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Simplifying System Integration™

USER GUIDE

6612_OMU_S2+2_URT_V1_14
Firmware Description Document

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UG_6612_017

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1 Introduction

This document describes the firmware 6612_OMU_S2+2_URT_V1_14, which can be used with the Teridian 78M6612 power and energy measurement IC. This firmware provides simple methods for calibration, relay control, and access to measurement data such as Watts, Voltage, Current, accumulated Energy and line frequency. It is optimized for measurement of up to two single phase AC loads using current shunts as the current sensors, but Current Transformer (CT) sensors may also be used if desired.

All measurement calculations are computed by the 78M6612 and communicated to the host processor over a serial interface (UART0) on the TX and RX pins of the 78M6612 device. RTC (real time clock), LCD Driver, and Battery Modes are not supported by this firmware. Additional 78M6612 hardware utilized by this firmware includes:

- DIO20 used as a configurable status alarm output pin
- DIO4, DIO5, and DIO8 as LED outputs for Active, Ready, and Fault status
- DIO7 and DIO19 used as configurable relay control ouputs
- DIO6 used as an optional pulse output

The following sections detail the commands to be sent by the host to configure the 78M6612 and for accessing measurement information.

2 Description of Basic Measurement Equations

The Teridian 78M6612 with firmware 6612_OMU_S2+2_URT_V1_14 provides the user with two types of continuously updating measurement data (on 1 second increments by default). One is defined as "Narrowband" (NB) and the other is defined as "Wideband" (WB).

Narrowband measurements are typically used by utilities where the measured waveforms are assumed to be sinusoidal.

Wideband measurements are generally of interest when measuring nonlinear systems such as switched mode power supplies that tend to have non-sinusoidal waveforms. This firmware utilizes an effective sampling rate of 3641 samples per second.

Table 1 lists the basic measurement equations for the Narrowband and the Wideband methods.

Table 1: Measurement Equations Definitions

Symbol	Parameter	Narrowband Equation	Wideband Equation
V	RMS Voltage	$V = \sqrt{\sum v(t)^2}$	$V = \sqrt{\sum v(t)^2}$
I	RMS Current	$I = S/V$	$I = \sqrt{\sum i(t)^2}$
P	Active Power	$P = \sum (i(t) * v(t))$	$P = \sum (i(t) * v(t))$
Q	Reactive Power	$Q = \sum (i(t) * v(t)\text{shift } 90º)$	$Q = \sqrt{(S^2 - P^2)}$
S	Apparent Power	$S = \sqrt{(P^2 + Q^2)}$	$S = V * I$
PF	Power Factor	P/S	P/S
PA	Phase Angle	ACOS (P/S)	ACOS (P/S)

Both types of measurement outputs are continuously available to the user. To obtain measurement outputs, the serial UART interface between the 78M6612 and the host processor must be set up and is described in the next section.

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:

>

Commands the host may send to the 78M6612 in order for the host to configure the 78M6612 or to receive the measurement data are given in the next section.

4 Command Line Interface

Firmware 6612_OMU_S2+2_URT_V1_14 implements an instruction set called the Command Line Interface (CLI), which facilitates communication via UART between the 78M6612 and the host processor. The CLI provides a set of commands which are used by the host to configure and to obtain information from the 78M6612.

4.1 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 send back to the host the following:

TSC 78M6612 OMU S2+2 URT v1.14, Feb 09 2010(c)2009 Teridian Semiconductor Corp.
All Rights Reserved
CE6612_OMU_S2+2_A01_V1_4
>

4.2 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. 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.

4.3 MPU Data Access Command

The most pertinent is the MPU data access command. All the measurement calculations are stored in the MPU data addresses 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 5.

4.3.1 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 the AB description).

An example of a command requesting the measured power in Watts from Outlet 1 (located at address 0x08) in decimal is as follows:

>)08?<CR>

An example of a command requesting the measured power in Watts from Outlet 1 (located at address 0x08) in hex is as follows:

>)08$<CR>

4.3.2 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.

4.3.3 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 Outlet 1 wideband information contained in Table 4 in decimal format:

>)20:3D?<CR>

4.3.4 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.

