
**Single-Phase High-Performance Wide-Span Energy
Metering IC**

PRELIMINARY DATASHEET**FEATURES****Metering Features**

- Metering features fully in compliance with the requirements of IEC62052-11 and IEC62053-21; applicable in class 1 or class 2 single-phase watt-hour meter.
- Accuracy of 0.1% for active energy over a dynamic range of 5000:1.
- Temperature coefficient is 15 ppm/ °C (typical) for on-chip reference voltage
- Single-point calibration over a dynamic range of 5000:1 for active energy.
- Energy Meter Constant doubling at low current to save verification time.
- Electrical parameters measurement: less than $\pm 0.5\%$ fiducial error for V_{rms} , I_{rms} , mean active/ apparent power, frequency, power factor and phase angle.
- Forward/ reverse active energy with independent energy registers. Active energy can be output by pulse or read through energy registers to adapt to different applications.
- Programmable startup and no-load power threshold.
- Dedicated ADC and different gains for L line and N line current sampling circuits. Current sampled over shunt resistor or current transformer (CT); voltage sampled over resistor divider network or potential transformer (PT).
- Programmable L line and N line metering modes: anti-tampering mode (larger power), L line mode (fixed L line), L+N mode (applicable for single-phase three-wire system) and flexible mode (configure through register).
- Programmable L line and N line power difference threshold in anti-tampering mode.

Other Features

- 3.3V single power supply. Operating voltage range: 2.8~3.6V. Metering accuracy guaranteed within 3.0V~3.6V. 5V compatible for digital input.
- Built-in hysteresis for power-on reset.
- Four-wire SPI interface or simplified three-wire SPI interface with fixed 24 cycles for all registers operation
- Parameter diagnosis function and programmable interrupt output of the IRQ interrupt signal and the WarnOut signal.
- Programmable voltage sag detection and zero-crossing output.
- Channel input range
 - Voltage channel (when gain is '1'): 120 μ V $_{rms}$ ~600mV $_{rms}$.
 - L line current channel (when gain is '24'): 5 μ V $_{rms}$ ~25mV $_{rms}$.
 - N line current channel (when gain is '1'): 120 μ V $_{rms}$ ~600mV $_{rms}$.
- Programmable L line current gain: 1, 4, 8, 16, 24; Programmable N line gain: 1, 2, 4.
- Support L line and N line offset compensation.
- CF1 outputs active energy pulses which can be used for calibration or energy accumulation.
- Crystal oscillator frequency: 8.192 MHz. On-chip 10pF capacitors and no need of external capacitors.
- Green SSOP28 package.
- Operating temperature: -40 °C ~ +85 °C .

APPLICATION

- The M90E25 is used for active energy metering for single-phase two-wire (1P2W), single-phase three-wire (1P3W) or anti-tampering energy meters. With the measurement function, the M90E25 can also be used in power instruments which need to measure voltage, current, etc.

DESCRIPTION

The M90E25 is high-performance wide-span energy metering chips. The ADC and DSP technology ensure the chips' long-term stability over variations in grid and ambient environmental conditions.

BLOCK DIAGRAM

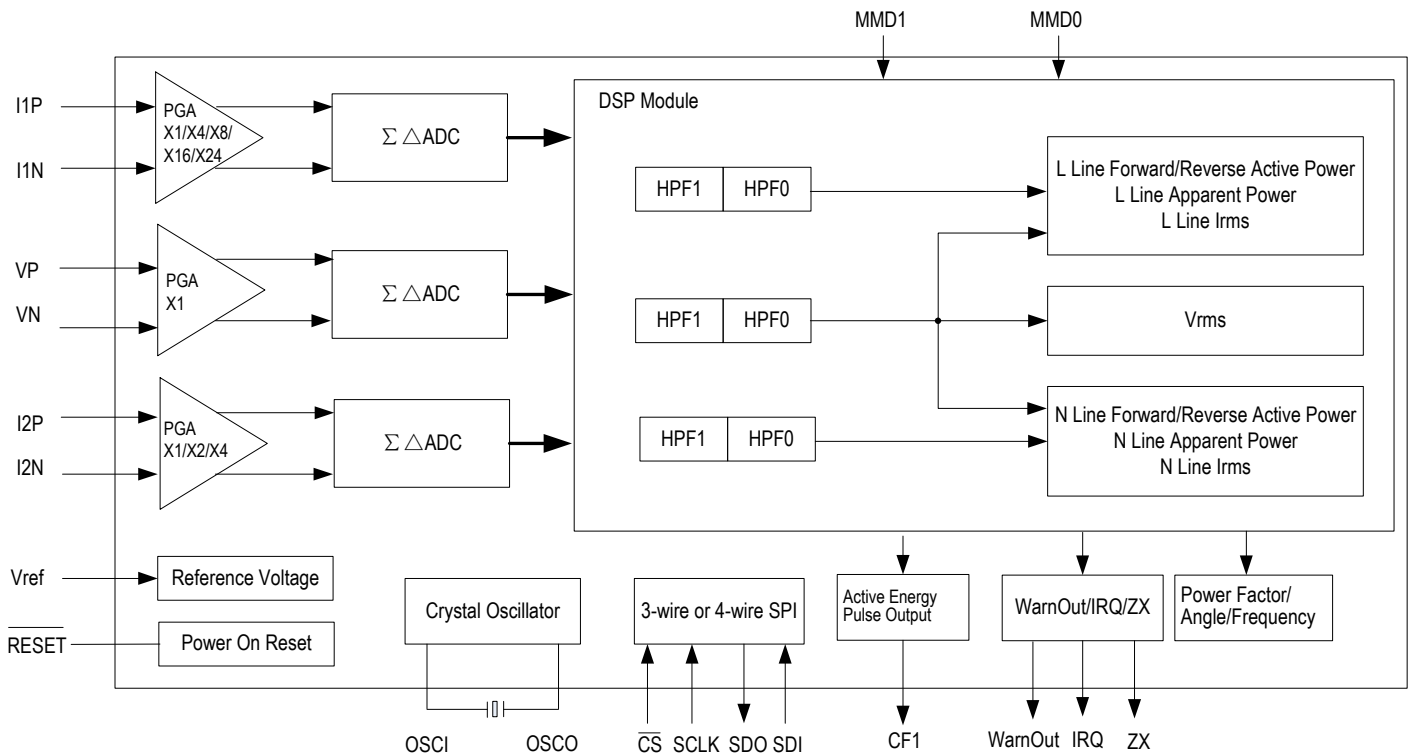


Figure-1 Block Diagram

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1 PIN ASSIGNMENT

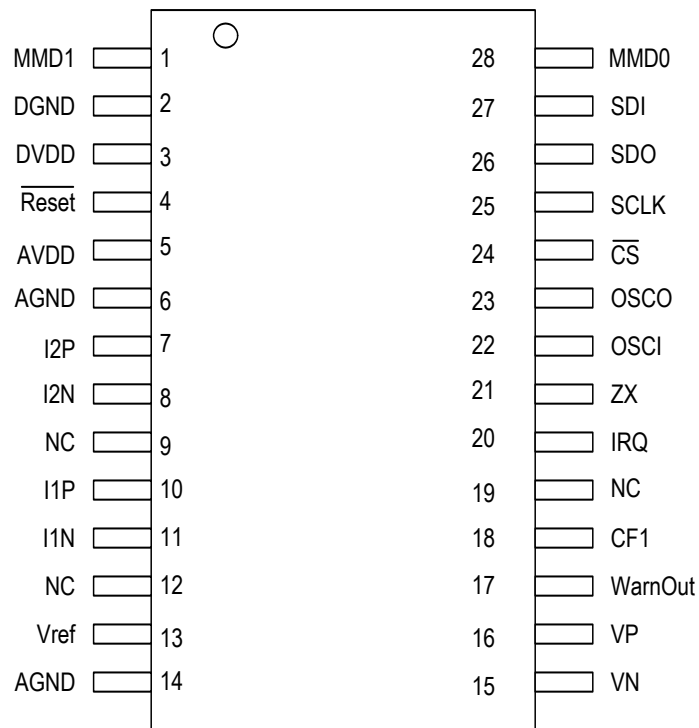


Figure-2 Pin Assignment (Top View)

2 PIN DESCRIPTION

Table-1 Pin Description

| Name | Pin No. | I/O ^{note 1} | Type | Description |
|---------------------------|-----------|-----------------------|--------|---|
| $\overline{\text{Reset}}$ | 4 | I | LVTTL | Reset: Reset Pin (active low) This pin should connect to ground through a 0.1 μ F filter capacitor. In application it can also directly connect to one output pin from microcontroller (MCU). |
| DVDD | 3 | I | Power | DVDD: Digital Power Supply This pin provides power supply to the digital part. It should be decoupled with a 10 μ F electrolytic capacitor and a 0.1 μ F capacitor. |
| DGND | 2 | I | Power | DGND: Digital Ground |
| AVDD | 5 | I | Power | AVDD: Analog Power Supply This pin provides power supply to the analog part. This pin should connect to DVDD through a 10 Ω resistor and be decoupled with a 0.1 μ F capacitor. |
| Vref | 13 | O | Analog | Vref: Output Pin for Reference Voltage This pin should be decoupled with a 1 μ F capacitor and a 1nF capacitor. |
| AGND | 6, 14 | I | Power | AGND: Analog Ground |
| I1P I1N | 10 11 | I | Analog | I1P: Positive Input for L Line Current I1N: Negative Input for L Line Current These pins are differential inputs for L line current. Input range is 5 μ Vrms~25mVrms when gain is '24'. |
| I2P I2N | 7 8 | I | Analog | I2P: Positive Input for N Line Current I2N: Negative Input for N Line Current These pins are differential inputs for N line current. Input range is 120 μ Vrms~600mVrms when gain is '1'. |
| VP VN | 16 15 | I | Analog | VP: Positive Input for Voltage VN: Negative Input for Voltage These pins are differential inputs for voltage. Input range is 120 μ Vrms~600mVrms. |
| NC | 9, 12, 19 | | | NC: These pins could be left open or connect to ground. |
| $\overline{\text{CS}}$ | 24 | I | LVTTL | $\overline{\text{CS}}$: Chip Select (Active Low) In 4-wire SPI mode, this pin must be driven from high to low for each read/write operation, and maintain low for the entire operation. In 3-wire SPI mode, this pin must be low all the time. Refer to section 4.1. |
| SCLK | 25 | I | LVTTL | SCLK: Serial Clock This pin is used as the clock for the SPI interface. Data on SDI is shifted into the chip on the rising edge of SCLK while data on SDO is shifted out of the chip on the falling edge of SCLK. |
| SDO | 26 | OZ | LVTTL | SDO: Serial Data Output This pin is used as the data output for the SPI interface. Data on this pin is shifted out of the chip on the falling edge of SCLK. |
| SDI | 27 | I | LVTTL | SDI: Serial Data Input This pin is used as the data input for the SPI interface. Address and data on this pin is shifted into the chip on the rising edge of SCLK. |
| MMD1 MMD0 | 1 28 | I | LVTTL | MMD1/0: Metering Mode Configuration 00: anti-tampering mode (larger power); 01: L line mode (fixed L line); 10: L+N mode (applicable for single-phase three-wire system); 11: flexible mode (line specified by the LNSel bit (MMode, 2BH)) |
| OSCI | 22 | I | LVTTL | OSCI: External Crystal Input An 8.192 MHz crystal is connected between OSCI and OSCO. There is an on-chip 10pF capacitor, therefore no need of external capacitors. |

Table-1 Pin Description (Continued)

| Name | Pin No. | I/O ^{note 1} | Type | Description |
|--|---------|-----------------------|-------|---|
| OSCO | 23 | O | LVTTL | OSCO: External Crystal Output An 8.192 MHz crystal is connected between OSC1 and OSC0. There is an on-chip 10pF capacitor, therefore no need of external capacitors. |
| CF1 | 18 | O | LVTTL | CF1: Active Energy Pulse Output This pin outputs active energy pulses. |
| ZX | 21 | O | LVTTL | ZX: Voltage Zero-Crossing Output This pin is asserted when voltage crosses zero. Zero-crossing mode can be configured to positive zero-crossing, negative zero-crossing or all zero-crossing by the Zxcon[1:0] bits (MMode , 2BH). |
| IRQ | 20 | O | LVTTL | IRQ: Interrupt Output This pin is asserted when one or more events in the SysStatus register (01H) occur. It is deasserted when there is no bit set in the SysStatus register (01H). |
| WarnOut | 17 | O | LVTTL | WarnOut: Fatal Error Warning This pin is asserted when there is metering parameter calibration error or voltage sag. Refer to section 4.2 . |
| Note 1: All digital inputs are 5V tolerant except for the OSC1 pin. | | | | |

3 FUNCTIONAL DESCRIPTION

3.1 DYNAMIC METERING RANGE

Accuracy is 0.1% for active energy metering over a dynamic range of 5000:1 (typical). Refer to [Table-2](#).

Table-2 Active Energy Metering Error

| Current | Power Factor | Error (%) |
|--|-------------------------------------|-----------|
| $20\text{mA} \leq I < 50\text{mA}$ | 1.0 | ± 0.2 |
| $50\text{mA} \leq I \leq 100\text{A}$ | | ± 0.1 |
| $50\text{mA} \leq I < 100\text{mA}$ | 0.5 (Inductive) 0.8 (Capacitive) | ± 0.2 |
| $100\text{mA} \leq I \leq 100\text{A}$ | | ± 0.1 |

Note: Shunt resistor is 250 $\mu\Omega$ or CT ratio is 1000:1 and load resistor is 6 Ω .

3.2 STARTUP AND NO-LOAD POWER

Startup and no-load power thresholds are programmable. The related registers are listed in [Table-3](#).

Table-3 Threshold Configuration for Startup and No-Load Power

| Threshold | Register |
|------------------------------------|--------------------------------|
| Threshold for Active Startup Power | PStartTh , 27H |
| Threshold for Active No-load Power | PNoIth , 28H |

The chip will start within 1.2 times of the theoretical startup time of the configured startup power, if startup power is less than the corresponding power of 20mA when power factor or $\sin\phi$ is 1.0.

The chip has no-load status bits, the Pnoload bit (EnStatus, 46H). The chip will not output any active pulse (CF1) in active no-load state.

