TERIDIAN SEMICONDUCTOR CORP.

A Maxim Integrated Products Brand

USER GUIDE

6613_PSU_1+1S_URT_v1_00 Firmware Description Document

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1 Introduction

This document describes the 6613_PSU_1+1S_URT_v1_00 firmware, which is used with the Teridian 78M6613 power and energy measurement IC. This firmware provides simple methods for calibration and access to measurement data such as Instantaneous Power, Voltage, Current, Power Factor, and Line Frequency. It is specifically optimized for measurement in single phase AC Power Supplies and appliances with the following key features:

- Optimized for using current shunt resistors with analog input A0 configured as single-ended Voltage input and input A1 configured as single-ended Current input. Inputs A2 and A3 unused.
- Phase error calibration routine included for maintaining accuracy over non-ideal power factors (optional).
- Accumulation or averaging intervals based on fixed number of AC-cycles for compliance with latest PMBus1.2 recommendations.
- Low-latency SAG status pin for sub-cycle AC fault detection.
- Dual mode host interface (Auto-Reporting or Command Line Interface).

All measurement calculations are computed by the 78M6613 and communicated to the host processor over a serial interface (UART0) on the TX and RX pins of the 78M6613 device. Digital IOs utilized by this firmware include:

- DIO17 is a SAG status pin updated every MUX cycle.
- DIO14 is a configurable alarm pin updated every accumulation interval.

Figure 1 shows a simplified connection diagram of the 78M6613 (emulator connections, decoupling capacitors and 3.3VDC power supply are omitted in this diagram).

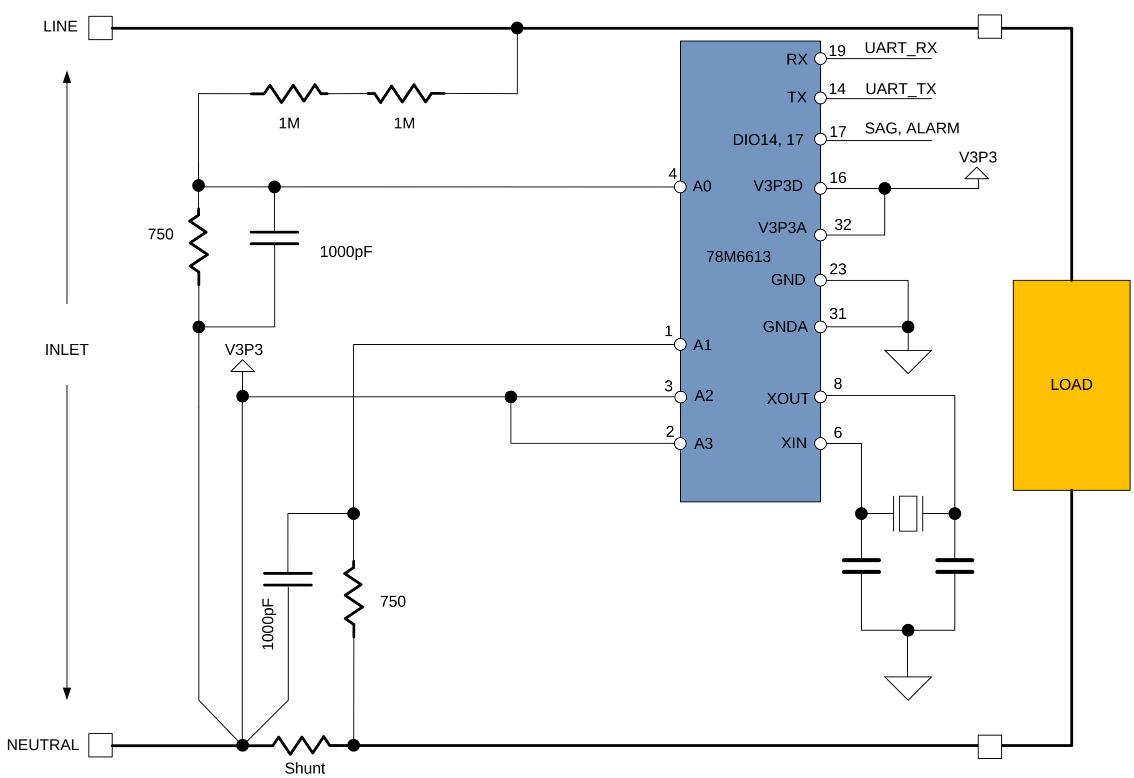

Figure 1: 78M6613 Simplified Connection Diagram for 6613_PSU_1+1S_URT_v1_00 Firmware