4.3.5 MPU/XDATA Access Commands

)	**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:	)08$<CR>	Reads data word 0x08 in hex format.
	)08$$<CR>	Reads data words 0x08, 0x09 in hex format.
	)08$$$<CR>	Reads data words 0x08, 0x09, 0x0A in hex format.
	)28:4D$	Read Outlet 1 narrowband data words in hex.
	)08?<CR>	Reads data word 0x08 in decimal format.
	)08??<CR>	Reads data words 0x08, 0x09 in decimal format.
	)08???<CR>	Reads data words 0x08, 0x09, 0x0A in decimal format.
	)28:4D?	Read Outlet 1 wideband data words in decimal.
	)04=12345678<CR>	Writes word @ 0x04 in hex format.
	)04=12345678=9876ABCD<CR>	Writes two words starting @ 0x04 in hex format.
	)04=+123<CR>	Writes word @ 0x04 in decimal format.
	)04=+123=+334<CR>	Writes two words starting @ 0x04 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.

4.4 Auxiliary Commands

4.4.1 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 nb overcurrent event count, Vrms SAG event count, Vrms overvoltage event count, voltage, power, and accumulated energy measurements for Outlet 1 with the following command string:

>)01????????<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.

4.5 Calibration Commands

Using the precision source method, the user provides a precision voltage and precision current load to the device for calibration. The 6612_OMU_S2+2_URT_V1_14 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.

4.5.1 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

4.5.1.1 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 (reads CE register 71, enters it into MPU register C0, and saves to flash), 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).

4.5.1.2 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 table below:

CALx	**Complete Calibration Commands**	
Description:	Allows the user to Calibrate the IC.	
Usage:	CAL	Calibrates temperature, then voltage, and finally current for Outlet 1.
	CAL2	Calibrates temperature, then voltage, and finally current for Outlet 2.
	CAL3	Calibrates temperature, then voltage, and finally current for both Outlet1 and Outlet 2.
	CALW	Calibrates temperature, then voltage, and finally power for Outlet 1.
	CALW2	Calibrates temperature, then voltage, and finally power for Outlet 2.
	CALW3	Calibrates temperature, then voltage, and finally power for both Outlet1 and Outlet 2.

4.5.2 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.

4.5.2.1 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
>

4.5.2.2 CLI Command

The user can then calibrate the current on Outlet 1 using the CLI1 command. The CLI1 command calibrates the current on Outlet 1 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
>

4.5.2.3 CLP Command

The user can calibrate for phase added by a current transformer by using the CLP command. The CLP command calibrates the phase on Outlet 1 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

4.5.2.4 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 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 on Outlet 1 only.
	CLI2	Calibrate current on Outlet 2 only.
	CLI3	Calibrate for current on both Outlet 1 and Outlet 2 only.
	CLW1	Calibrate for power on Outlet 1 only.
	CLW2	Calibrate for power on Outlet 2 only.
	CLW3	Calibrate for power on both Outlet 1 and Outlet 2.
	CLP	Calibrate for phase on Outlet 1 only. Generally only used when using current transformers.
	CLP2	Calibrate for phase on Outlet 2 only. Generally only used when using current transformers.
	CLP3	Calibrate for phase on both Outlet 1 and Outlet 2. Generally only used when using current transformers.
	CLT	Calibrate temperature only.

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

4.6 CE Data Access Commands

The CE is the main signal processing unit in the 78M6612. 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 (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 5.

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

4.6.1 Single Register CE Access

An example of a command requesting the calibration constant for current on Outlet 1 (located at address 0x08) in decimal is as follows:

>]08?<CR>

An example of a command requesting the calibration constant for current on Outlet 1 (located at address 0x08) in hex is as follows:

>]08$<CR>

4.6.2 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 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 no more than 60.

4.6.3 U Command

The U command is used for updating default values of the CE Data in flash. The description is given in the CE control Command section.

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.

4.7 CE Control Commands

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

4.7.1 CE Data Write

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

>]08=FFFFC9B0<CR>

4.7.2 Turn Off CE Command

For this value to be the default value, the U command is used. The CE must first be turned off using the CE0 command:

>CE0<CR>

4.7.3 U Command

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

>]U<CR>

4.7.4 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.