3.3 ENERGY REGISTERS

The M90E25 provides energy pulse output CF1 which is proportionate to active energy. Energy is usually accumulated by adding the CF1 pulses in system applications. Alternatively, the M90E25 provides energy registers. There are forward (inductive), reverse (capacitive) and absolute energy registers. Refer to [Table-4](#).

Table-4 Energy Registers

| Energy | Register |
|------------------------|--------------------------------|
| Forward Active Energy | APenergy , 40H |
| Reverse Active Energy | ANenergy , 41H |
| Absolute Active Energy | ATenergy , 42H |

Each energy register is cleared after read. The resolution of energy registers is 0.1CF, i.e. one LSB represents 0.1 energy pulse.

3.4 N LINE METERING AND ANTI-TAMPERING

3.4.1 METERING MODE AND L/N LINE CURRENT SAMPLING GAIN CONFIGURATION

The M90E25 has two current sampling circuits with N line metering and anti-tampering functions. The MMD1 and MMD0 pins are used to configure the metering mode. Refer to [Table-5](#).

Table-5 Metering Mode

| MMD1 | MMD0 | Metering Mode | CF1 Output |
|------|------|--|---|
| 0 | 0 | Anti-tampering Mode (larger power) | CF1 represents the larger energy line. Refer to section 3.4.2 . |
| 0 | 1 | L Line Mode (fixed L line) | CF1 represents L line energy all the time. |
| 1 | 0 | L+N Mode (applicable for single-phase three-wire system) | CF1 represents the arithmetic sum of L line and N line energy |
| 1 | 1 | Flexible Mode (line specified by the LNSel bit (MMode, 2BH)) | CF1 represents energy of the specified line. |

The M90E25 has two current sampling circuits with different gain configurations. L line gain can be 1, 4, 8, 16 and 24, and N line gain can be 1, 2 and 4. The configuration is made by the [MMode](#) register (2BH). Generally L line can be sampled over shunt resistor or CT. N line can be sampled over CT for isolation consideration. Note that Rogowski coil is not supported.

3.4.2 ANTI-TAMPERING MODE

Threshold

In anti-tampering mode, the power difference threshold between L line and N line can be: 1%, 2%,... 12%, 12.5%, 6.25%, 3.125% and 1.5625%, altogether 16 choices. The configuration is made by the Pthresh[3:0] bits ([MMode](#), 2BH) and the default value is 3.125%.

Compare Method

In anti-tampering mode, the compare method is as follows:

If current metering line is L line and

$$\frac{\text{NLine Active Power} - \text{LLine Active Power}}{\text{LLine Active Power}} * 100\% > \text{Threshold}$$

N line is switched as the metering line, otherwise L line keeps as the metering line.

If current metering line is N line and

$$\frac{\text{LLine Active Power} - \text{NLine Active Power}}{\text{NLine Active Power}} * 100\% > \text{Threshold}$$

L line is switched as the metering line, otherwise N line keeps as the metering line.

This method can achieve hysteresis around the threshold automatically. L line is employed after reset by default.

Special Treatment at Low Power

When power is low, general factors such as the quantization error or calibration difference between L line and N line might cause the power difference to be exceeded. To ensure L line and N line to start up normally, special treatment as follows is adopted:

The line with higher power is selected as the metering line when both L line and N line power are lower than 8 times of the startup power but higher than the startup power.

3.5 MEASUREMENT AND ZERO-CROSSING

3.5.1 MEASUREMENT

The M90E25 has the following measurements:

- voltage rms
- current rms (L line/N line)
- mean active power (L line/N line)
- voltage frequency
- power factor (L line/N line)
- phase angle between voltage and current (L line/N line)
- mean apparent power (L line/N line)

The above measurements are all calculated with fiducial error except for frequency. The frequency accuracy is 0.01Hz, and the other measurement accuracy is 0.5%. Fiducial error is calculated as follow:

$$\text{Fiducial_Error} = \frac{U_{\text{mea}} - U_{\text{real}}}{U_{\text{FV}}} * 100\%$$

Where U_{mea} is the measured voltage, U_{real} is the actual voltage and U_{FV} is the fiducial value.

Table-6 The Measurement Format

| Measurement | Fiducial Value (FV) | M90E25 Defined Format | Range | Comment |
|---------------------------------------|---------------------------------|-----------------------|-----------------------|---------------------------------|
| Voltage rms | U_n | XXX.XX | 0~655.35V | |
| Current rms ^{note 1, note 2} | I_{max} as 4lb | XX.XXX | 0~65.535A | |
| Active Power ^{note 1} | maximum power as $U_n * 4lb$ | XX.XXX | -32.768~+32.767 kW | Complement, MSB as the sign bit |
| Apparent Power ^{note 1} | $U_n * 4lb$ | XX.XXX | 0~+32.767 kVA | Complement, MSB always '0' |
| Frequency | f_n | XX.XX | 45.00~65.00 Hz | |
| Power Factor ^{note 3} | 1.000 | X.XXX | -1.000~+1.000 | Signed, MSB as the sign bit |
| Phase Angle ^{note 4} | 180° | XXX.X | -180°~+180° | Signed, MSB as the sign bit |

Note 1: All registers are of 16 bits. For cases when the current and active/apparent power goes beyond the above range, it is suggested to be handled by microcontroller (MCU) in application. For example, register value can be calibrated to 1/2 of the actual value during calibration, then multiply 2 in application. Note that if the actual current is twice of that of the M90E25, the actual active/apparent power is also twice of that of the chip.

Note 2: The accuracy is not guaranteed when the current is lower than 15mA. Note that the tolerance is 25 mA at I_{FV} of 5A and fiducial accuracy of 0.5%.

Note 3: Power factor is obtained by active power dividing apparent power

Note 4: Phase angle is obtained when voltage/current crosses zero at the frequency of 256kHz. Precision is not guaranteed at small current.

3.5.2 ZERO-CROSSING

The ZX pin is asserted when the sampling voltage crosses zero. Zero-crossing mode can be configured to positive zero-crossing, negative zero-crossing and all zero-crossing by the $Zxcon[1:0]$ bits (MMode, 2BH). Refer to section 6.4.

The zero-crossing signal can facilitate operations such as relay operation and power line carrier transmission in typical smart meter applications.

3.6 CALIBRATION

Calibration includes metering and measurement calibration.

Metering Calibration

The M90E25 design methodology guarantees the accuracy over the entire dynamic range, after metering calibration at one specific current, i.e. the basic current of I_b .

The calibration procedure includes the following steps:

1. Calibrate gain at unity power factor;
2. Calibrate phase angle compensation at 0.5 inductive power factor.

Generally, line current sampling is susceptible to the circuits around the sensor when shunt resistor is employed as the current sensor in L line. For example, the transformer in the energy meter's power supply may conduct interference to the shunt resistor. Such interference will cause perceptible metering error, especially at low current conditions. The total interference is at a statistically constant level. In this case, the M90E25 provides the power offset compensation feature to improve metering performance.

L line and N line need to be calibrated sequentially.

Measurement Calibration

Measurement calibration includes gain calibration for voltage rms and current rms.

Considering the possible nonlinearity around zero caused by external components, the M90E25 also provides offset compensation for voltage rms, current rms and mean active power.

The M90E25 design methodology guarantees automatic calibration for frequency, phase angle and power factor measurement.

3.7 RESET

The M90E25 has an on-chip power supply monitor circuit with built-in hysteresis. The M90E25 only works within the voltage range.

The M90E25 has three means of reset: power-on reset, hardware reset and software reset. All registers resume to their default value after reset.

Power-on Reset: Power-on reset is initiated during power-up. Refer to section [6.3](#).

Hardware Reset: Hardware Reset is initiated when the $\overline{\text{reset}}$ pin is pulled low. The width of the reset signal should be over 200 μs .

Software Reset: Software Reset is initiated when '789AH' is written to the software reset register ([SoftReset](#), 00H).

4 INTERFACE

4.1 SERIAL PERIPHERAL INTERFACE (SPI)

SPI is a full-duplex, synchronous channel. There are two SPI modes: four-wire mode and three-wire mode. In four-wire mode, four pins are used: \overline{CS} , SCLK, SDI and SDO. In three-wire mode, three pins are used: SCLK, SDI and SDO. Data on SDI is shifted into the chip on the rising edge of SCLK while data on SDO is shifted out of the chip on the falling edge of SCLK. The `LastSPIData` register (06H) stores the 16-bit data that is just read or written.

4.1.1 FOUR-WIRE MODE

In four-wire mode, the \overline{CS} pin must be driven low for the entire read or write operation. The first bit on SDI defines the access type and the lower 7-bit is decoded as address.

Read Sequence

As shown in [Figure-3](#), a read operation is initiated by a high on SDI followed by a 7-bit register address. A 16-bit data in this register is then shifted out of the chip on SDO. A complete read operation contains 24 cycles.

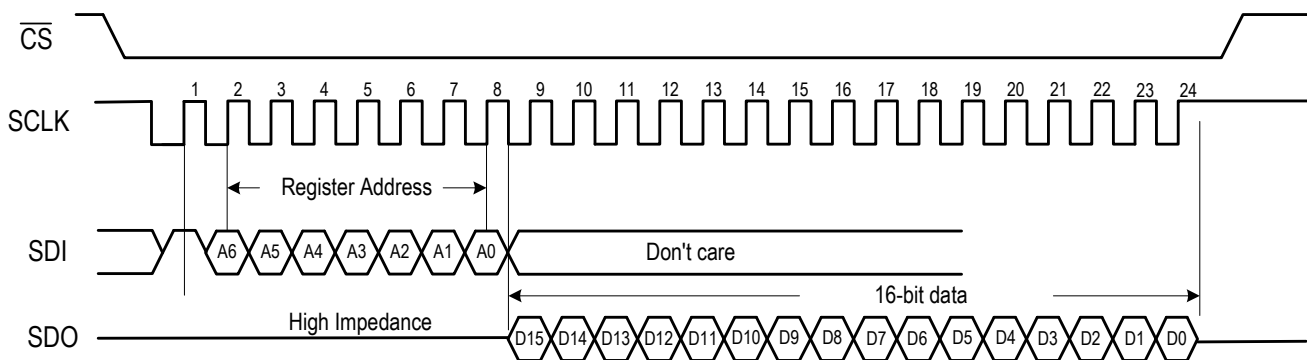


Figure-3 Read Sequence in Four-Wire Mode

Write Sequence

As shown in [Figure-4](#), a write operation is initiated by a low on SDI followed by a 7-bit register address. A 16-bit data is then shifted into the chip on SDI. A complete write operation contains 24 cycles.

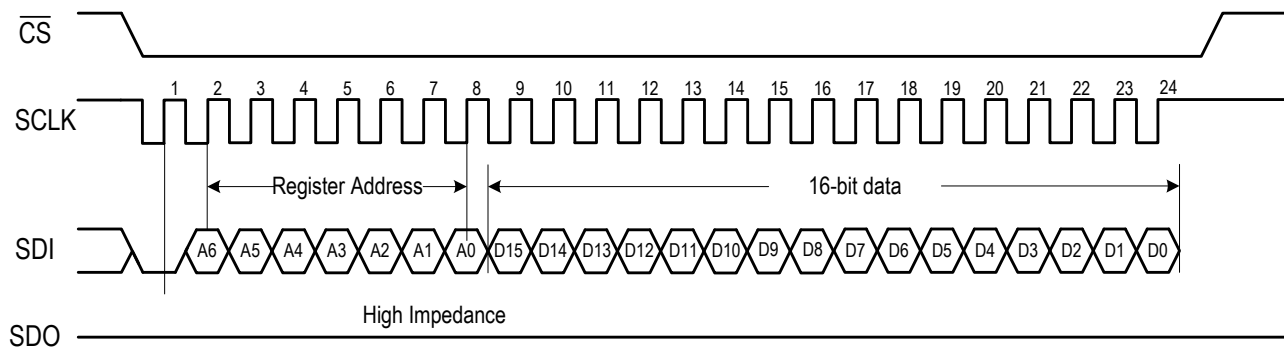


Figure-4 Write Sequence in Four-Wire Mode

4.1.2 THREE-WIRE MODE

In three-wire mode, \overline{CS} is always at low level. When there is no operation, SCLK keeps at high level. The start of a read or write operation is triggered if SCLK is consistently low for at least 400 μ s. The subsequent read or write operation is similar to that in four-wire mode. Refer to [Figure-5](#) and [Figure-6](#).

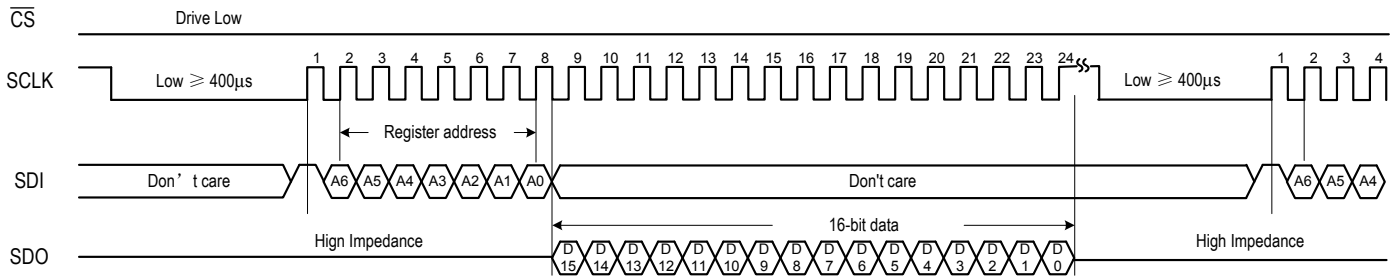


Figure-5 Read Sequence in Three-Wire Mode

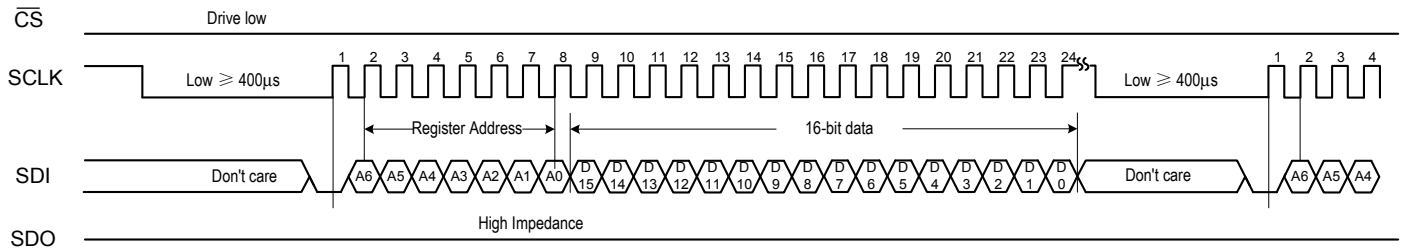


Figure-6 Write Sequence in Three-Wire Mode

4.1.3 TIMEOUT AND PROTECTION

Timeout occurs if SCLK does not toggle for 6ms in both four-wire and three-wire modes. When timeout, the read or write operation is aborted.