2 Measurement Description

2.1 Basic Measurement Equations

The Teridian 78M6613 with firmware 6613_PSU_1+1S_URT_v1_00 provides the user with measurement data referred to as “Wideband” (WB). Wideband measurements are generally of interest when measuring non-sinusoidal current/voltage, a typical condition in switched mode power supplies or similar systems.

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)

The measurement outputs are continuously available to the user. To obtain measurement outputs, the serial UART interface between the 78M6613 and the host processor must be set up and is described in Section 3.

2.2 Sample Rate and Accumulation Interval

This firmware utilizes an effective sampling rate of 6554 samples per second for each input.

The values described in section 2.1 are calculated over a period commonly referred as accumulation interval. The registers containing the measurements are updated at the completion of every accumulation time. In firmware 6613_PSU_1+1S_URT_v1_00, the accumulation interval is based on multiples of the Input Voltage AC cycle. For example if the accumulation interval is set to 30AC cycles, at 50Hz line frequency, it will result in 20ms * 30 = 600ms. In this case the RMS values will be calculated over 3932 samples.

Accumulation interval can be changed in CLI mode by the following command (see Section 6 for details of the CLI commands):

>]18=+30 (Changes accumulation interval to 30 AC cycles)

3 Serial Communication

The serial communication with the 78M6613 takes place over a UART (UART0) interface. The default settings for the UART of the 78M6613, as implemented in this firmware, are given below:

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

The firmware allows two types of communication protocols (modes) through UART0: CLI (Command Line Interface) mode and auto-report mode (default operation).

4 Auto-reporting Mode

Upon application of 3.3VDC power, the 78M6613 will operate in Auto-reporting mode.

Data Packet : Auto-reported AC measurement data packet consisting of Voltage, Current, Watt, Power Factor and Line Frequency send every accumulation cycle. Measurement data packet is send over UART in ASCII format followed by line feed and carriage return.

Vrms	Irms	Watts	PF	Freq	LF + CR

Measurement Parameter: The following table lists the measurement parameters and their respective bit resolutions (LSB) that is sent over UART in ASCII format.

Measurement Parameter	**Resolution (LSB)**
Voltage (Vrms)	mV
Current (Irms)	mA
Active Power(Watts)	mW
Power Factor(PF)	Range between 0 and 1000. 1000 indicative of 1.0 PF
Line Frequency(Freq)	0.01 Hz

5 Auto-reporting “Toggle” Command

To change from Auto-reporting mode to CLI mode (see Section 6 for details of the CLI mode), **Ctrl Z** command must be sent from the host to the 78M6613 over the UART interface. A subsequent **Ctrl Z** command will cause the 78M6613 to toggle back to Auto-Reporting mode.

6 Command Line Interface

The 6613_PSU_1+1S_URT_v1_00 firmware implements an instruction set called the Command Line Interface (CLI), which facilitates communication via UART between the 78M6613 and the host processor.

6.1 Identification and Information Commands

The I command is used to identify the revisions of the 6613_PSU_1+1S_URT_v1_00 firmware code and the embedded CE code. The host sends the I command to the 78M6613 as follows:

><CR>

The 78M6613 will reply the following:

TSC 78M6613 PSU 1+1S URT V1.00,Oct 15 2010(c) 2010 Teridian Semiconductor Corp.
All Rights Reserved
CEVI4ACF0
>

6.2 Reset Commands

A soft reset of the 78M6613 can be performed by using the Z command. The soft reset restarts code execution at addr 0000 and does not alter flash contents. To issue a soft reset to the 78M6613, the host sends the following:

>Z<CR>

The W command acts like a hardware reset. The energy 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.