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.

4.8 I/O RAM (Configuration RAM) Command

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 case where the RI command could be used would be to change the accumulation interval for energy measurements. The default accumulation interval is 1 second (999.75 ms). The accumulation interval is set by the following:

> 0.01666 * *SUM_CYCLES[5:0]* (in seconds) where *SUM_CYCLE[5:0]* are register bits in the I/O RAM that can be between 15d and 63d (default is 60d). *SUM_CYCLES* must never be set below 15 (0.250 seconds).

To reduce the accumulation interval to 0.5 seconds, enter the following via the UART:

RI1=+30<CR>

Entering a U command will preserve the new accumulation value across power resets, by writing them to flash.

R	**I/O RAM Control**	
Description:	Allows the user to read from and write to I/O RAM.	
Usage:	RI {option} {register} … {option} <CR>	
Command Combinations:	RIx…<CR>	Select I/O RAM location x (0x2000 offset is automatically added).
Example:	RI60$$$$<CR>	Read all four RTM probe registers.

Configuration RAM space is the address range 0x2000 to 0x20FF. This RAM contains registers used for configuring basic hardware and functional properties of the 78M6612 and is organized in bytes (8 bits). The 0x2000 offset is automatically added when the command RI is typed.

5 MPU Measurement Outputs

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

Table 2 lists the Narrowband outputs for Outlet 1.

Table 2: Outlet 1 MPU Outputs for Narrowband Method

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 – 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 – MAXIA_NB – maximum narrowband current exceeded on Outlet 1. Bit 8 – MAXIA_WB – maximum wideband current exceeded on Outlet 1. Bit 9 – PFA_NB negative – Narrowband Power Factor Negative Threshold Alarm for Outlet 1. Only available is)F2 bit 2 is 1. Bit 10 – PFA_NB positive – Narrowband Power Factor Positive Threshold Alarm for Outlet 1. Bit 11 – PFA_WB negative - Wideband Power Factor Negative Threshold Alarm for Outlet 1. Only available is)F2 bit 2 is 1. Bit 12 – PFA_WB positive – Wideband Power Factor Positive Threshold Alarm for Outlet 1. Bit 13 – MAXIB_NB – maximum narrowband current exceeded on Outlet 2. Bit 14 – MAXIB_WB – maximum wideband current exceeded on Outlet 2.	Alarms become “1” when thresholds exceeded. Note: Additional Status Alert is Located at addr 0xBD (see Table 8) 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.

Output	Location (hex)	LSB	Comment	Example
			Bit 15 – PFB_NB negative – Narrowband Power Factor Negative Threshold Alarm for Outlet 2. Only available is)F2 bit 2 is 1. Bit 16 – PFB_NB positive – Narrowband Power Factor Positive Threshold Alarm for Outlet 2. Bit 17 – PFB_WB negative – Wideband Power Factor Negative Threshold Alarm for Outlet 2. Only available is)F2 bit 2 is 1. Bit 18– PFB_WB positive – Wideband Power Factor Positive Threshold Alarm for Outlet 2. Bit 19 – MAXIT_WB – maximum total wideband current exceeded on both Outlet 1 and Outlet 2. Bit 20 – MAXIT_NB – maximum total narrowband current exceeded on both Outlet 1 and Outlet 2. Bit 21 – CREEP A Alert – Creep Alert on Outlet 1. Bit 22 – CREEP B Alert – Creep Alert on Outlet 2. Bit 23 – Line/Neutral Reversal detected. Only available in non-isolated mode (CESTATE, Bit 2=1) Bit 24 – Reserved. Bit 25 – Reserved. Bit 26 – Unexpected Reset. Bits 27-31 – Reserved.	
Irms_nb A Overcurrent Event Count	03	1	Counter increments on each edge event.	If four narrowband over current events have occurred on Outlet 1:)03?<CR> Returns: +4
Vrms Under Voltage Event Count	04	1	Counter increments on each edge event.	If four under voltage events have occurred:)04?<CR> Returns: +4
Vrms Over Voltage Event Count	05	1	Counter increments on each edge event.	If four over voltage events have occurred:)05?<CR> Returns: +4
Vrms A	06	mVrms	Vrms voltage.	If the line voltage is 120 V)06?<CR> Returns: +120.000