If there are more than 24 SCLK cycles when \overline{CS} is driven low in four-wire mode or between two starts in three-wire mode, writing operation is prohibited while normal reading operation can be completed by taking the first 24 SCLK cycles as the valid ones. However, the reading result might not be the intended one.

A read access to an invalid address returns all zero. A write access to an invalid address is discarded.

Table-7 and Table-8 list the read or write result in different conditions.

Table-7 Read / Write Result in Four-Wire Mode

| Condition | | | Result | |
|-----------|-------------------|-------------------------------|-------------------|-----------------------------|
| Operation | Timeout | SCLK Cycles ^{note 1} | Read/Write Status | LastSPIData Register Update |
| Read | _{note 2} | ≥ 24 | Normal Read | Yes |
| | _{note 2} | < 24 | Partial Read | No |
| Write | No | $= 24$ | Normal Write | Yes |
| | No | $\neq 24$ | No Write | No |
| | Yes | - | No Write | No |

Note 1: The number of SCLK cycles when \overline{CS} is driven low or the number of SCLK cycles before timeout if any.
Note 2: '-' stands for Don't Care.

Table-8 Read / Write Result in Three-Wire Mode

| Condition | | | Result | |
|-----------|--------------------------|-------------------------------|-------------------|-----------------------------|
| Operation | Timeout | SCLK Cycles ^{note 1} | Read/Write Status | LastSPIData Register Update |
| Read | No | ≥ 24 ^{note 2} | Normal Read | Yes |
| | Timeout after 24 cycles | > 24 | Normal Read | Yes |
| | Timeout before 24 cycles | _{note 3} | Partial Read | No |
| | Timeout at 24 cycles | $= 24$ | Normal Read | Yes |
| Write | No | $= 24$ | Normal Write | Yes |
| | No | $\neq 24$ | No Write | No |
| | Yes | - | No Write | No |

Note 1: The number of SCLK cycles between 2 starts or the number of SCLK cycles before timeout if any.
Note 2: There is no such case of less than 24 SCLK cycles when there is no timeout in three-wire mode, because the first few SCLK cycles in the next operation is counted into this operation. In this case, data is corrupted.
Note 3: '-' stands for Don't Care.

4.2 WARNOUT PIN FOR FATAL ERROR WARNING

Fatal error warning is raised through the WarnOut pin in two cases: checksum calibration error and voltage sag.

Calibration Error

The M90E25 performs diagnosis on a regular basis for important parameters such as calibration parameters and metering configuration. When checksum is not correct, the CalErr[1:0] bits ([SysStatus](#), 01H) are set, and both the WarnOut pin and the IRQ pin are asserted. When checksum is not correct, the metering part does not work to prevent a large number of pulses during power-on or any abnormal situation upon incorrect parameters.

Voltage Sag

Voltage sag is detected when voltage is continuously below the voltage sag threshold for one cycle which starts from any zero-crossing point. Voltage threshold is configured by the [SagTh](#) register (03H). Refer to section 6.5.

When voltage sag occurs, the SagWarn bit ([SysStatus](#), 01H) is set and the WarnOut pin is asserted if the [FuncEn](#) register (02H) enables voltage sag warning through the WarnOut pin. This function helps reduce power-down detection circuit in system design. In addition, the method of judging voltage sag by detecting AC side voltage eliminates the influence of large capacitor in traditional rectifier circuit, and can detect voltage sag earlier.

4.3 LOW COST IMPLEMENTATION IN ISOLATION WITH MCU

The following functions can be achieved at low cost when the M90E25 is isolated from the MCU:

SPI: MCU can perform read and write operations through low speed optocoupler (e.g. PS2501) when the M90E25 is isolated from the MCU. The SPI interface can be of 3-wire or 4-wire.

Energy Pulses CF1: Energy can be accumulated by reading values in corresponding energy registers. CF1 can also connect to the optocoupler and the energy pulse light can be turned on by CF1.

Fatal Error WarnOut: Fatal error can be acquired by reading the CalErr[1:0] bits ([SysStatus](#), 01H).

IRQ: IRQ interrupt can be acquired by reading the [SysStatus](#) register (01H).

Reset: The M90E25 is reset when '789AH' is written to the software reset register ([SoftReset](#), 00H).

5 REGISTER

5.1 REGISTER LIST

Table-9 Register List

| Register Address | Register Name | Read/Write Type | Functional Description | Page |
|--|-----------------------------|-----------------|---------------------------------------|----------------------|
| Status and Special Register | | | | |
| 00H | SoftReset | W | Software Reset | P 21 |
| 01H | SysStatus | R/C | System Status | P 22 |
| 02H | FuncEn | R/W | Function Enable | P 23 |
| 03H | SagTh | R/W | Voltage Sag Threshold | P 23 |
| 04H | SmallPMod | R/W | Small-Power Mode | P 24 |
| 06H | LastSPIData | R | Last Read/Write SPI Value | P 24 |
| Metering Calibration and Configuration Register | | | | |
| 20H | CalStart | R/W | Calibration Start Command | P 25 |
| 21H | PLconstH | R/W | High Word of PL_Constant | P 25 |
| 22H | PLconstL | R/W | Low Word of PL_Constant | P 26 |
| 23H | Lgain | R/W | L Line Calibration Gain | P 26 |
| 24H | Lphi | R/W | L Line Calibration Angle | P 26 |
| 25H | Ngain | R/W | N Line Calibration Gain | P 27 |
| 26H | Nphi | R/W | N Line Calibration Angle | P 27 |
| 27H | PStartTh | R/W | Active Startup Power Threshold | P 27 |
| 28H | PNoITh | R/W | Active No-Load Power Threshold | P 28 |
| 2BH | MMode | R/W | Metering Mode Configuration | P 29 |
| 2CH | CS1 | R/W | Checksum 1 | P 31 |
| Measurement Calibration Register | | | | |
| 30H | AdjStart | R/W | Measurement Calibration Start Command | P 32 |
| 31H | Ugain | R/W | Voltage rms Gain | P 32 |
| 32H | IgainL | R/W | L Line Current rms Gain | P 33 |
| 33H | IgainN | R/W | N Line Current rms Gain | P 33 |
| 34H | Uoffset | R/W | Voltage Offset | P 33 |
| 35H | IoffsetL | R/W | L Line Current Offset | P 34 |
| 36H | IoffsetN | R/W | N Line Current Offset | P 34 |
| 37H | PoffsetL | R/W | L Line Active Power Offset | P 34 |
| 39H | PoffsetN | R/W | N Line Active Power Offset | P 35 |
| 3BH | CS2 | R/W | Checksum 2 | P 36 |
| Energy Register | | | | |
| 40H | APenergy | R/C | Forward Active Energy | P 37 |
| 41H | ANenergy | R/C | Reverse Active Energy | P 38 |
| 42H | ATenergy | R/C | Absolute Active Energy | P 38 |
| 46H | EnStatus | R | Metering Status | P 39 |
| Measurement Register | | | | |
| 48H | Irms | R | L Line Current rms | P 40 |
| 49H | Urms | R | Voltage rms | P 40 |
| 4AH | Pmean | R | L Line Mean Active Power | P 41 |
| 4CH | Freq | R | Voltage Frequency | P 41 |

Table-9 Register List (Continued)

| Register Address | Register Name | Read/Write Type | Functional Description | Page |
|-------------------------|-------------------------|------------------------|--|----------------------|
| 4DH | PowerF | R | L Line Power Factor | P 42 |
| 4EH | Pangle | R | Phase Angle between Voltage and L Line Current | P 42 |
| 4FH | Smean | R | L Line Mean Apparent Power | P 43 |
| 68H | Irms2 | R | N Line Current rms | P 43 |
| 6AH | Pmean2 | R | N Line Mean Active Power | P 44 |
| 6DH | PowerF2 | R | N Line Power Factor | P 44 |
| 6EH | Pangle2 | R | Phase Angle between Voltage and N Line Current | P 45 |
| 6FH | Smean2 | R | N Line Mean Apparent Power | P 45 |

5.2 STATUS AND SPECIAL REGISTER

SoftReset Software Reset

| Address: 00H | | | | | | | |
|----------------------|-----------------|---|-------------|-------------|-------------|------------|------------|
| Type: Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SoftReset15 | SoftReset14 | SoftReset13 | SoftReset12 | SoftReset11 | SoftReset10 | SoftReset9 | SoftReset8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SoftReset7 | SoftReset6 | SoftReset5 | SoftReset4 | SoftReset3 | SoftReset2 | SoftReset1 | SoftReset0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | SoftReset[15:0] | Software reset register. The XXXXXX resets if only 789AH is written to this register. | | | | | |

SysStatus System Status

Address: 01H
Type: Read/Clear
Default Value: 0000H

| | | | | | | | |
|----------|---------|---------|---------|----|----|---------|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| CalErr1 | CalErr0 | AdjErr1 | AdjErr0 | - | - | - | - |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| LNchange | - | RevPchg | - | - | - | SagWarn | - |

| Bit | Name | Description |
|---------|-------------|---|
| 15 - 14 | CalErr[1:0] | These bits indicate CS1 checksum status. 00: CS1 checksum correct (default) 11: CS1 checksum error. At the same time, the WarnOut pin is asserted. |
| 13 - 12 | AdjErr[1:0] | These bits indicate CS2 checksum status. 00: CS2 checksum correct (default) 11: CS2 checksum error. |
| 11 - 8 | - | Reserved. |
| 7 | LNchange | This bit indicates whether there is any change of the metering line (L line and N line). 0: metering line no change (default) 1: metering line changed |
| 6 | - | Reserved. |
| 5 | RevPchg | This bit indicates whether there is any change with the direction of active energy. 0: direction of active energy no change (default) 1: direction of active energy changed This status is enabled by the RevPEn bit (FuncEn , 02H). |
| 4 - 2 | - | Reserved. |
| 1 | SagWarn | This bit indicates the voltage sag status. 0: no voltage sag (default) 1: voltage sag Voltage sag is enabled by the SagEn bit (FuncEn , 02H). Voltage sag status can also be reported by the WarnOut pin. It is enabled by the SagWo bit(FuncEn , 02H). |
| 0 | - | Reserved. |

Note: Any of the above events will prompt the IRQ pin to be asserted, which can be supplied to external MCU as an interrupt.

FuncEn Function Enable

| Address: 02H | | | | | | | |
|----------------------|--------|---|-------|----|--------|---|---|
| Type: Read/Write | | | | | | | |
| Default Value: 000CH | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| - | - | - | - | - | - | - | - |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| - | - | SagEn | SagWo | - | RevPEn | - | - |
| Bit | Name | Description | | | | | |
| 15 - 6 | - | Reserved. | | | | | |
| 5 | SagEn | This bit determines whether to enable the voltage sag interrupt. 0: disable (default) 1: enable | | | | | |
| 4 | SagWo | This bit determines whether to enable voltage sag to be reported by the WarnOut pin. 0: disable (default) 1: enable | | | | | |
| 3 | - | Reserved. | | | | | |
| 2 | RevPEn | This bit determines whether to enable the direction change interrupt of active energy. 0: disable 1: enable (default) | | | | | |
| 1 - 0 | - | Reserved. | | | | | |

SagTh Voltage Sag Threshold

| Address: 03H | | | | | | | |
|----------------------|-------------|--|---------|---------|---------|--------|--------|
| Type: Read/Write | | | | | | | |
| Default Value: 1D6AH | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SagTh15 | SagTh14 | SagTh13 | SagTh12 | SagTh11 | SagTh10 | SagTh9 | SagTh8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SagTh7 | SagTh6 | SagTh5 | SagTh4 | SagTh3 | SagTh2 | SagTh1 | SagTh0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | SagTh[15:0] | Voltage sag threshold configuration. Data format is XXX.XX. Unit is V. The power-on value of SagTh is 1D6AH, which is calculated by $22000 \cdot \sqrt{2} \cdot 0.78 / (4 \cdot U_{\text{gain}} / 32768)$ For details, please refer to application note 46101. | | | | | |

SmallPMod Small-Power Mode

| Address: 04H | | | | | | | |
|----------------------|------------------|---|-----------------|-----------------|-----------------|------------|------------|
| Type: Read/Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| SmallPMod1 5 | SmallPMod1 4 | SmallPMod1 3 | SmallPMod1 2 | SmallPMod1 1 | SmallPMod1 0 | SmallPMod9 | SmallPMod8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| SmallPMod7 | SmallPMod6 | SmallPMod5 | SmallPMod4 | SmallPMod3 | SmallPMod2 | SmallPMod1 | SmallPMod0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | SmallP-Mod[15:0] | Small-power mode command. A987H: small-power mode. The relationship between the register value of L line and N line active power in small-power mode and normal mode is: power in normal mode = power in small-power mode *10*Igain*Ugain /2^42 Others: Normal mode. Small-power mode is mainly used in the power offset calibration. | | | | | |

LastSPIData Last Read/Write SPI Value

| Address: 06H | | | | | | | |
|----------------------|--------------------|--|-------------------|-------------------|-------------------|--------------|--------------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| LastSPIData1 5 | LastSPIData1 4 | LastSPIData1 3 | LastSPIData1 2 | LastSPIData1 1 | LastSPIData1 0 | LastSPIData9 | LastSPIData8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| LastSPIData7 | LastSPIData6 | LastSPIData5 | LastSPIData4 | LastSPIData3 | LastSPIData2 | LastSPIData1 | LastSPIData0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | LastSPI-Data[15:0] | This register stores the data that is just read or written through the SPI interface. Refer to Table-7 and Table-8 . | | | | | |