6.3 MPU Data Access Command

All the measurement calculations are stored in the MPU data addresses of the 78M6613. 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 7.

6.3.1 Individual Address Read

The host can request the information in hex or decimal format. $ requests information in hex, and ? requests information in decimal. When requesting information in decimal, the data is preceded by a + or a -. The exception is)AB? which returns a string (see Table 3, MPU location address 0xAB).

An example of a command requesting the measured power in Watts (located at address 0x08) in decimal is as follows:

>)08?<CR>

An example of a command requesting the measured power in Watts (located at address 0x08) in hex is as follows:

>)08$<CR>

6.3.2 Consecutive 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 0x12 is:

>)12??????????<CR>

An example of requests for the contents in hex of ten consecutive addresses starting with 0x12 would be:

>)12$$$$$$$$$$<CR>

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

6.3.3 Block Reads

The block read command can also be used to read consecutive registers:)saddr:eaddr? For decimal format or)saddr:eaddr$ for hex format where saddr is the start address and eaddr is the final address.

The following block read command requests the information contained in Table 2 in decimal format:

>)20:3D?<CR>

6.3.4 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:

>)12?)15?)20:3D?<CR>

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

6.3.5 U Command

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. An example of a U command is as follows:

>)U

Additional examples of MPU Data Access commands are provided in the following table:

)	**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.

	)U<CR>	Updates the default values of the MPU Data permanently in the flash.
Examples:	)08$<CR>	Reads data word at MPU address location 0x08 in hex format.
	)08$$<CR>	Reads data words at MPU address location 0x08, 0x09 in hex format.
	)08$$$<CR>	Reads data words at MPU address location 0x08, 0x09, 0x0A in hex format.
	)28:4D$	Read data words in hex.
	)08?<CR>	Reads data word at MPU address location 0x08 in decimal format.
	)08??<CR>	Reads data words at MPU address location 0x08, 0x09 in decimal format.
	)08???<CR>	Reads data words at MPU address location 0x08, 0x09, 0x0A in decimal format.
	)28:4D?	Read data words at MPU address location starting 0x28 to 0x4D in decimal.
	)04=12345678<CR>	Writes 0x12345678 to MPU address location 0x04 in the hex format.
	)04=12345678=9876ABCD<CR>	Writes 0x12345678 to MPU address location 0x04 and 0x9876ABCD at MPU address location 0x05 in the hex format.
	)04=+123<CR>	Writes 123 to MPU address location 0x04 in the decimal format.
	)04=+123=-334<CR>	Writes 123 to MPU address location 0x04 and -334 to MPU address location 0x05 in the decimal format.

6.4 Auxiliary Commands

6.4.1 Repeat Command

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

If the host requests line frequency, alarm status, Irms wb overcurrent event count, Vrms SAG event count, Vrms overvoltage event count, voltage, power, and accumulated energy measurements with the following command string:

>)20????????<CR>

If the host then desires this same request without issuing another command, the repeat command can be used:

>, (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. This is very helpful when examining the value at a certain address over time, such as the CE DRAM address for the temperature.
	/	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.

6.5 Calibration Commands

Using the precision source method, the user provides a precision voltage and precision current load to the device for calibration. The 6613_PSU_1+1S_URT_v1_00 firmware provides commands to calibrate the measurement units. For linear current sensors, such as current shunt, no phase calibration is necessary.

There are two types of calibration commands. The first type provides complete calibration. The second group, called atomic calibration commands, provides calibration for individual portions of the IC.

6.5.1 Complete Calibration Command (“Single Command Calibration”)

There are two calibration commands in this first group: CAL and CALW. **Only one of these commands is needed to calibrate the System/Unit.**

To use these commands, a precision voltage source and a precision current source are required for the calibration routine to use as a reference.