Output	Location (hex)	LSB	Comment	Example
Watts A	07	mW	Outlet 1 active power measurement (per second).	If 120 Watts are measured on Outlet 1)07?<CR> Returns: +120.000
Wh A	08	mWh	Outlet 1 active accumulated energy measurement (per hour).	If 120 Wh are measured on Outlet 1)08?<CR> Returns: +120.000
Total Cost A	09	mUnits	Outlet 1 cost of Wh A.	If the cost is 102.536 units on Outlet 1)09?<CR> +102.536
Irms_nb A	0A	mArms	Outlet 1 narrowband rms current measurement.	If narrowband current measured on Outlet 1 is 12 Amps)0A?<CR> Returns: +12.000
VARs_nb A	0B	mW	Outlet 1 narrowband reactive power measurement (per second).	If narrowband 120 VARs are measured on Outlet 1)0B?<CR> Returns: +120.000
VAs_nb A	0C	mW	Outlet 1 narrowband apparent power measurement (per second).	If narrowband 120 VAs are measured on Outlet 1)0C?<CR> Returns: +120.000
Power Factor_nb A	0D	–	Outlet 1 narrowband 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 narrowband power factor on Outlet 1 is 0.95)0D?<CR> Returns: +0.950
Phase Angle_nb A	0E	–	Outlet 1 narrowband phase angle. The output will be between 180.000 and -180.000.	If the narrowband phase angle measured on Outlet 1 is 60 degrees)0E?<CR> Returns: +60.000
Reserved	0F	–	Reserved	Reserved
Vrms A Min	10	mV	Minimum Vrms measured.	If the minimum line voltage measured was 105 V)10<CR> Returns: +15.000
Vrms A Max	11	mV	Maximum Vrms measured.	If the maximum line voltage measured was 130 V)11<CR> Returns: +130.000

Output	Location (hex)	LSB	Comment	Example
Watts A Min	12	mW	Minimum Outlet 1 active power measured (per second).	If the minimum power measured on Outlet 1 is 80 Watts)12?<CR> Returns: +80.000
Watts A Max	13	mW	Maximum Outlet 1 active power measured (per second).	If the maximum power measured on Outlet 1 is 200 Watts)13?<CR> Returns: +200.000
Irms_nb A Min	14	mArms	Outlet 1 minimum narrowband rms current measured.	If the smallest narrowband current measured on Outlet 1 is 1 Amp)14?<CR> Returns: +1.000
Irms_nb A Max	15	mArms	Outlet 1 maximum narrowband rms current measured.	If the largest narrowband current measured on Outlet 1 is 30 Amps)15?<CR> Returns: +30.000
VARs_nb A Min	16	mW	Outlet 1 minimum narrowband reactive power measured (per second).	If the largest VARs measured on Outlet 1 is 80 VARs)16?<CR> Returns: +80.000
VARs_nb A Max	17	mWs	Outlet 1 maximum narrowband reactive power measured (per second).	If the largest narrowband VARs measured on Outlet 1 is 300VARs)17?<CR> Returns: +300.000
VAs_nb A Min	18	mW	Outlet 1 minimum narrowband apparent power measured (per second).	If the smallest narrowband VAs measured on Outlet 1 is 80 VARs)18?<CR> Returns: +80.000
VAs_nb A Max	19	mWs	Outlet 1 maximum narrowband apparent power measured (per second).	If the largest narrowband VAs measured on Outlet 1 is 300VARs)19?<CR> Returns: +300.000
Power Factor_nb A Min	1A	–	Outlet 1 minimum narrowband power factor measured. Minimum is defined as the most negative or least positive number.	If minimum narrowband power factor measured on Outlet 1 is -0.6)1A?<CR> Returns: -0.600
Power Factor_nb A Max	1B	–	Outlet 1 maximum narrowband power factor measured. Maximum is defined as the most positive or least negative number.	If maximum narrowband power factor measured on Outlet 1 is 0.9)1B?<CR> Returns: +0.900
Phase Angle_nb A Min	1C	–	Outlet 1 minimum narrowband phase angle measured.	If the minimum narrowband phase angle measured on Outlet 1 is 10 degrees)1C?<CR> Returns: +10.000

Output	Location (hex)	LSB	Comment	Example
Phase Angle_nb A Max	1D	–	Outlet 1 maximum narrowband phase angle measured.	If the maximum narrowband phase angle measured on Outlet 1 is 70 degrees)1D?<CR> Returns: +70.000
Reserved	1E	–	Reserved	Reserved
Reserved	1F	–	Reserved	Reserved

Table 3 lists the wideband measurement outputs for Outlet 1.