5.3 METERING/ MEASUREMENT CALIBRATION AND CONFIGURATION

5.3.1 METERING CALIBRATION AND CONFIGURATION REGISTER

CalStart Calibration Start Command

| Address: 20H | | | | | | | |
|----------------------|----------------|---|------------|------------|------------|-----------|-----------|
| Type: Read/Write | | | | | | | |
| Default Value: 6886H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| CalStart15 | CalStart14 | CalStart13 | CalStart12 | CalStart11 | CalStart10 | CalStart9 | CalStart8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CalStart7 | CalStart6 | CalStart5 | CalStart4 | CalStart3 | CalStart2 | CalStart1 | CalStart0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | CalStart[15:0] | <p>Metering calibration start command:</p> <p>6886H: Power-on value. Metering function is disabled.</p> <p>5678H: Metering calibration startup command. After 5678H is written to this register, registers 21H-2BH resume to their power-on values. The M90E25 starts to meter and output energy pulses regardless of the correctness of diagnosis. The CalErr[1:0] bits (SysStatus, 01H) are not set and the WarnOut/IRQ pins do not report any warning/interrupt.</p> <p>8765H: Check the correctness of the 21H-2BH registers. If correct, normal metering. If not correct, metering function is disabled, the CalErr[1:0] bits (SysStatus, 01H) are set and the WarnOut/IRQ pins report warning/interrupt.</p> <p>Others: Metering function is disabled. The CalErr[1:0] bits (SysStatus, 01H) are set and the WarnOut/IRQ pins report warning/interrupt.</p> | | | | | |

PLconstH High Word of PL_Constant

| Address: 21H | | | | | | | |
|----------------------|----------------|---|------------|------------|------------|-----------|-----------|
| Type: Read/Write | | | | | | | |
| Default Value: 0015H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PLconstH15 | PLconstH14 | PLconstH13 | PLconstH12 | PLconstH11 | PLconstH10 | PLconstH9 | PLconstH8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PLconstH7 | PLconstH6 | PLconstH5 | PLconstH4 | PLconstH3 | PLconstH2 | PLconstH1 | PLconstH0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | PLconstH[15:0] | <p>The PLconstH[15:0] and PLconstL[15:0] bits are high word and low word of PL_Constant respectively. PL_Constant is a constant which is proportional to the sampling ratios of voltage and current, and inversely proportional to the Meter Constant. PL_Constant is a threshold for energy calculated inside the chip, i.e., energy larger than PL_Constant will be accumulated in the corresponding energy registers and then output on CF1.</p> <p>It is suggested to set PL_constant as a multiple of 4 so as to double or redouble Meter Constant in low current state to save verification time.</p> <p>Note: PLconstH takes effect after PLconstL are configured.</p> <p>For details, please refer to application note 46101.</p> | | | | | |

PLconstL
Low Word of PL_Constant

| Address: 22H | | | | | | | |
|----------------------|----------------|--|------------|------------|------------|-----------|-----------|
| Type: Read/Write | | | | | | | |
| Default Value: D174H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PLconstL15 | PLconstL14 | PLconstL13 | PLconstL12 | PLconstL11 | PLconstL10 | PLconstL9 | PLconstL8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PLconstL7 | PLconstL6 | PLconstL5 | PLconstL4 | PLconstL3 | PLconstL2 | PLconstL1 | PLconstL0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | PLconstL[15:0] | The PLconstH[15:0] and PLconstL[15:0] bits are high word and low word of PL_Constant respectively. It is suggested to set PL_constant as a multiple of 4. For details, please refer to application note 46101. | | | | | |

Lgain
L Line Calibration Gain

| Address: 23H | | | | | | | |
|----------------------|-------------|---|---------|---------|---------|--------|--------|
| Type: Read/Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Lgain15 | Lgain14 | Lgain13 | Lgain12 | Lgain11 | Lgain10 | Lgain9 | Lgain8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Lgain7 | Lgain6 | Lgain5 | Lgain4 | Lgain3 | Lgain2 | Lgain1 | Lgain0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Lgain[15:0] | L line calibration gain. For details, please refer to application note 46101. | | | | | |

Lphi
L Line Calibration Angle

| Address: 24H | | | | | | | |
|----------------------|------------|--|-------|-------|-------|-------|-------|
| Type: Read/Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Lphi15 | - | - | - | - | - | Lphi9 | Lphi8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Lphi7 | Lphi6 | Lphi5 | Lphi4 | Lphi3 | Lphi2 | Lphi1 | Lphi0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Lphi[15:0] | L line calibration phase angle. For details, please refer to application note 46101. | | | | | |

Ngain N Line Calibration Gain

| | | | | | | | |
|----------------------|-------------|---|---------|---------|---------|--------|--------|
| Address: 25H | | | | | | | |
| Type: Read/Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Ngain15 | Ngain14 | Ngain13 | Ngain12 | Ngain11 | Ngain10 | Ngain9 | Ngain8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Ngain7 | Ngain6 | Ngain5 | Ngain4 | Ngain3 | Ngain2 | Ngain1 | Ngain0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Ngain[15:0] | N line calibration gain. For details, please refer to application note 46101. | | | | | |

Nphi N Line Calibration Angle

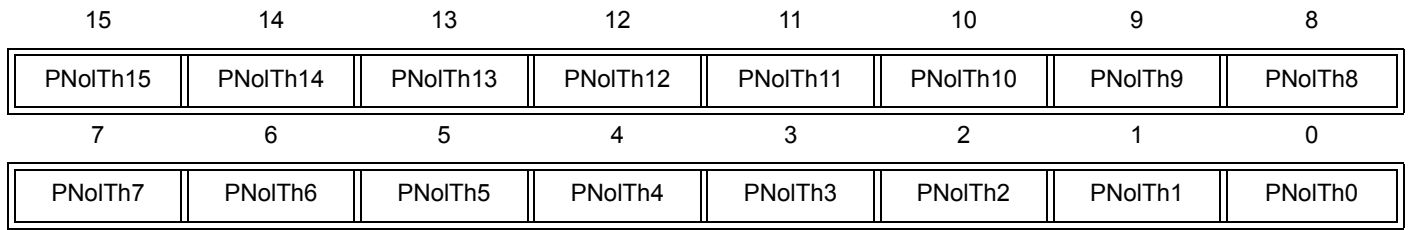
| | | | | | | | |
|----------------------|-------------|--|-------|-------|-------|-------|-------|
| Address: 26H | | | | | | | |
| Type: Read/Write | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Nphi15 | - | - | - | - | - | Nphi9 | Nphi8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Nphi7 | Nphi6 | Nphi5 | Nphi4 | Nphi3 | Nphi2 | Nphi1 | Nphi0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Nphi[15:0] | N line calibration phase angle. For details, please refer to application note 46101. | | | | | |

PStartTh Active Startup Power Threshold

| | | | | | | | |
|----------------------|----------------|--|------------|------------|------------|-----------|-----------|
| Address: 27H | | | | | | | |
| Type: Read/Write | | | | | | | |
| Default Value: 08BDH | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PStartTh15 | PStartTh14 | PStartTh13 | PStartTh12 | PStartTh11 | PStartTh10 | PStartTh9 | PStartTh8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PStartTh7 | PStartTh6 | PStartTh5 | PStartTh4 | PStartTh3 | PStartTh2 | PStartTh1 | PStartTh0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | PStartTh[15:0] | Active startup power threshold. For details, please refer to application note 46101. | | | | | |

PNoITh
Active No-Load Power Threshold

Address: 28H
 Type: Read/Write
 Default Value: 0000H



| Bit | Name | Description |
|--------|--------------|--|
| 15 - 0 | PNoITh[15:0] | Active no-load power threshold. For details, please refer to application note 46101. |

MMode Metering Mode Configuration

Address: 2BH
Type: Read/Write
Default Value: 9422H

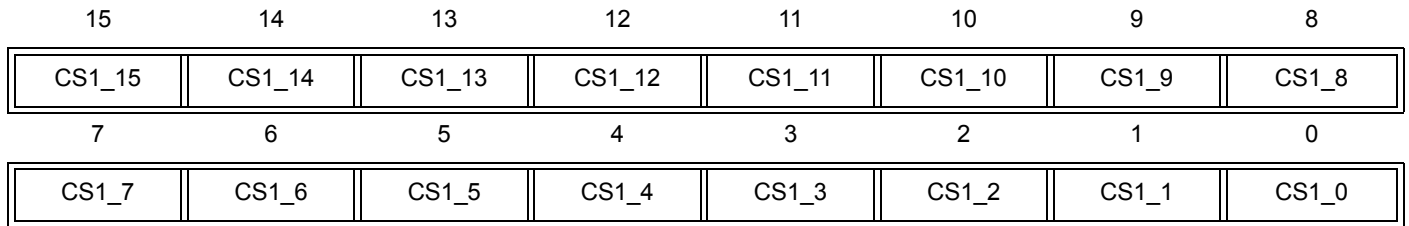
| | | | | | | | |
|--------|--------|--------|--------|----------|----------|----------|----------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Lgain2 | Lgain1 | Lgain0 | Ngain1 | Ngain0 | LNSel | DisHPF1 | DisHPF0 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Amod | - | ZXCon1 | ZXCon0 | Pthresh3 | Pthresh2 | Pthresh1 | Pthresh0 |

| Bit | Name | Description | | | | | | | | | | | | | | | | | | | | | | | | |
|---------|-------------|--|----------------------|----------|-------------------|----------------------|---|--------------------------------|---|---|----------------------------|---|---|----------------------------|---|---|-----------------------|---|---|---|---|----|---|---|---|----|
| 15 - 13 | Lgain[2:0] | L line current gain, default value is '100'. <table border="1"> <thead> <tr> <th>Lgain2</th><th>Lgain1</th><th>Lgain0</th><th>Current Channel Gain</th></tr> </thead> <tbody> <tr> <td>1</td><td>X</td><td>X</td><td>1</td></tr> <tr> <td>0</td><td>0</td><td>0</td><td>4</td></tr> <tr> <td>0</td><td>0</td><td>1</td><td>8</td></tr> <tr> <td>0</td><td>1</td><td>0</td><td>16</td></tr> <tr> <td>0</td><td>1</td><td>1</td><td>24</td></tr> </tbody> </table> | Lgain2 | Lgain1 | Lgain0 | Current Channel Gain | 1 | X | X | 1 | 0 | 0 | 0 | 4 | 0 | 0 | 1 | 8 | 0 | 1 | 0 | 16 | 0 | 1 | 1 | 24 |
| Lgain2 | Lgain1 | Lgain0 | Current Channel Gain | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | X | X | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 4 | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 1 | 8 | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | 16 | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 1 | 24 | | | | | | | | | | | | | | | | | | | | | | | |
| 12 - 11 | Ngain[1:0] | N line current gain 00: 2 01: 4 10: 1 (default) 11: 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | LNSel | This bit specifies metering as L line or N line when metering mode is set to flexible mode by MMD1 and MMD0 pins. 0: N line 1: L line (default) | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 - 8 | DisHPF[1:0] | These bits configure the High Filter Pass (HPF) after ADC. There are two first-order HPF in serial: HPF1 and HPF0. The configuration are applicable to all channels: <table border="1"> <thead> <tr> <th>DisHPF1</th><th>DisHPF 0</th><th>HPF Configuration</th></tr> </thead> <tbody> <tr> <td>0</td><td>0</td><td>enable HPF1 and HPF0 (default)</td></tr> <tr> <td>0</td><td>1</td><td>enable HPF1, disable HPF0;</td></tr> <tr> <td>1</td><td>0</td><td>disable HPF1, enable HPF0;</td></tr> <tr> <td>1</td><td>1</td><td>disable HPF1 and HPF0</td></tr> </tbody> </table> | DisHPF1 | DisHPF 0 | HPF Configuration | 0 | 0 | enable HPF1 and HPF0 (default) | 0 | 1 | enable HPF1, disable HPF0; | 1 | 0 | disable HPF1, enable HPF0; | 1 | 1 | disable HPF1 and HPF0 | | | | | | | | | |
| DisHPF1 | DisHPF 0 | HPF Configuration | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | enable HPF1 and HPF0 (default) | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | enable HPF1, disable HPF0; | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | disable HPF1, enable HPF0; | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | disable HPF1 and HPF0 | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Amod | CF1 output for active power: 0: forward or reverse energy pulse output (default) 1: absolute energy pulse output | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | - | Reserved. | | | | | | | | | | | | | | | | | | | | | | | | |

| 5 - 4 | Zxcon[1:0] | <p>These bits configure zero-crossing mode. The ZX pin outputs 5ms-width high level when voltage crosses zero.</p> <p>00: positive zero-crossing 01: negative zero-crossing 10: all zero-crossing: both positive and negative zero-crossing (default) 11: no zero-crossing output</p> | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------|--------------|--|-----------|------------------|-----------|----------|-----------|---|---|---|---|-------|---|---|---|---|-------|---|---|---|---|------------------|---|---|---|---|---------|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|----|---|---|---|---|-----|---|---|---|---|-----|---|---|---|---|-----|
| 3 - 0 | Pthresh[3:0] | <p>These bits configure the L line and N line power difference threshold in anti-tampering mode.</p> <table border="1" data-bbox="570 457 1369 982"> <thead> <tr> <th>Pthresh 3</th> <th>Pthresh 2</th> <th>Pthresh 1</th> <th>Pthresh0</th> <th>Threshold</th> </tr> </thead> <tbody> <tr><td>0</td><td>0</td><td>0</td><td>0</td><td>12.5%</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>1</td><td>6.25%</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>0</td><td>3.125% (default)</td></tr> <tr><td>0</td><td>0</td><td>1</td><td>1</td><td>1.5625%</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1%</td></tr> <tr><td>0</td><td>1</td><td>0</td><td>1</td><td>2%</td></tr> <tr><td>0</td><td>1</td><td>1</td><td>0</td><td>3%</td></tr> <tr><td>0</td><td>1</td><td>1</td><td>1</td><td>4%</td></tr> <tr><td>1</td><td>0</td><td>0</td><td>0</td><td>5%</td></tr> <tr><td>1</td><td>0</td><td>0</td><td>1</td><td>6%</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>0</td><td>7%</td></tr> <tr><td>1</td><td>0</td><td>1</td><td>1</td><td>8%</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>0</td><td>9%</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>1</td><td>10%</td></tr> <tr><td>1</td><td>1</td><td>1</td><td>0</td><td>11%</td></tr> <tr><td>1</td><td>1</td><td>1</td><td>1</td><td>12%</td></tr> </tbody> </table> | Pthresh 3 | Pthresh 2 | Pthresh 1 | Pthresh0 | Threshold | 0 | 0 | 0 | 0 | 12.5% | 0 | 0 | 0 | 1 | 6.25% | 0 | 0 | 1 | 0 | 3.125% (default) | 0 | 0 | 1 | 1 | 1.5625% | 0 | 1 | 0 | 0 | 1% | 0 | 1 | 0 | 1 | 2% | 0 | 1 | 1 | 0 | 3% | 0 | 1 | 1 | 1 | 4% | 1 | 0 | 0 | 0 | 5% | 1 | 0 | 0 | 1 | 6% | 1 | 0 | 1 | 0 | 7% | 1 | 0 | 1 | 1 | 8% | 1 | 1 | 0 | 0 | 9% | 1 | 1 | 0 | 1 | 10% | 1 | 1 | 1 | 0 | 11% | 1 | 1 | 1 | 1 | 12% |
| Pthresh 3 | Pthresh 2 | Pthresh 1 | Pthresh0 | Threshold | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | 12.5% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 1 | 6.25% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 1 | 0 | 3.125% (default) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 1 | 1 | 1.5625% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | 0 | 1% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | 1 | 2% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 1 | 0 | 3% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 1 | 1 | 4% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 5% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 0 | 1 | 6% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 1 | 0 | 7% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 1 | 1 | 8% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | 0 | 9% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 0 | 1 | 10% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 0 | 11% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | 12% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