6.5.1.1 CAL Command

To use the CAL command, enter the following:

>CAL<CR>

The response is:

TCal OK
VCal OK:
ICal 0 OK:
>

The device would calibrate the temperature (adjust the Temperature Nominal MPU location 0xA6, saves to flash and will initiate temperature gain compensation), calibrate the voltage (adjusts CAL VA and CAL VB registers and saves them to flash), and finally calibrate the current (adjusts CAL IA register and saves to flash).

6.5.1.2 CALW Command

To use the CALW command, enter the following:

>CALW<CR>

The response is:

TCal OK
VCal OK:
WCal 0 OK:
>
The device will calibrate the temperature, calibrate the voltage, and finally calibrate the power and save all values to flash.

The commands are summarized in the following table:

CALx	**Complete Calibration Commands**	
Description:	Allows the user to Calibrate the IC.	
Usage:	CAL	Calibrates temperature, then voltage, and finally current.
	CALW	Calibrates temperature, then voltage, and finally power.

6.5.2 Atomic Calibration Commands

The atomic calibration commands provide individual calibration of voltage, current, temperature, watts and a sequence of these results in providing full calibration for the unit.

6.5.2.1 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:
>

6.5.2.2 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:
>

6.5.2.3 CLP Command

The user can calibrate for phase added by a current transformer by using the CLP command. The CLP command calibrates the phase to the target value and tolerance and saves the coefficient to flash. An example of the procedure is given below.

Apply a controlled precision voltage and current signal at a set phase angle.

1. Enter target phase angle at)C3.
2. Enter phase tolerance at)BF
3. Enter phase calibration command.

   >CLP<CR>

   The response is

   >PCal 1 OK:

6.5.2.4 CLT Command

The CLT command is used for the temperature calibration. This command adjusts the Temperature Nominal at MPU location 0xA6, saves to flash and will initiate temperature gain compensation. The CLT command example is given below:

>CLT<CR>

The response is:

TCal OK
>

A summary of the atomic calibration commands are given in the table below:

CLxx	**Atomic Calibration Commands**	
Description:	Allows the user to Calibrate individual sections of the IC.	
Usage:	CLV	Calibrates voltage only.
	CLI1	Calibrate current only.
	CLW1	Calibrate for power only.
	CLP	Calibrate for phase only.
	CLT	Calibrate temperature only.

The commands that follow are mainly for advanced users and are included for reference only.

6.6 CE Data Access Commands

The CE is the main signal processing unit in the 78M6613. The 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] is used for the CE data access command.

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 location (in hex), 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 8.2.

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

6.6.1 Single Register CE Access

An example of a command requesting the calibration constant for current (located at address 0x08) in decimal is as follows:

>]08?<CR>

An example of a command requesting the calibration constant for current (located at address 0x08) in hex is as follows:

>]08$<CR>

6.6.2 Consecutive CE Reads

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 0x08 would be:

>]08??????????<CR>

An example of requests for the contents in hex of ten consecutive addresses starting with 0x08 would be:

>]08$$$$$$$$$$<CR>

Note: The number of characters per line is limited to 60 characters. Any character beyond the 60 character limit will be ignored by the CLI command interpreter.

6.6.3 CE Data Write

An example of a command writing to calibration constant for current (located at address 0x08) in decimal is as follows:

>]08 = +16384 <CR>

An example of a command writing to calibration constant for current (located at address 0x08) in hex is as follows:

>]08=4000 <CR>

6.6.4 U Command

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

An example of a U command is as follows:

>CE0
>]U

Additional examples of CE Data Access commands are provided in the following table:

]	**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 at address location 0x40 in the hex format.
	]40$$<CR>	Reads CE data word at address location 0x40 and 0x41 in the hex format.
	]40$$$<CR>	Reads CE data word at address location 0x40,0x41 and 0x42 in the hex format.
	]40?<CR>	Reads CE data word at address location 0x40 in the decimal format.
	]40??<CR>	Reads CE data word at address location 0x40 and 0x41 in the decimal format.
	]40???<CR>	Reads CE data word at address location 0x40,0x42 and 0x43 in the decimal format.
	]7E=12345678<CR>	Writes 0x12345678 to CE address location 0x7E in the hex format.
	]7E=12345678=9876ABCD<CR>	Writes 0x12345678 to CE address location 0x7E and 0x9876ABCD to CE address location 0x7F in the hex format.
	]7E=+2255<CR>	Writes 2255 to CE address location 0x7E in the decimal format.
	]7E=+2255=-456<CR>	Writes 2255 to CE address location 0x7E and -456 to CE address location 0x7F in the decimal format.