Table 3: Outlet 1 MPU Outputs for Wideband Method

Output	Location (hex)	LSB	Comment	Example
Delta Temperature	20	0.1 °C	Temperature difference from 22° C. Note: Duplicate of address 0x00 (see Table 2)	If external temperature is 32 °C)20?<CR> Returns: +10.0
Line Frequency	21	0.01 Hz	Line Frequency Note: Duplicate of address 0x01 (see Table 2)	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 – MAXIA_NB – maximum narrowband current exceeded on Outlet 1. Bit 8 – MAXIA_WB – maximum wideband current exceeded on Outlet 1. Bit 9 – PFA_NB negative – Narrowband Power Factor Negative Threshold Alarm for Outlet 1. Only available is)F2 bit 2 is 1. Bit 10 – PFA_NB positive – Narrowband Power Factor Positive Threshold Alarm for Outlet 1. Bit 11 – PFA_WB negative - Wideband Power Factor Negative Threshold Alarm for Outlet 1. Only available is)F2 bit 2 is 1. Bit 12 – PFA_WB positive – Wideband Power Factor Positive Threshold Alarm for Outlet 1. Bit 13 – MAXIB_NB – maximum narrowband current exceeded on Outlet 2.	Alarms become "1" when thresholds exceeded. Note: Additional Status Alert is Located at addr 0xBD (see Table 8) 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.

Output	Location (hex)	LSB	Comment	Example
			Bit 14 – MAXIB_WB – maximum wideband current exceeded on Outlet 2. Bit 15 – PFB_NB negative – Narrowband Power Factor Negative Threshold Alarm for Outlet 2. Only available is)F2 bit 2 is 1. Bit 16 – PFB_NB positive – Narrowband Power Factor Positive Threshold Alarm for Outlet 2. Bit 17 – PFB_WB negative – Wideband Power Factor Negative Threshold Alarm for Outlet 2. Only available is)F2 bit 2 is 1. Bit 18– PFB_WB positive – Wideband Power Factor Positive Threshold Alarm for Outlet 2. Bit 19 – MAXIT_WB – maximum total wideband current exceeded on both Outlet 1 and Outlet 2. Bit 20 – MAXIT_NB – maximum total narrowband current exceeded on both Outlet 1 and Outlet 2. Bit 21 – CREEP A Alert – Creep Alert on Outlet 1. Bit 22 – CREEP B Alert – Creep Alert on Outlet 2. Bit 23 – Line/Neutral Reversal detected. Only available in non-isolated mode (CESTATE, Bit 2=1) Bit 24 – Reserved. Bit 25 – Reserved. Bit 26 – Unexpected Reset. Bits 27-31 – Reserved. Note: Duplicate of address 0x02 (see Table 2)	
Irms_wb A Overcurrent Event Count	23		Counter increments on each edge event.	If four wideband over current events have occurred on Outlet 1:)23?<CR> Returns: +4
Vrms Under Voltage Event Count	24		Counter increments on each edge event. Note: Duplicate of address 0x04 (see Table 2).	If four under voltage events have occurred:)24?<CR> Returns: +4
Vrms Over Voltage Event Count	25		Counter increments on each edge event. Note: Duplicate of address 0x06 (see Table 2).	If four over voltage events have occurred:)25?<CR> Returns: +4
Vrms A	26	mV	Vrms voltage Note: Duplicate of address 0x06 (see Table 2).	If the line voltage is 120 V)26?<CR> Returns: +120.000
Watts A	27	mW	Outlet 1 active power measurement (per second). Note: Duplicate of address 0x07 (see Table 2).	If 120 Watts are measured on Outlet 1)27?<CR> Returns: +120.000