**CS1
Checksum 1**

Address: 2CH
Type: Read/Write
Default Value: 0000H



| Bit | Name | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|-----------|--|------------------|-----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|
| 15 - 0 | CS1[15:0] | <p>The CS1 register should be written after the 21H-2BH registers are written. Suppose the high byte and the low byte of the 21H-2BH registers are shown in below table.</p> <table border="1" style="margin: 10px auto; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">Register Address</th> <th style="width: 20%;">High Byte</th> <th style="width: 20%;">Low Byte</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">21H</td><td style="text-align: center;">H_{21}</td><td style="text-align: center;">L_{21}</td></tr> <tr><td style="text-align: center;">22H</td><td style="text-align: center;">H_{22}</td><td style="text-align: center;">L_{22}</td></tr> <tr><td style="text-align: center;">23H</td><td style="text-align: center;">H_{23}</td><td style="text-align: center;">L_{23}</td></tr> <tr><td style="text-align: center;">24H</td><td style="text-align: center;">H_{24}</td><td style="text-align: center;">L_{24}</td></tr> <tr><td style="text-align: center;">25H</td><td style="text-align: center;">H_{25}</td><td style="text-align: center;">L_{25}</td></tr> <tr><td style="text-align: center;">26H</td><td style="text-align: center;">H_{26}</td><td style="text-align: center;">L_{26}</td></tr> <tr><td style="text-align: center;">27H</td><td style="text-align: center;">H_{27}</td><td style="text-align: center;">L_{27}</td></tr> <tr><td style="text-align: center;">28H</td><td style="text-align: center;">H_{28}</td><td style="text-align: center;">L_{28}</td></tr> <tr><td style="text-align: center;">29H</td><td style="text-align: center;">H_{29}</td><td style="text-align: center;">L_{29}</td></tr> <tr><td style="text-align: center;">2AH</td><td style="text-align: center;">H_{2A}</td><td style="text-align: center;">L_{2A}</td></tr> <tr><td style="text-align: center;">2BH</td><td style="text-align: center;">H_{2B}</td><td style="text-align: center;">L_{2B}</td></tr> </tbody> </table> <p>The calculation of the CS1 register is as follows:</p> <p>The low byte of 2CH register is: $L_{2C} = \text{MOD}(H_{21} + H_{22} + \dots + H_{2B} + L_{21} + L_{22} + \dots + L_{2B}, 2^8)$</p> <p>The high byte of 2CH register is: $H_{2C} = H_{21} \text{ XOR } H_{22} \text{ XOR } \dots \text{ XOR } H_{2B} \text{ XOR } L_{21} \text{ XOR } L_{22} \text{ XOR } \dots \text{ XOR } L_{2B}$</p> <p>A part of registers are not used. These registers can be dealt as 0000H in CS calculation.</p> <p>The M90E25 calculates CS1 regularly. If the value of the CS1 register and the calculation by the M90E25 is different when CalStart=8765H, the CalErr[1:0] bits (SysStatus, 01H) are set and the WarnOut and IRQ pins are asserted.</p> <p>Note: The readout value of the CS1 register is the calculation by the M90E25, which is different from what is written.</p> | Register Address | High Byte | Low Byte | 21H | H_{21} | L_{21} | 22H | H_{22} | L_{22} | 23H | H_{23} | L_{23} | 24H | H_{24} | L_{24} | 25H | H_{25} | L_{25} | 26H | H_{26} | L_{26} | 27H | H_{27} | L_{27} | 28H | H_{28} | L_{28} | 29H | H_{29} | L_{29} | 2AH | H_{2A} | L_{2A} | 2BH | H_{2B} | L_{2B} |
| Register Address | High Byte | Low Byte | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21H | H_{21} | L_{21} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22H | H_{22} | L_{22} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23H | H_{23} | L_{23} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24H | H_{24} | L_{24} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25H | H_{25} | L_{25} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26H | H_{26} | L_{26} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27H | H_{27} | L_{27} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28H | H_{28} | L_{28} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29H | H_{29} | L_{29} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2AH | H_{2A} | L_{2A} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2BH | H_{2B} | L_{2B} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

5.3.2 MEASUREMENT CALIBRATION REGISTER

AdjStart Measurement Calibration Start Command

| Address: 30H | | | | | | | |
|----------------------|----------------|--|------------|------------|------------|-----------|-----------|
| Type: Read/Write | | | | | | | |
| Default Value: 6886H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| AdjStart15 | AdjStart14 | AdjStart13 | AdjStart12 | AdjStart11 | AdjStart10 | AdjStart9 | AdjStart8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| AdjStart7 | AdjStart6 | AdjStart5 | AdjStart4 | AdjStart3 | AdjStart2 | AdjStart1 | AdjStart0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | AdjStart[15:0] | <p>Measurement Calibration Start Command</p> <p>6886H: Power-on value. No measurement.</p> <p>5678H: Measurement calibration startup command. After 5678H is written to this register, registers 31H-3AH resume to their power-on values. The M90E25 starts to measure regardless of the correctness of diagnosis. The AdjErr[1:0] bits (SysStatus, 01H) are not set and the IRQ pin does not report any interrupt.</p> <p>8765H: Check the correctness of the 31H-3AH registers. If correct, normal measurement. If not correct, measurement function is disabled, the AdjErr[1:0] bits (SysStatus, 01H) are set and the IRQ pin reports interrupt.</p> <p>Others: No measurement. The AdjErr[1:0] bits (SysStatus, 01H) are set and the IRQ pin reports interrupt.</p> | | | | | |

Ugain Voltage rms Gain

| Address: 31H | | | | | | | |
|----------------------|-------------|--|---------|---------|---------|--------|--------|
| Type: Read/Write | | | | | | | |
| Default Value: 6720H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Ugain15 | Ugain14 | Ugain13 | Ugain12 | Ugain11 | Ugain10 | Ugain9 | Ugain8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Ugain7 | Ugain6 | Ugain5 | Ugain4 | Ugain3 | Ugain2 | Ugain1 | Ugain0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Ugain[15:0] | <p>Voltage rms Gain. For details, please refer to application note 46101.</p> <p>Note: the Ugain15 bit should only be '0'</p> | | | | | |

IgainL L Line Current rms Gain

Address: 32H
Type: Read/Write
Default Value: 7A13H

| | | | | | | | |
|----------|----------|----------|----------|----------|----------|---------|---------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| IgainL15 | IgainL14 | IgainL13 | IgainL12 | IgainL11 | IgainL10 | IgainL9 | IgainL8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IgainL7 | IgainL6 | IgainL5 | IgainL4 | IgainL3 | IgainL2 | IgainL1 | IgainL0 |

| Bit | Name | Description |
|--------|--------------|---|
| 15 - 0 | IgainL[15:0] | L Line Current rms Gain, For details, please refer to application note 46101. |

IgainN N Line Current rms Gain

Address: 33H
Type: Read/Write
Default Value: 7530H

| | | | | | | | |
|----------|----------|----------|----------|----------|----------|---------|---------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| IgainN15 | IgainN14 | IgainN13 | IgainN12 | IgainN11 | IgainN10 | IgainN9 | IgainN8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| IgainN7 | IgainN6 | IgainN5 | IgainN4 | IgainN3 | IgainN2 | IgainN1 | IgainN0 |

| Bit | Name | Description |
|--------|--------------|---|
| 15 - 0 | IgainN[15:0] | N Line Current rms Gain. For details, please refer to application note 46101. |

Uoffset Voltage Offset

Address: 34H
Type: Read/Write
Default Value: 0000H

| | | | | | | | |
|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Uoffset15 | Uoffset14 | Uoffset13 | Uoffset12 | Uoffset11 | Uoffset10 | Uoffset9 | Uoffset8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Uoffset7 | Uoffset6 | Uoffset5 | Uoffset4 | Uoffset3 | Uoffset2 | Uoffset1 | Uoffset0 |

| Bit | Name | Description |
|--------|---------------|---|
| 15 - 0 | Uoffset[15:0] | Voltage offset. For calculation method, please refer to application note 46101. |

loffsetL
L Line Current Offset

Address: 35H
 Type: Read/Write
 Default Value: 0000H

| | | | | | | | |
|------------|------------|------------|------------|------------|------------|-----------|-----------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| loffsetL15 | loffsetL14 | loffsetL13 | loffsetL12 | loffsetL11 | loffsetL10 | loffsetL9 | loffsetL8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| loffsetL7 | loffsetL6 | loffsetL5 | loffsetL4 | loffsetL3 | loffsetL2 | loffsetL1 | loffsetL0 |

| Bit | Name | Description |
|--------|----------------|--|
| 15 - 0 | loffsetL[15:0] | L line current offset. For calculation method, please refer to application note 46101. |

loffsetN
N Line Current Offset

Address: 36H
 Type: Read/Write
 Default Value: 0000H

| | | | | | | | |
|------------|------------|------------|------------|------------|------------|-----------|-----------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| loffsetN15 | loffsetN14 | loffsetN13 | loffsetN12 | loffsetN11 | loffsetN10 | loffsetN9 | loffsetN8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| loffsetN7 | loffsetN6 | loffsetN5 | loffsetN4 | loffsetN3 | loffsetN2 | loffsetN1 | loffsetN0 |

| Bit | Name | Description |
|--------|----------------|--|
| 15 - 0 | loffsetN[15:0] | N line current offset. For calculation method, please refer to application note 46101. |

PoffsetL
L Line Active Power Offset

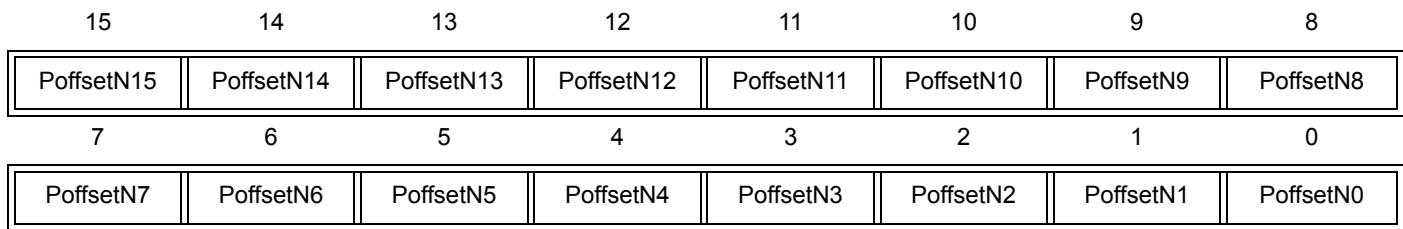
Address: 37H
 Type: Read/Write
 Default Value: 0000H

| | | | | | | | |
|------------|------------|------------|------------|------------|------------|-----------|-----------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PoffsetL15 | PoffsetL14 | PoffsetL13 | PoffsetL12 | PoffsetL11 | PoffsetL10 | PoffsetL9 | PoffsetL8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PoffsetL7 | PoffsetL6 | PoffsetL5 | PoffsetL4 | PoffsetL3 | PoffsetL2 | PoffsetL1 | PoffsetL0 |

| Bit | Name | Description |
|--------|----------------|---|
| 15 - 0 | PoffsetL[15:0] | L line active power offset. Complement, MSB is the sign bit. For calculation method, please refer to application note 46101. |

PoffsetN
N Line Active Power Offset

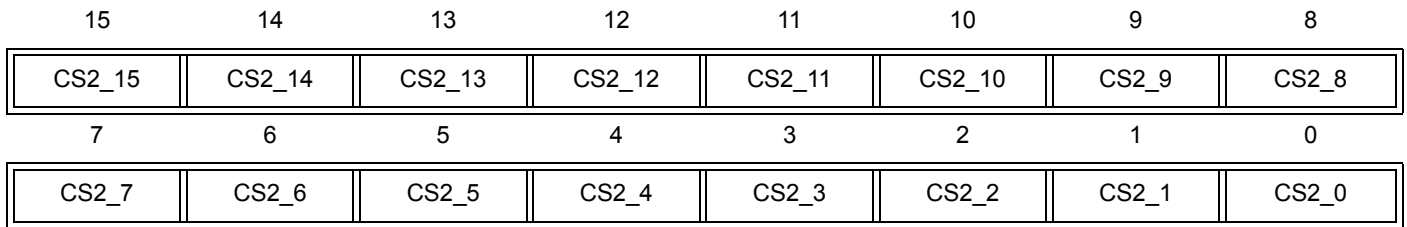
Address: 39H
 Type: Read/Write
 Default Value: 0000H



| Bit | Name | Description |
|--------|----------------|---|
| 15 - 0 | PoffsetN[15:0] | N line active power offset. Complement, MSB is the sign bit. For calculation method, please refer to application note 46101. |