The commands that follow are included for reference only.

6.7 CE Control Commands

The most pertinent command is the CE enable command, CEn. It is mainly used to turn the CE on or off. The CE is normally enabled but in order to update the CE data entry to flash, the CE must first be turned off using the CE0 command.

6.7.1 Disable CE Command

The CE can be disabled by using the following command:

>CE0<CR>

6.7.2 Turn On CE Command

The CE can be enabled by following command:

>CE1<CR>

Additional examples of CE Control Commands are provided in the following table:

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.

7 MPU Measurement Outputs

This section describes the measurement outputs that can be obtained in Manual CLI Mode. Energy outputs are accumulated numbers. The host accessing the measurement information from the 78M6613 more frequently than the accumulation interval will not result in any update in the information.

Table 2 lists the wideband measurement outputs.

Table 2: MPU Outputs

Output	Location (hex)	LSB	Comment	Example
Delta Temperature	20	0.1 °C	Temperature difference from 22° C.	If external temperature is 32 °C)20?<CR> Returns: +10.0
Line Frequency	21	0.01 Hz	Line Frequency	If the line frequency is 60 Hz:)21?<CR> Returns: +60.00
Alarm Status	22		**Definition for Status Register** **Bit 0:** Minimum Temperature Alarm. **Bit 1:** Maximum Temperature Alarm. **Bit 2:** Minimum Frequency Alarm. **Bit 3:** Maximum Frequency Alarm. **Bit 4:** SAG Voltage Alarm. **Bit 5:** MINVA – under minimum voltage on VA input. **Bit 6:** MAXVA – over maximum voltage on VA input. **Bit 7:** Reserved. **Bit 8:** MAXIA WB– maximum WB current exceeded. **Bit 9:** Reserved. **Bit 10:** Reserved. **Bit 11:** PFA negative WB - Power Factor Negative Threshold Alarm. Only available if)F2 bit 2 is 1. **Bit 12:** PFA positive WB – Power Factor Positive Threshold Alarm. **Bits 13 - 20**: Reserved. **Bit 21** – CREEP Alert. **Bit 22 - 31**: Reserved.	Alarms become "1" when thresholds exceeded. Note: Additional Status Alert is Located at addr 0xBD (see Table 3) 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.
Irms A Overcurrent Event Count	23		Counter increments on each edge event.	If four over current events have occurred:)23?<CR> Returns: +4

Output	Location (hex)	LSB	Comment	Example
Vrms Under Voltage Event Count	24		Counter increments on each edge event.	If four under voltage events have occurred:)24?<CR> Returns: +4
Vrms Over Voltage Event Count	25		Counter increments on each edge event.	If four over voltage events have occurred:)25?<CR> Returns: +4
Vrms A	26	mV	Vrms voltage	If the line voltage is 120 V)26?<CR> Returns: +120.000
Watts A	27	mW	Active power measurement (per second).	If 120 Watts are measured)27?<CR> Returns: +120.000
Wh A	28	mWh	Active accumulated energy measurement (per hour).	If 120 Wh are measured)28?<CR> Returns: +120.000
Total Cost A	29	mUnits	Cost of Wh A.	If the cost is 102.536 units)29?<CR> +102.536
Irms A	2A	mA	rms current measurement.	If current measured is 12 Amps)2A?<CR> Returns: +12.000
VARs A	2B	mW	Reactive power measurement (per second).	If 120 VARs are measured)2B?<CR> Returns: +120.000
VAs A	2C	mW	Apparent power measurement (per second).	If 120 VAs are measured)2C?<CR> Returns: +120.000
Power Factor A	2D	–	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 power factor is 0.95)2D?<CR> Returns: +0.950
Phase Angle A	2E	–	Phase angle. The output will be between 180.000 and -180.000.	If the phase angle measured is 60 degrees)2E?<CR> Returns: +60.000

