{option}…{option}<CR>	
Command Combinations:	]saddr?<CR>	Read 32-bit word in decimal.
	]saddr??<CR>	Read two consecutive 32-bit words in decimal.
	]saddr???<CR>	Read three consecutive 32-bit words in decimal.
	]saddr$<CR>	Read 32-bit words in hex.
	]saddr$$<CR>	Read two consecutive 32-bit words in hex.
	]saddr$$$<CR>	Read three consecutive 32-bit words in hex.
	]U<CR>	Update default version of CE Data in FLASH. **Important: The CE must be stopped (CE0) before issuing this command! Also, remember to restart by executing the CE1 command prior to attempting measurements.**
Examples:	]40$<CR>	Reads CE data word 0x40 in hex.
	]40$$<CR>	Reads CE data words 0x40 and 0x41 in hex.
	]40$$$<CR>	Reads CE data words 0x40, 0x41 and 0x42 in hex.
	]40?<CR>	Reads CE data words 0x40 in decimal.
	]40??<CR>	Reads CE data words 0x40 and 0x41 in decimal.
	]40???<CR>	Reads CE data words 0x40, 0x41 and 0x42 in decimal.
	]7E=12345678<CR>	Writes word at 0x7E (hex format).
	]7E=12345678=9876ABCD<CR>	Writes two words starting at 0x7E (hex format).
	]7E=+2255<CR>	Write the value 2255 in decimal to location 0x7E.
	]7E=+2255=+456<CR>	Write the value 2255 in decimal to location 0x7E and the value 456 in decimal to location 0x7F.

CE data space is the address range for the CE DRAM (0x1000 to 0x13FF). All CE data words are in 4-byte (32-bit) format. The offset of 0x1000 does not have to be entered when using the] command, thus typing]A? will access the 32-bit word located at the byte address 0x1000 + 4 * A = 0x1028.

The CE Control Commands are highlighted in the table below:

C	**Compute Engine Control**	
Description:	Allows the user to enable and configure the compute engine.	
Usage:	C {option} {argument}<CR>	
Command Combinations:	CEn<CR>	Compute Engine Enable (1 → Enable, 0 → Disable)
	CTn<CR>	Select input n for TMUX output pin. Enter n in hex notation.
	CREn<CR>	RTM output control (1 → Enable, 0 → Disable)
	CRSa.b.c.d<CR>	Selects CE addresses for RTM output. (maximum of four).
Examples:	CE0<CR>	Disables the CE.
	CE1<CR>	Enables the CE.
	CT1E<CR>	Selects the CE_BUSY signal for the TMUX output pin.