CS2 Checksum 2

Address: 3BH
Type: Read/Write
Default Value: 0000H



| Bit | Name | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|------------------|-----------|--|------------------|-----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|-----|----------|----------|
| 15 - 0 | CS2[15:0] | <p>The CS2 register should be written after the 31H-3AH registers are written. Suppose the high byte and the low byte of the 31H-3AH registers are shown in below table.</p> <table border="1" style="margin: 10px auto; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;">Register Address</th> <th style="width: 20%;">High Byte</th> <th style="width: 20%;">Low Byte</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">31H</td><td style="text-align: center;">H_{31}</td><td style="text-align: center;">L_{31}</td></tr> <tr><td style="text-align: center;">32H</td><td style="text-align: center;">H_{32}</td><td style="text-align: center;">L_{32}</td></tr> <tr><td style="text-align: center;">33H</td><td style="text-align: center;">H_{33}</td><td style="text-align: center;">L_{33}</td></tr> <tr><td style="text-align: center;">34H</td><td style="text-align: center;">H_{34}</td><td style="text-align: center;">L_{34}</td></tr> <tr><td style="text-align: center;">35H</td><td style="text-align: center;">H_{35}</td><td style="text-align: center;">L_{35}</td></tr> <tr><td style="text-align: center;">36H</td><td style="text-align: center;">H_{36}</td><td style="text-align: center;">L_{36}</td></tr> <tr><td style="text-align: center;">37H</td><td style="text-align: center;">H_{37}</td><td style="text-align: center;">L_{37}</td></tr> <tr><td style="text-align: center;">38H</td><td style="text-align: center;">H_{38}</td><td style="text-align: center;">L_{38}</td></tr> <tr><td style="text-align: center;">39H</td><td style="text-align: center;">H_{39}</td><td style="text-align: center;">L_{39}</td></tr> <tr><td style="text-align: center;">3AH</td><td style="text-align: center;">H_{3A}</td><td style="text-align: center;">L_{3A}</td></tr> </tbody> </table> <p>The calculation of the CS2 register is as follows:</p> <p>The low byte of 3BH register is: $L_{3B} = \text{MOD}(H_{31} + H_{32} + \dots + H_{3A} + L_{31} + L_{32} + \dots + L_{3A}, 2^8)$</p> <p>The high byte of 3BH register is: $H_{3B} = H_{31} \text{ XOR } H_{32} \text{ XOR } \dots \text{ XOR } H_{3A} \text{ XOR } L_{31} \text{ XOR } L_{32} \text{ XOR } \dots \text{ XOR } L_{3A}$</p> <p>The M90E25 calculates CS2 regularly. If the value of the CS2 register and the calculation by the M90E25 is different when AdjStart=8765H, the AdjErr[1:0] bits (SysStatus, 01H) are set.</p> <p>Note: The readout value of the CS2 register is the calculation by the XXXXXX, which is different from what is written.</p> | Register Address | High Byte | Low Byte | 31H | H_{31} | L_{31} | 32H | H_{32} | L_{32} | 33H | H_{33} | L_{33} | 34H | H_{34} | L_{34} | 35H | H_{35} | L_{35} | 36H | H_{36} | L_{36} | 37H | H_{37} | L_{37} | 38H | H_{38} | L_{38} | 39H | H_{39} | L_{39} | 3AH | H_{3A} | L_{3A} |
| Register Address | High Byte | Low Byte | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31H | H_{31} | L_{31} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32H | H_{32} | L_{32} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33H | H_{33} | L_{33} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34H | H_{34} | L_{34} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35H | H_{35} | L_{35} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36H | H_{36} | L_{36} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37H | H_{37} | L_{37} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 38H | H_{38} | L_{38} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 39H | H_{39} | L_{39} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3AH | H_{3A} | L_{3A} | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

5.4 ENERGY REGISTER

Theory of Energy Registers

The internal energy resolution is 0.01 pulse. Within 0.01 pulse, forward and reverse energy are counteracted. When energy exceeds 0.01 pulse, the respective forward/reserve energy is increased. The forward and reverse energy are not counteracted in absolute energy registers. Take the example of active energy, suppose:

T0: Forward energy is 12.34 pulses and reverse energy is 1.23 pulses;

From T0 to T1: 0.005 forward pulse appeared

From T1 to T2: 0.004 reverse pulse appeared

From T2 to T3: 0.003 reverse pulse appeared

| | T0 | T1 | T2 | T3 |
|-----------------------|-------|--------|--------|--------|
| Forward Active Pulse | 12.34 | 12.345 | 12.341 | 12.34 |
| Reserve Active Pulse | 1.23 | 1.23 | 1.23 | 1.232 |
| Absolute Active Pulse | 13.57 | 13.575 | 13.579 | 13.582 |

When forward/reverse energy or absolute energy reaches 0.1 pulse, the respective register is updated. When forward/reverse energy or absolute energy reaches 1 pulse, the CF1 pins outputs pulse and the REVP/REVQ bits ([EnStatus](#), 46H) are updated.

Absolute energy might be more than the sum of forward and reverse energies. If “consistency” is required between absolute energy and forward/reverse energy in system application, absolute energy can be obtained by calculating the readout of the forward and reverse energy registers.

APenergy

Forward Active Energy

| Address: 40H | | | | | | | |
|----------------------|----------------|--|------------|------------|------------|-----------|-----------|
| Type: Read/Clear | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| APenergy15 | APenergy14 | APenergy13 | APenergy12 | APenergy11 | APenergy10 | APenergy9 | APenergy8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| APenergy7 | APenergy6 | APenergy5 | APenergy4 | APenergy3 | APenergy2 | APenergy1 | APenergy0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | APenergy[15:0] | Forward active energy; cleared after read. Data format is XXXX.X pulses. Resolution is 0.1 pulse. Maximum is 6553.5 pulses. When the accumulation of this register has achieved FFFFH, the continuation accumulation will return to 0000H. | | | | | |

ANenergy Reverse Active Energy

| Address: 41H | | | | | | | |
|----------------------|----------------|--|------------|------------|------------|-----------|-----------|
| Type: Read/Clear | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ANenergy15 | ANenergy14 | ANenergy13 | ANenergy12 | ANenergy11 | ANenergy10 | ANenergy9 | ANenergy8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ANenergy7 | ANenergy6 | ANenergy5 | ANenergy4 | ANenergy3 | ANenergy2 | ANenergy1 | ANenergy0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | ANenergy[15:0] | Reverse active energy, cleared after read. Data format is XXXX.X pulses. Resolution is 0.1 pulse. Maximum is 6553.5 pulses. When the accumulation of this register has achieved FFFFH, the continuation accumulation will return to 0000H. | | | | | |

ATenergy Absolute Active Energy

| Address: 42H | | | | | | | |
|----------------------|----------------|---|------------|------------|------------|-----------|-----------|
| Type: Read/Clear | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| ATenergy15 | ATenergy14 | ATenergy13 | ATenergy12 | ATenergy11 | ATenergy10 | ATenergy9 | ATenergy8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| ATenergy7 | ATenergy6 | ATenergy5 | ATenergy4 | ATenergy3 | ATenergy2 | ATenergy1 | ATenergy0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | ATenergy[15:0] | Absolute active energy, cleared after read. Data format is XXXX.X pulses. Resolution is 0.1 pulse. Maximum is 6553.5 pulses. When the accumulation of this register has achieved FFFFH, the continuation accumulation will return to 0000H. | | | | | |

EnStatus Metering Status

Address: 46H

Type: Read

Default Value After Power On: C800H

| | | | | | | | |
|----|---------|----|------|-------|----|---------|---------|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| - | Pnoload | - | RevP | Lline | - | - | - |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| - | - | - | - | - | - | LNMode1 | LNMode0 |

| Bit | Name | Description | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------|-------------|--|------------|---|------------|------------|-------------------|---|---|---|---|------------------------------------|---|---|---|---|----------------------------|---|---|---|---|--|---|---|---|---|---|
| 15 | - | Reserved. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | Pnoload | This bit indicates whether the M90E25 is in active no-load status. 0: not active no-load state 1: active no-load state | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | - | Reserved. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | RevP | This bit indicates the direction of the last CF1 (active output). 0: active forward 1: active reverse Note: This bit is always '0' when the CF1 output is configured to be absolute energy. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Lline | This bit indicates the current metering line in anti-tampering mode. 0: N line 1: L line | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 - 2 | - | Reserved. | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 - 0 | LNMode[1:0] | These bits indicate the configuration of MMD1 and MMD0 pins. Their relationship is as follows: <table border="1" style="margin-left: 20px;"> <thead> <tr> <th>MMD 1</th><th>MMD 0</th><th>LNmo d1</th><th>LNmo d0</th><th>L/N Metering Mode</th></tr> </thead> <tbody> <tr> <td>0</td><td>0</td><td>0</td><td>0</td><td>anti-tampering mode (larger power)</td></tr> <tr> <td>0</td><td>1</td><td>0</td><td>1</td><td>L line mode (fixed L line)</td></tr> <tr> <td>1</td><td>0</td><td>1</td><td>0</td><td>L+N mode (applicable for single-phase three-wire system)</td></tr> <tr> <td>1</td><td>1</td><td>1</td><td>1</td><td>Flexible mode (Line specified by the LNSel bit (MMode, 2BH))</td></tr> </tbody> </table> | MMD 1 | MMD 0 | LNmo d1 | LNmo d0 | L/N Metering Mode | 0 | 0 | 0 | 0 | anti-tampering mode (larger power) | 0 | 1 | 0 | 1 | L line mode (fixed L line) | 1 | 0 | 1 | 0 | L+N mode (applicable for single-phase three-wire system) | 1 | 1 | 1 | 1 | Flexible mode (Line specified by the LNSel bit (MMode , 2BH)) |
| MMD 1 | MMD 0 | LNmo d1 | LNmo d0 | L/N Metering Mode | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 0 | 0 | 0 | anti-tampering mode (larger power) | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 1 | 0 | 1 | L line mode (fixed L line) | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 0 | 1 | 0 | L+N mode (applicable for single-phase three-wire system) | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 | 1 | 1 | Flexible mode (Line specified by the LNSel bit (MMode , 2BH)) | | | | | | | | | | | | | | | | | | | | | | | |

5.5 MEASUREMENT REGISTER

Irms

L Line Current rms

| Address: 48H | | | | | | | |
|----------------------|------------|---|--------|--------|--------|-------|-------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Irms15 | Irms14 | Irms13 | Irms12 | Irms11 | Irms10 | Irms9 | Irms8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Irms7 | Irms6 | Irms5 | Irms4 | Irms3 | Irms2 | Irms1 | Irms0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Irms[15:0] | L line current rms. Data format is XX.XXX, which corresponds to 0 ~ 65.535A. For cases when the current exceeds 65.535A, it is suggested to be handled by MCU in application. For example, the register value can be calibrated to 1/2 of the actual value during calibration, then multiplied by 2 in application. | | | | | |

Urms

Voltage rms

| Address: 49H | | | | | | | |
|----------------------|------------|--|--------|--------|--------|-------|-------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Urms15 | Urms14 | Urms13 | Urms12 | Urms11 | Urms10 | Urms9 | Urms8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Urms7 | Urms6 | Urms5 | Urms4 | Urms3 | Urms2 | Urms1 | Urms0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Urms[15:0] | Voltage rms. Data format is XXX.XX, which corresponds to 0 ~ 655.35V. | | | | | |

Pmean
L Line Mean Active Power

| Address: 4AH | | | | | | | |
|----------------------|-------------|---|---------|---------|---------|--------|--------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Pmean15 | Pmean14 | Pmean13 | Pmean12 | Pmean11 | Pmean10 | Pmean9 | Pmean8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Pmean7 | Pmean6 | Pmean5 | Pmean4 | Pmean3 | Pmean2 | Pmean1 | Pmean0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Pmean[15:0] | L line mean active power. Complement, MSB is the sign bit. Data format is XX.XXX, which corresponds to -32.768~+32.768kW. If current is specially handle by MCU, the power of the M90E25 and the actual power have the same multiple relationship as the current. | | | | | |

Freq
Voltage Frequency

| Address: 4CH | | | | | | | |
|----------------------|------------|--|--------|--------|--------|-------|-------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Freq15 | Freq14 | Freq13 | Freq12 | Freq11 | Freq10 | Freq9 | Freq8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Freq7 | Freq6 | Freq5 | Freq4 | Freq3 | Freq2 | Freq1 | Freq0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Freq[15:0] | Voltage frequency. Data format is XX.XX. Frequency measurement range is 45.00~65.00Hz. For example, 1388H corresponds to 50.00Hz. | | | | | |

PowerF
L Line Power Factor

| Address: 4DH | | | | | | | |
|----------------------|--------------|---|----------|----------|----------|---------|---------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PowerF15 | PowerF14 | PowerF13 | PowerF12 | PowerF11 | PowerF10 | PowerF9 | PowerF8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PowerF7 | PowerF6 | PowerF5 | PowerF4 | PowerF3 | PowerF2 | PowerF1 | PowerF0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | PowerF[15:0] | L line power factor. Signed, MSB is the sign bit. Data format is X.XXX. Power factor range: -1.000~+1.000. For example, 03E8H corresponds to the power factor of 1.000, and 83E8H corresponds to the power factor of -1.000. | | | | | |

Pangle
Phase Angle between Voltage and L Line Current

| Address: 4EH | | | | | | | |
|----------------------|--------------|--|----------|----------|----------|---------|---------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Pangle15 | Pangle14 | Pangle13 | Pangle12 | Pangle11 | Pangle10 | Pangle9 | Pangle8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Pangle7 | Pangle6 | Pangle5 | Pangle4 | Pangle3 | Pangle2 | Pangle1 | Pangle0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Pangle[15:0] | L line voltage current angle. Signed, MSB is the sign bit. Data format is XXX.X. Angle range: -180.0~+180.0 degree. | | | | | |

Smean L Line Mean Apparent Power

| Address: 4FH | | | | | | | |
|----------------------|-------------|---|---------|---------|---------|--------|--------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Smean15 | Smean14 | Smean13 | Smean12 | Smean11 | Smean10 | Smean9 | Smean8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Smean7 | Smean6 | Smean5 | Smean4 | Smean3 | Smean2 | Smean1 | Smean0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Smean[15:0] | L line mean apparent power. Complement, MSB is always '0'. Data format is XX.XXX, which corresponds to 0~+32.767kVA. If current is specially handled by MCU, the power of the M90E25 and the actual power have the same multiple relationship as the current. | | | | | |