Output	Location (hex)	LSB	Comment	Example
Reserved	2F	–	Reserved	Reserved
Vrms A Min	30	mV	Minimum Vrms measured	If the minimum line voltage measured was 105 V)30<CR> Returns: +105.000
Vrms A Max	31	mV	Maximum Vrms measured	If the maximum line voltage measured was 130 V)31<CR> Returns: +130.000
Watts A Min	32	mW	Minimum active power measured (per second)	If the minimum power measured is 80 Watts)32?<CR> Returns: +80.000
Watts A Max	33	mW	Maximum active power measured (per second)	If the maximum power measured is 200 Watts)33?<CR> Returns: +200.000
Irms A Min	34	mArms	Minimum rms current measured.	If the smallest current measured is 1 Amp)34?<CR> Returns: +1.000
Irms A Max	35	mArms	Maximum rms current measured.	If the largest current measured is 30 Amps)35?<CR> Returns: +30.000
VARs A Min	36	mW	Minimum reactive power measured (per second).	If the largest VARs measured is 80 VARs)36?<CR> Returns: +80.000
VARs A Max	37	mW	Maximum reactive power measured (per second).	If the largest VARs measured is 300 VARs)37?<CR> Returns: +300.000
VAs A Min	38	mW	Minimum apparent power measured (per second).	If the smallest VAs measured is 80 VARs)38?<CR> Returns: +80.000

Output	Location (hex)	LSB	Comment	Example
VAs A Max	39	mW	Maximum apparent power measured (per second).	If the largest VAs measured is 300 VARs)39?<CR> Returns: +300.000
Power Factor A Min	3A	–	Minimum power factor measured. Minimum is defined as the most negative or least positive number.	If minimum power factor measured is –0.6)3A?<CR> Returns: -0.600
Power Factor A Max	3B	–	Maximum power factor measured. Maximum is defined as the most positive or least negative number.	If maximum power factor measured is 0.9)3B?<CR> Returns: +0.900
Phase Angle A Min	3C	–	Minimum phase angle measured.	If the minimum phase angle measured is 10 degrees)3C?<CR> Returns: +10.000
Phase Angle A Max	3D	–	Maximum phase angle measured.	If the maximum phase angle measured is 70 degrees)3D?<CR> Returns: +70.000
Reserved	3E	–	Reserved	Reserved
Reserved	3F	–	Reserved	Reserved

8 Configuration Parameter Entry

8.1 MPU Parameters

Table 3 lists the MPU parameters configurable by the 6613_PSU_1+1S_URT_v1_00 Firmware.

Table 3: 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 78M6613. 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>
Starting IA	A1	mArms	+0.007	Minimum current value to be measured on the IA input. Currents below this value will be ignored. Also known as CREEP IA.	Default setting is 7 mA. If start current on channel A desired is 10 mA:)A1=+0.010<CR>
IMAX A	A2	mArms	+52.000	External rms current corresponding to 250 mVpk at the IA input of the 78M6613.	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>
Unused	A3 - A5	–	–	Unused	
Temperature Nominal	A6	–	+0	Temp_raw_x reading at 22 °C. Needed to enable temperature compensation.	Temp _raw_x is obtained from the CE:]71?<CR> This value is then entered here:)A6=+value in decimal Also, the command: >CLT<CR> Will do the same as the steps above.
Reserved	A7	–	–	Reserved	
PPMC	A8	ppm/°C	-668	ppm per °C.	Do not change the default setting.
PPMC^2	A9	ppm/°C^2	-341	ADC temperature compensation ppm per °C^2.	Do not change the default setting.