Irms2 N Line Current rms

| Address: 68H | | | | | | | |
|----------------------|-------------|---|----------|----------|----------|---------|---------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Irms2_15 | Irms2_14 | Irms2_13 | Irms2_12 | Irms2_11 | Irms2_10 | Irms2_9 | Irms2_8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Irms2_7 | Irms2_6 | Irms2_5 | Irms2_4 | Irms2_3 | Irms2_2 | Irms2_1 | Irms2_0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Irms2[15:0] | N line current rms. Data format is XX.XXX, which corresponds to 65.535A. For cases when the current exceeds 65.535A, it is suggested to be handled by MCU in application. For example, the register value can be calibrated to 1/2 of the actual value during calibration, then multiplied by 2 in application. | | | | | |

Pmean2
N Line Mean Active Power

| Address: 6AH | | | | | | | |
|----------------------|--------------|--|-----------|-----------|-----------|----------|----------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Pmean2_15 | Pmean2_14 | Pmean2_13 | Pmean2_12 | Pmean2_11 | Pmean2_10 | Pmean2_9 | Pmean2_8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Pmean2_7 | Pmean2_6 | Pmean2_5 | Pmean2_4 | Pmean2_3 | Pmean2_2 | Pmean2_1 | Pmean2_0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Pmean2[15:0] | N line mean active power. Complement, MSB is the sign bit. Data format is XX.XXX, which corresponds to -32.768~+32.767kW. If current is specially handled by MCU, the power of the M90E25 and the actual power have the same multiple relationship as the current. | | | | | |

PowerF2
N Line Power Factor

| Address: 6DH | | | | | | | |
|----------------------|---------------|---|------------|------------|------------|-----------|-----------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| PowerF2_15 | PowerF2_14 | PowerF2_13 | PowerF2_12 | PowerF2_11 | PowerF2_10 | PowerF2_9 | PowerF2_8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| PowerF2_7 | PowerF2_6 | PowerF2_5 | PowerF2_4 | PowerF2_3 | PowerF2_2 | PowerF2_1 | PowerF2_0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | PowerF2[15:0] | N line power factor. Signed, MSB is the sign bit. Data format is X.XXX. Power factor range: -1.000~+1.000. For example, 03E8H corresponds to the power factor of 1.000, and 83E8H corresponds to the power factor of -1.000. | | | | | |

Pangle2
Phase Angle between Voltage and N Line Current

| Address: 6EH | | | | | | | |
|----------------------|---------------|---|------------|------------|------------|-----------|-----------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Pangle2_15 | Pangle2_14 | Pangle2_13 | Pangle2_12 | Pangle2_11 | Pangle2_10 | Pangle2_9 | Pangle2_8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Pangle2_7 | Pangle2_6 | Pangle2_5 | Pangle2_4 | Pangle2_3 | Pangle2_2 | Pangle2_1 | Pangle2_0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Pangle2[15:0] | N line voltage current angle Signed, MSB is the sign bit. Data format is XXX.X. Angle range: -180.0~+180.0 degree. | | | | | |

Smean2
N Line Mean Apparent Power

| Address: 6FH | | | | | | | |
|----------------------|--------------|--|-----------|-----------|-----------|----------|----------|
| Type: Read | | | | | | | |
| Default Value: 0000H | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Smean2_15 | Smean2_14 | Smean2_13 | Smean2_12 | Smean2_11 | Smean2_10 | Smean2_9 | Smean2_8 |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Smean2_7 | Smean2_6 | Smean2_5 | Smean2_4 | Smean2_3 | Smean2_2 | Smean2_1 | Smean2_0 |
| Bit | Name | Description | | | | | |
| 15 - 0 | Smean2[15:0] | N line mean apparent power Complement, MSB is always '0'. Data format is XX.XXX, which corresponds to 0~+32.767kVA. If current is specially handled by MCU, the power of M90E25 and the actual power have the same multiple relationship as the current. | | | | | |

6 ELECTRICAL SPECIFICATION

6.1 ELECTRICAL SPECIFICATION

| Parameters and Description | Min. | Typical | Max. | Unit | Test Conditions and Comments |
|---|-----------|----------|-----------|-------------------------|---|
| Accuracy | | | | | |
| DC Power Supply Rejection Ratio (PSRR) | | | ± 0.1 | % | VDD=3.3V \pm 0.3V, 100Hz, I=5A, V=220V, L line shunt resistor 150 $\mu\Omega$, N line CT 1000:1, sampling resistor 4.8 Ω |
| AC Power Supply Rejection Ratio (PSRR) | | | ± 0.1 | % | VDD=3.3V superimposes 400mVrms, 100Hz Sinusoidal signal, I=5A, V=220V, L line shunt resistor 150 $\mu\Omega$, N line CT 1000:1, sampling resistor 4.8 Ω |
| Active Energy Error (Dynamic Range 5000:1) | | | ± 0.1 | % | L line current gain is '24'; N line current gain is '1' |
| Channel Characteristics | | | | | |
| Sampling Frequency | | 8 | | kHz | |
| L Line Current Channel Equivalent Input Noise | | | 19.1 | nV/ $\sqrt{\text{Hz}}$ | Single side band noise (measured at 50Hz, and PGA gain is '24') |
| N Line Current Channel Equivalent Input Noise | | | 458.4 | nV/ $\sqrt{\text{Hz}}$ | Single side band noise (measured at 50Hz, and PGA gain is '1') |
| Voltage Channel Equivalent Input Noise | | | 458.4 | nV/ $\sqrt{\text{Hz}}$ | Single side band noise (measured at 50Hz, and PGA gain is '1') |
| Total Harmonic Distortion for Each Channel | 80 | | | dB | 25°C, PGA gain is '1', 500mVrms input |
| Active Energy Metering Bandwidth | | 4 | | kHz | |
| Irms and Vrms Measurement Bandwidth | | 4 | | kHz | |
| Measurement Error | | | ± 0.5 | % | |
| Analog Input | | | | | |
| L Line Current Channel Differential Input | 5 μ | | 25m | Vrms | PGA gain is '24' |
| | 7.5 μ | | 37.5m | | PGA gain is '16' |
| | 15 μ | | 75m | | PGA gain is '8' |
| | 30 μ | | 150m | | PGA gain is '4' |
| | 120 μ | | 600m | | PGA gain is '1' |
| N Line Current Channel Differential Input | 30 μ | | 150m | Vrms | PGA gain is '4' |
| | 60 μ | | 300m | | PGA gain is '2' |
| | 120 μ | | 600m | | PGA gain is '1' |
| Voltage Channel Differential Input | 120 μ | | 600m | Vrms | PGA gain is '1' |
| L Line Current Channel Input Impedance | | 1 | | K Ω | |
| N Line Current Channel Input Impedance | | 50 | | K Ω | |
| Voltage Channel Input Impedance | | 50 | | K Ω | |
| L Line Current Channel DC Offset | | | 10 | mV | PGA gain is '24' |
| N Line Current Channel DC Offset | | | 10 | mV | PGA gain is '1' |
| Voltage Channel DC Offset | | | 10 | mV | PGA gain is '1' |
| Reference | | | | | |
| On-Chip Reference | 1.398 | 1.417 | 1.440 | V | Reference voltage test mode |
| Reference Voltage Temperature Coefficient | | ± 15 | ± 40 | ppm/ $^{\circ}\text{C}$ | |
| Clock | | | | | |
| Crystal or External Clock | | 8.192 | | MHz | The Accuracy of crystal or external clock is ± 100 ppm |

| SPI Interface | | | | | |
|---|------|------|---------|-----|--|
| SPI Interface Bit Rate | 200 | | 160k | bps | |
| Pulse Width | | | | | |
| CF1 Pulse Width | | 80 | | ms | If T ≥ 160 ms, width=80ms; if T<160 ms, width = 0.5T. Refer to Section 6.6 |
| ESD | | | | | |
| Machine Model (MM) | 400 | | | V | JESD22-A115 |
| Charged Device Model (CDM) | 1000 | | | V | JESD22-C101 |
| Human Body Model (HBM) | 4000 | | | V | JESD22-A114 |
| Latch Up | | | ±100 | mA | JESD78A |
| Latch Up | | | 4.95 | V | JESD78A |
| Operating Conditions | | | | | |
| AVDD, Analog Power Supply | 2.8 | 3.3 | 3.6 | V | Metering precision guaranteed within 3.0V~3.6V. |
| DVDD, Digital Power Supply | 2.8 | 3.3 | 3.6 | V | Metering precision guaranteed within 3.0V~3.6V. |
| I _{AVDD} , Analog Current | | 3.75 | | mA | L line/ N line current channel and voltage channel are open |
| I _{DVDD} , Digital Current | | 2.75 | | mA | VDD=3.3V |
| DC Characteristics | | | | | |
| Digital Input High Level (all digital pins except OSCI) | 2.0 | | VDD+2.6 | V | VDD=3.3V ± 10%, |
| Digital Input High Level (OSCI) | 2.0 | | VDD+0.3 | V | VDD=3.3V ± 10% |
| Digital Input Low Level | | | 0.8 | V | VDD=3.3V ± 10% |
| Digital Input Leakage Current | | | ±1 | μA | VDD=3.6V, VI=VDD or GND |
| Digital Output Low Level (CF1) | | | 0.4 | V | VDD=3.3V, I _{OL} =10mA |
| Digital Output Low Level (IRQ, WarnOut, ZX, SDO) | | | 0.4 | V | VDD=3.3V, I _{OL} =5mA |
| Digital Output High Level (CF1) | 2.4 | | | V | VDD=3.3V, I _{OH} =-10mA |
| Digital Output High Level (IRQ, WarnOut, ZX, SDO) | 2.4 | | | V | VDD=3.3V, I _{OH} =-5mA |
| Digital Output Low Level (OSCO) | | | 0.4 | V | VDD=3.3V, I _{OL} =1mA |
| Digital Output High Level (OSCO) | 2.4 | | | V | VDD=3.3V, I _{OH} =-1mA |

6.2 SPI INTERFACE TIMING

The SPI interface timing is as shown in Figure-7, Figure-8 and Table-10.

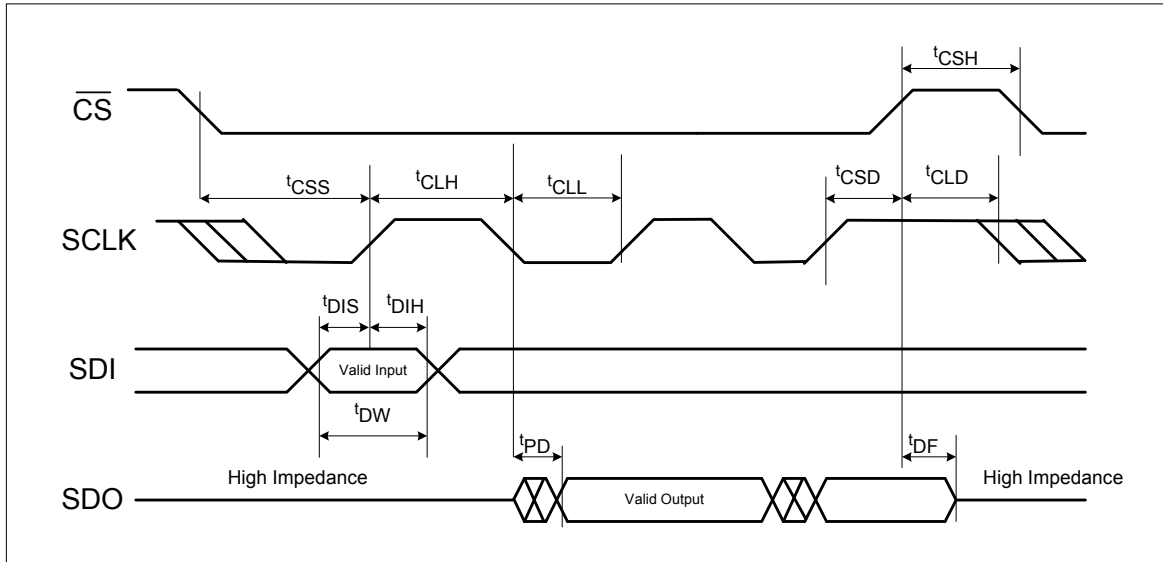


Figure-7 4-Wire SPI Timing Diagram

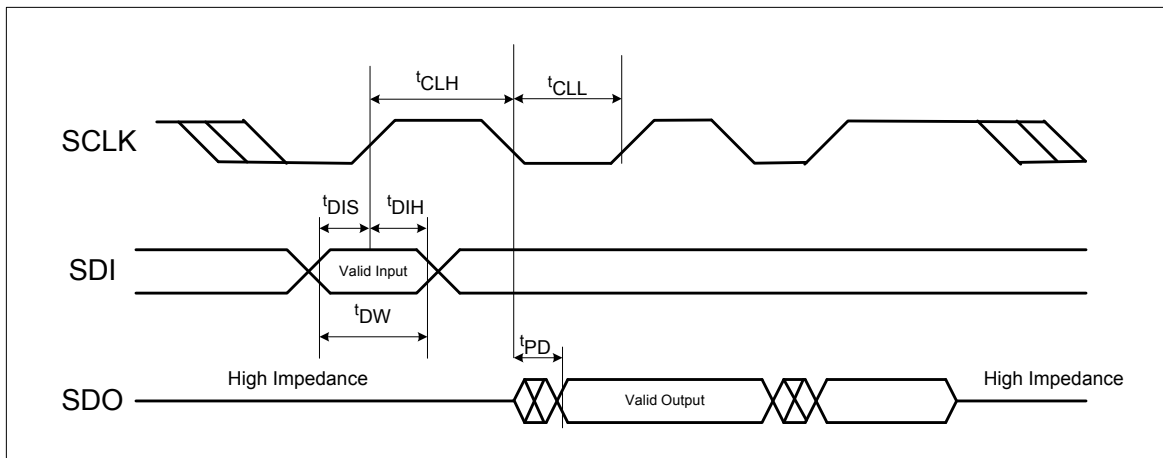


Figure-8 3-Wire SPI Timing Diagram

Table-10 SPI Timing Specification

| Symbol | Description | Min. | Typical | Max. | Unit |
|---------------------|---|--------------------|---------|----------|------|
| $t_{CSH}^{note\ 1}$ | Minimum \overline{CS} High Level Time | $30T^{note\ 2}+10$ | | | ns |
| $t_{CSS}^{note\ 1}$ | \overline{CS} Setup Time | $3T+10$ | | | ns |
| $t_{CSD}^{note\ 1}$ | \overline{CS} Hold Time | $30T+10$ | | | ns |
| $t_{CLD}^{note\ 1}$ | Clock Disable Time | $1T$ | | | ns |
| t_{CLH} | Clock High Level Time | $30T+10$ | | | ns |
| t_{CLL} | Clock Low Level Time | $16T+10$ | | | ns |
| t_{DIS} | Data Setup Time | $3T+10$ | | | ns |
| t_{DIH} | Data Hold Time | $22T+10$ | | | ns |
| t_{DW} | Minimum Data Width | $30T+10$ | | | ns |
| t_{PD} | Output Delay | $14T$ | | $15T+20$ | ns |
| $t_{DF}^{note\ 1}$ | Output Disable Time | | | $16T+20$ | ns |