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Cost/kWh	AA	mUnits	+0.150	Cost per kWh (kilowatt hour) in milliunits.	If the cost per kWh is to be 10 units:)AD=+10.000<CR>
Units of Cost	AB	N/A	USD	4-byte string describing unit of cost (e.g. USD, EURO etc.). There must be 4 characters. If entering US dollars, USD, there needs to be a space after the D to make it a four character string.	To enter US Dollars:)AB="USD "<CR> To enter Euros:)AB="EURO"<CR>
Reserved	A0 - 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.	
Unused	BE	–			
Tolerance on Phase	BF	0.001°	0.100°	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 phase is desired to be more coarse, to within 0.5°, the user can enter the following: >)BF=+0.500<CR>
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>

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
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>
Calibration Phase	C3	0.1°	+0	Target Phase (voltage to current). Normally set to zero.	
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>

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
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>
Calibration WRATE	CD	1	+6350	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

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Frequency Minimum Threshold	D2	0.01Hz	+59.00	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 59.50 Hz then enter the following: >)D2=+59.50
Frequency Maximum Threshold	D3	0.01Hz	+61.00	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 60.50 Hz then enter the following: >)D2=+60.50
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	–			
Peak IA Alarm Threshold	D9	mArms	+15.000	Maximum Current measured on the IA channel above which a flag must set (bit 8 of the Alarm Status Register).	If the peak current threshold is to be changed from the default value of 15 Amps to 30 Amps then set as follows:)D9=+30.000<CR>

MPU Parameter	Location (hex)	LSB	Default	Comment	Example
Unused	DA - DB	–			
PFA_ Neg Threshold	DC	–	-0.700	Power Factor Negative Threshold. A less negative 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 power factor threshold is to be changed from the default to -0.6 then set as follows:)DC=-0.600<CR>
PFA_ Pos Threshold	DD	–	+0.700	Power Factor Positive Threshold. A positive power factor less than this threshold will set an alarm (bit 12 of the Alarm Status Register).	If the positive power factor threshold is to be changed from the default to +0.6 then set as follows:)DD=+0.600<CR>
Unused	DE - DF	–	–	Unused	
Unused	E0 - E5	–	–	Unused	
Alarm Mask_Reg	E6	–	00201FFF	Alarm mask for bits in the Alarm Status register. A “0” masks the alarm from the register bit.	If bits 0 and 1 are to be masked then set as follows: >)E6=00801FFC
Alarm Mask_DIO	E7	–	00201FFF	Alarm mask for an alarm pin (DIO20). A “0” masks the alarm from DIO20	Alarm mask for an alarm pin (DIO20). A “0” masks the alarm from DIO20
AC Cycle Count for CAL	EF	1	30	Number of AC cycles to average during calibration	
Reserved	F0	–	0	Reserved	Reserved
Min/Max Control	F1	–	0	BIT1 – 1 Start/Stop MIN/MAX recording. 1 = Start 0 = Stop BIT0 – 1 Reset MIN/MAX registers before recording. Bit autoclears.	Reset & Start MIN/MAX recording.)F1=3<CR> Stop MIN/MAX recording)AC=00<CR>
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.	

8.2 CE Parameters

Table 4 lists the CE parameters configurable by the 6613_PSU_1+1S_URT_v1_00 Firmware. The user does not need to alter any of these parameters.

Table 4: 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>
Unused	09				
CAL VA	0A	16384 is the default and is a gain of 1. 32767 is max giving a gain of 2.	+16384	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>
Unused	0B				
PHASE_ ADJ_IA	0C	-16384 ≤ PHASE_ADJ_IA ≤ +16384	0	Phase adjustment =15 * PHASE_ADJ_IA * 2^{-14} (degrees)	No adjustment should be necessary when using current shunts.
Unused	0D				
CESTATE	0E		5001h	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 gain factor Bits 1 and 0 00 – 6x 01 – (6/64)x 10 – 96x 11 – 1.5x	]0E=5001 Selects at least 80 (50h) consecutive voltage samples below SAG_Threshold before SAG alarm. Selects Pulse Gain Factor equal to 6/64 (1h)

CE Parameter	Location(hex)	LSB	Default	Comment	Example
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)	+168225	The voltage threshold for SAG warnings. The default value is 80 Vpk if VMAX = 600 V.	]11=+313350 80 Vpk SAG Threshold.
QUANTA	12	VMAX A * IMAX A * 1.8541E-10 (Watt)	0	Compensation added to the Watt calculation. Used for compensation at low current levels. Keep below 10000d.	
Unused	13-15				
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.	
Unused	17				
AC Cycle Count	18	1	+4	Number of AC cycles for accumulation interval (**min=4**)	To changes accumulation interval to 10 AC cycles:]18=+10<CR> **Note:** Set value of AC cycles between 4 and 100/120 (for 50/60Hz respectively).
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-1B	–	–	Reserved	Reserved

9 Address Content Summary

Table 5: MPU Output Summary Chart

	Address	Output
Common Data	20	Delta Temp
	21	Line Frequency
	22	Alarm Status
	23	Over Current Event Count
	24	Under Voltage Event Count
	25	Over Voltage Event Count
	26	Volts
	27	Watts (A)
	28	Energy (A)
	29	Cost (A)
Wideband Data	2A	Current (A)
	2B	VAR (A)
	2C	VA (A)
	2D	Power Factor (A)
	2E	Phase (A)
	2F	(Reserved for Future)
Min/Max Data	30	Vrms Min
	31	Vrms Max
	32	Watts Min (A)
	33	Watts Max (A)
	34	Current Min (A)
	35	Current Max (A)
	36	VAR Min (A)
	37	VAR Max (A)
	38	VA Min (A)
	39	VA Max (A)
	3A	Power Factor Min (A)
	3B	Power Factor Max (A)
	3C	Phase Min (A)
	3D	Phase Max(A)
	3E	(Reserved for Future)
	3F	(Reserved for Future)

Table 6: MPU Input Summary Chart

Voltage	A0	Vmax
Current	A1	Imin (Creep A)
	A2	Imax (A)
Unused	A3 - A5	Unused
Temperature	A6	TEMPERATURE NOMINAL
	A7	Reserved
	A8	PPMC
	A9	PPMC2
Cost	AA	Cost per KWh
	AB	Cost Unit string
Reserved	AC - BC	Reserved
Misc. Config	BD	Configuration
Unused	BE	Unused
	BF	Tolerance on Phase Calibration
Quick Calibration Parameters	C0	Calibration Type
	C1	Calibration Voltage (Target)
	C2	Calibration Current (Target)
	C3	Calibration Phase
	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

Voltage	D4	SAG Voltage Alarm Threshold
	D5	Min Voltage Alarm Threshold
	D6	Max Voltage Alarm Threshold
Unused	D7	Unused
Current	D8	Unused
	D9	Max Current Alarm Threshold
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
AC Cycle Count for CAL	EF	AC Cycle Count for Calibration.
Reserved	F0	Reserved
Min/Max Controls	F1	Min/Max Controls
Clear Control	F2	Accumulator and Counter Clear. Power Factor Polarity

Table 7: 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
	13-15	Unused
	16	Quantization offset IA
	17	Unused
Accumulation Interval	18	AC Cycle Count for Accumulation Interval
Gain Adjust	19	Temperature Gain Adjust

10 Digital IOs

DIO17 is a dedicated SAG status pin that is set high when SAG Voltage alarm triggers. SAG Voltage alarm status is checked every MUX cycle for low latency detection of AC fault conditions. Both the instantaneous voltage alarm threshold and sample count for the SAG alarm are configurable. See CE STATE and SAG Threshold registers for more information.

DIO14 is a configurable alarm pin that is an 'OR function' of several mask-able alarm bits. The alarm status is checked and updated following an update of the measurement output registers (once every Accumulation cycle). See registers E6 and E7 for mask settings.

11 Contact Information

For more information about Maxim products or to check the availability of the 78M6613, contact technical support at www.maxim-ic.com/support.

Document Revision History

Version	Date	History
1.0	10/29/2010	First publication.