Note:

1. Not applicable for three-wire SPI.
2. T means SCLK cycle. T=122ns. (Typical value for four-wire SPI)

6.3 POWER ON RESET TIMING

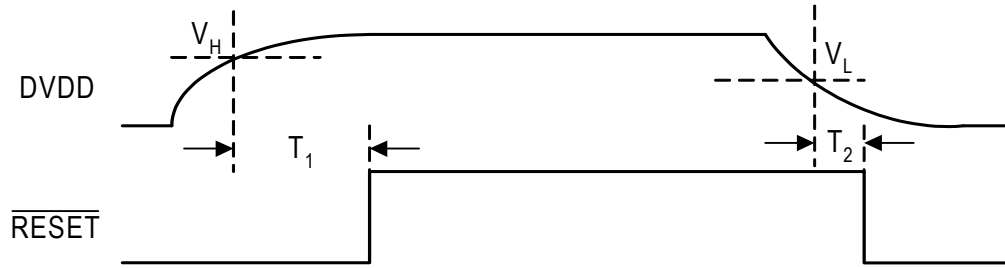


Figure-9 Power On Reset Timing Diagram

Table-11 Power On Reset Specification

| Symbol | Description | Min. | Typical | Max. | Unit |
|-------------|-------------------------------|-------|---------|-------|---------|
| V_H | Power On Trigger Voltage | 2.47 | 2.6 | 2.73 | V |
| V_L | Power Off Trigger Voltage | 2.185 | 2.3 | 2.415 | V |
| $V_H - V_L$ | Hysteretic Voltage Difference | 0.285 | 0.3 | 0.315 | V |
| T_1 | Delay Time After Power On | 5 | | | ms |
| T_2 | Delay Time After Power Off | 10 | | | μ s |

6.4 ZERO-CROSSING TIMING

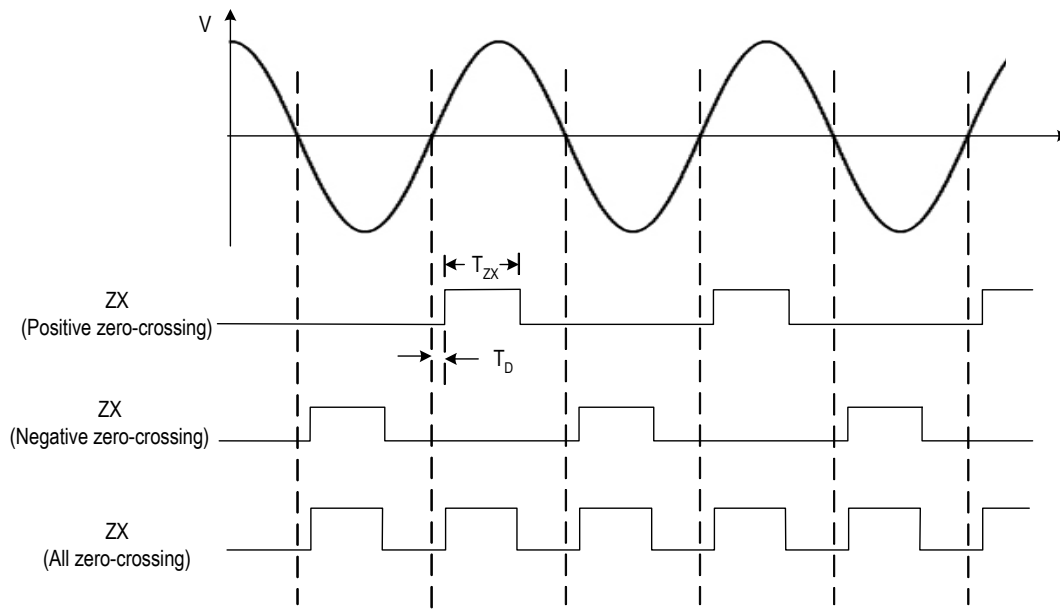


Figure-10 Zero-Crossing Timing Diagram

Table-12 Zero-Crossing Specification

| Symbol | Description | Min. | Typical | Max. | Unit |
|----------|------------------|------|---------|------|------|
| T_{ZX} | High Level Width | | 5 | | ms |
| T_D | Delay Time | | | 0.5 | ms |

6.5 VOLTAGE SAG TIMING

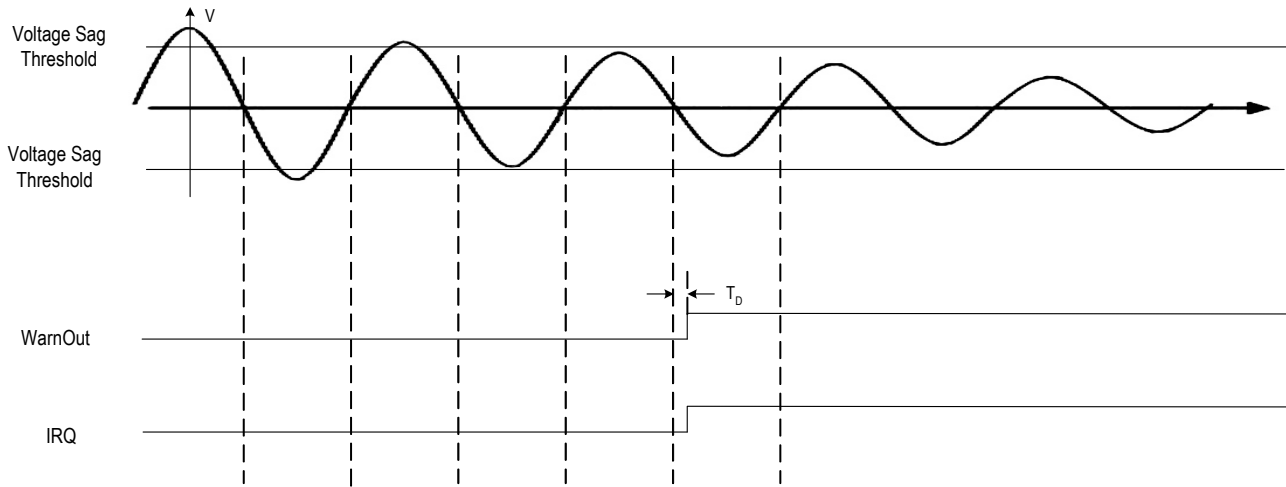


Figure-11 Voltage Sag Timing Diagram

Table-13 Voltage Sag Specification

| Symbol | Description | Min. | Typical | Max. | Unit |
|--------|-------------|------|---------|------|------|
| T_D | Delay Time | | | 0.5 | ms |

6.6 PULSE OUTPUT

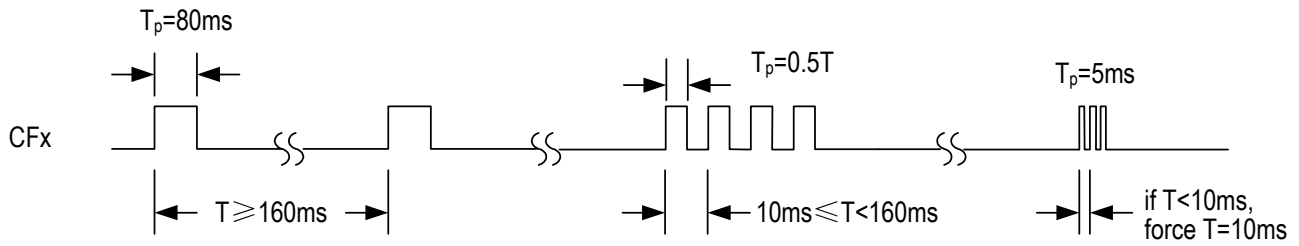


Figure-12 Output Pulse Width

6.7 ABSOLUTE MAXIMUM RATING

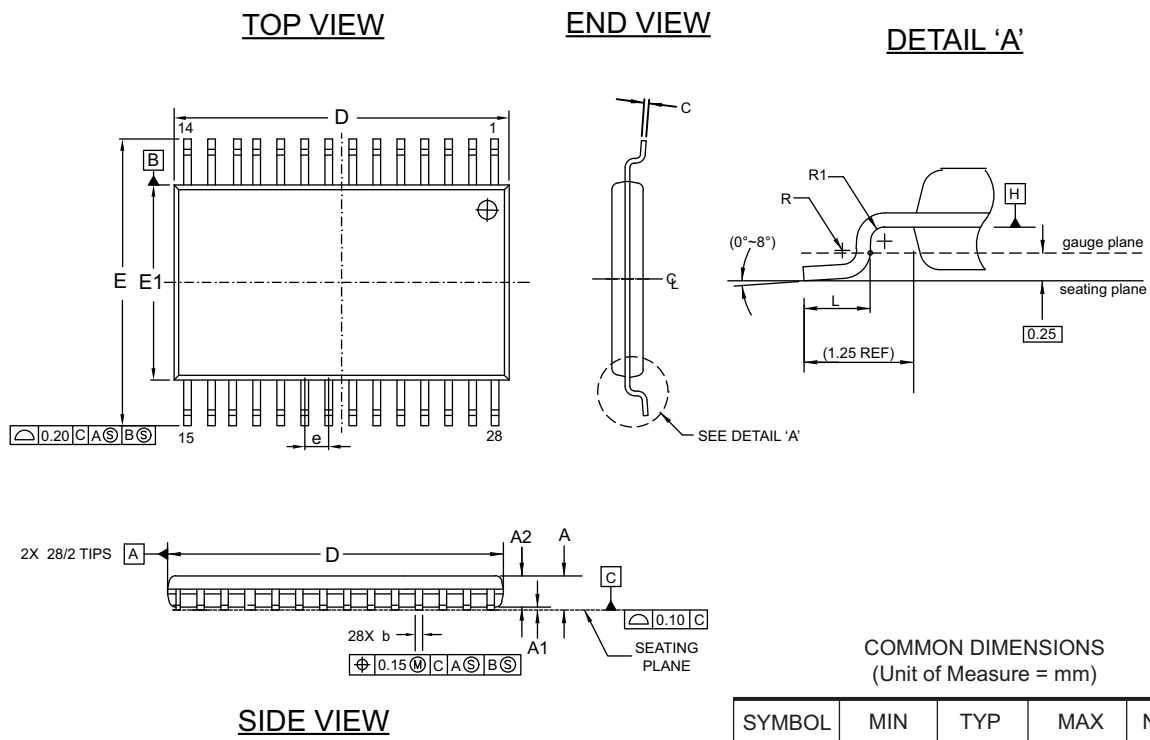
| Parameter | Maximum Limit |
|---|----------------|
| Relative Voltage Between AVDD and AGND | -0.3V~3.7V |
| Relative Voltage Between DVDD and DGND | -0.3V~3.7V |
| Analog Input Voltage (I1P, I1N, I2P, I2N, VP, VN) | -1V~VDD |
| Digital Input Voltage | -0.3V~VDD+2.6V |
| Operating Temperature Range | -40~85 °C |
| Maximum Junction Temperature | 150 °C |

| Package Type | Thermal Resistance θ_{JA} | Unit | Condition |
|--------------|----------------------------------|------|------------|
| Green SSOP28 | 63.2 | °C/W | No Airflow |

ORDERING INFORMATION

| Atmel Ordering Code | Package | Carrier | Temperature Range |
|---------------------|---------|-----------|---------------------------|
| ATM90E25-YU-R | SSOP28 | Tape&Reel | Industry (-40°C to +85°C) |
| ATM90E25-YU-B | SSOP28 | Tube | Industry (-40°C to +85°C) |

PACKAGE DIMENSIONS



COMMON DIMENSIONS
(Unit of Measure = mm)

| SYMBOL | MIN | TYP | MAX | NOTE |
|--------|----------|-------|-------|------|
| A | 1.73 | 1.86 | 1.99 | |
| A1 | 0.05 | 0.13 | 0.21 | |
| A2 | 1.68 | 1.73 | 1.78 | |
| b | 0.25 | - | 0.38 | 3 |
| c | 0.13 | - | 0.20 | |
| D | 10.07 | 10.20 | 10.33 | 2 |
| E | 7.65 | 7.80 | 7.90 | |
| E1 | 5.20 | 5.30 | 5.38 | 2 |
| e | 0.65 BSC | | | |
| L | 0.55 | 0.75 | 0.95 | |
| R | 0.09 | - | - | |
| R1 | 0.09 | - | - | |

- NOTE:
1. Refer to JEDEC drawing MO-150, Variation AH.
 2. 'D' and 'E1' dimensions do not include mold flash or protrusions, but do include mold mismatch and are measured at datum plane 'H'. Mold flash or protrusion shall not exceed 0.20mm per side.
 3. Dimension 'b' does not include dambar protrusion/intrusion. Allowable dambar protrusion shall be 0.13mm total in excess of b dimension at maximum material condition. Dambar intrusion shall not reduce dimension b by more than 0.07mm at least material condition.

2/25/14

| | | | | |
|---|--|------------------------------|--------------------------------------|-----------------------------|
| <p>Package Drawing Contact: packagedrawings@atmel.com</p> | <p>TITLE</p> <p>28Y, 28-lead 5.3 mm Body Width, 0.65mm pitch, 1.25mm lead length, Plastic Shrink Small Outline Package (SSOP)</p> | <p>GPC</p> <p>TBF</p> | <p>DRAWING NO.</p> <p>28Y</p> | <p>REV.</p> <p>B</p> |
| | | | | |

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|-----------|------------|------------------------------------|
| 46001A | 04/18/2014 | Initial document release in Atmel. |
| | | |



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