Atmel

Application Note

Poly-Phase Energy Metering IC

M90E32AS

APPLICATION OUTLINE

This document describes system application issues when using the M90E32AS (poly-phase energy metering ICs) to design poly-phase energy meters.

The M90E32AS is applicable in class 0.5S or class 1 poly-phase meter design and also supports Three-Phase Four-Wire (3P4W, Y0) or Three-Phase Three-Wire (3P3W, Y or Δ) connection modes.

The M90E32AS uses 3.3V single power supply. In a typical 3P4W design, there are three transformers&regulators to provide power supply. The AC power supply outputs 3.3V to chip digital power supply DVDD after rectifier and voltage regulation. The analog power supply AVDD should be connected directly to digital power supply DVDD.

The M90E32AS has on-chip power-on-reset circuit. The $\overline{\text{RESET}}$ pin should be connected to DVDD through a 10kΩ resistor and a 0.1μF filter capacitor to ground. The M90E32AS has highly stable on-chip reference power supply. The Vref pin should be decoupled with a 4.7μF capacitor and a 0.1μF ceramic capacitor.

The M90E32AS employs 16.384MHz as the system frequency. The M90E32AS has built-in crystal oscillator circuit and 10pF matching capacitance. Users only need to connect a 16.384MHz crystal between OSCI and OSCO pins in application.

The M90E32AS provides ADC sampling on three voltage channels (V1, V2 and V3) and three current channels (I1, I2 and I3). These 6 ADC channels can be flexibly mapped in different PCB design.

The M90E32AS provides a 4-wire SPI interface ($\overline{\text{CS}}$, SCLK, SDI and SDO) for external MCU connection. MCU can perform chip configuration and register reading/writing through SPI.

The M90E32AS provides four energy pulse output pins: active energy pulse CF1, reactive energy pulse CF2 (can also be configured as apparent energy pulse), fundamental energy pulse CF3 and harmonic energy pulse CF4. They can be used for energy metering calibration and can also be connected to MCU for energy accumulation.

The M90E32AS provides three zero-crossing pins ZX0, ZX1 and ZX2 which can select different phase's voltage or current as zero-crossing judgement.

The M90E32AS provides three output pins IRQ0, IRQ1 and WarnOut to generate interrupt and warn out signals at different levels.

The default application in this document is 3P4W, otherwise it will be specially indicated.

Atmel-46103A-SE-M90E32AS-ApplicationNote_050514

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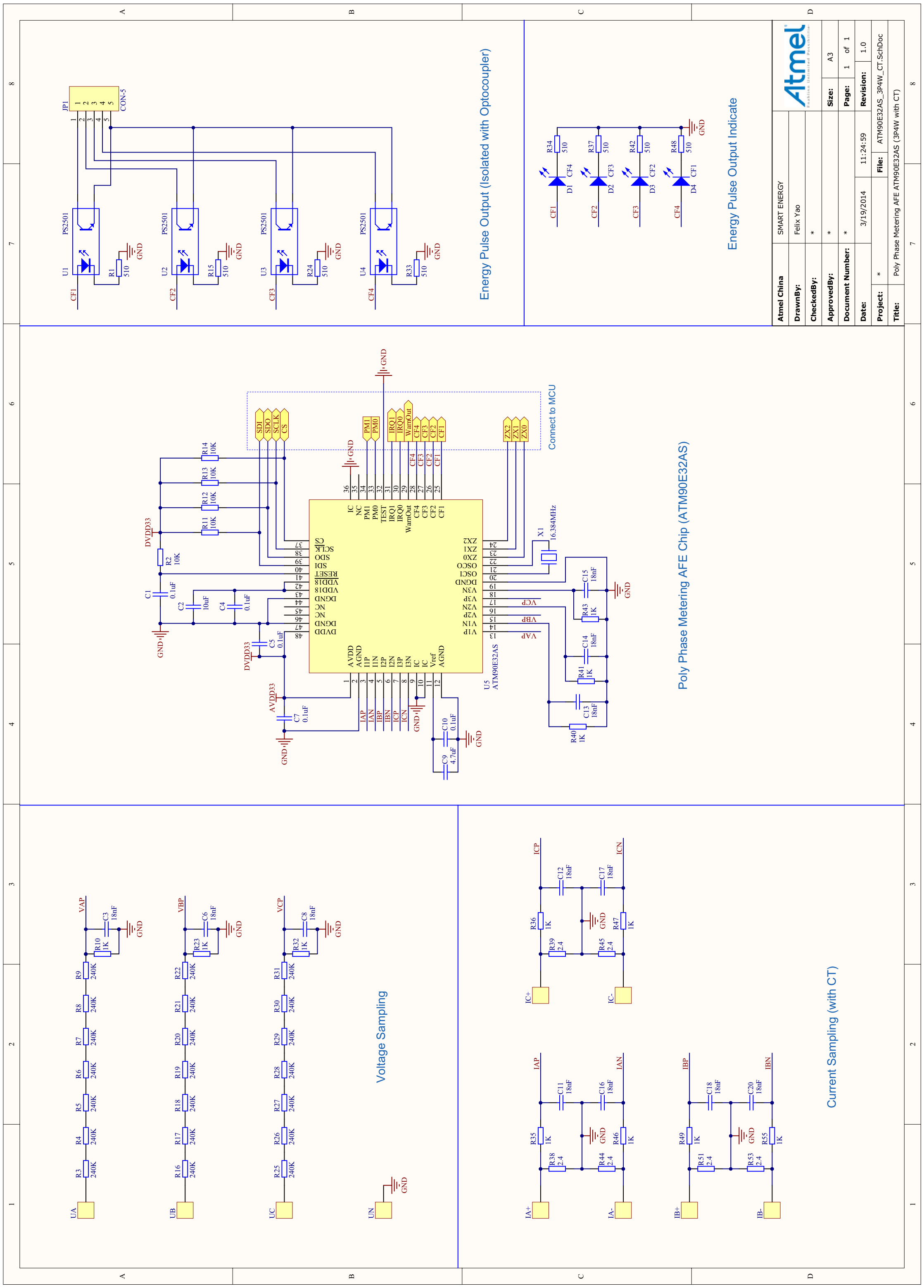
1 HARDWARE REFERENCE DESIGN

1.1 3P4W Application

1.1.1 Schematics (Current Transformer (CT))

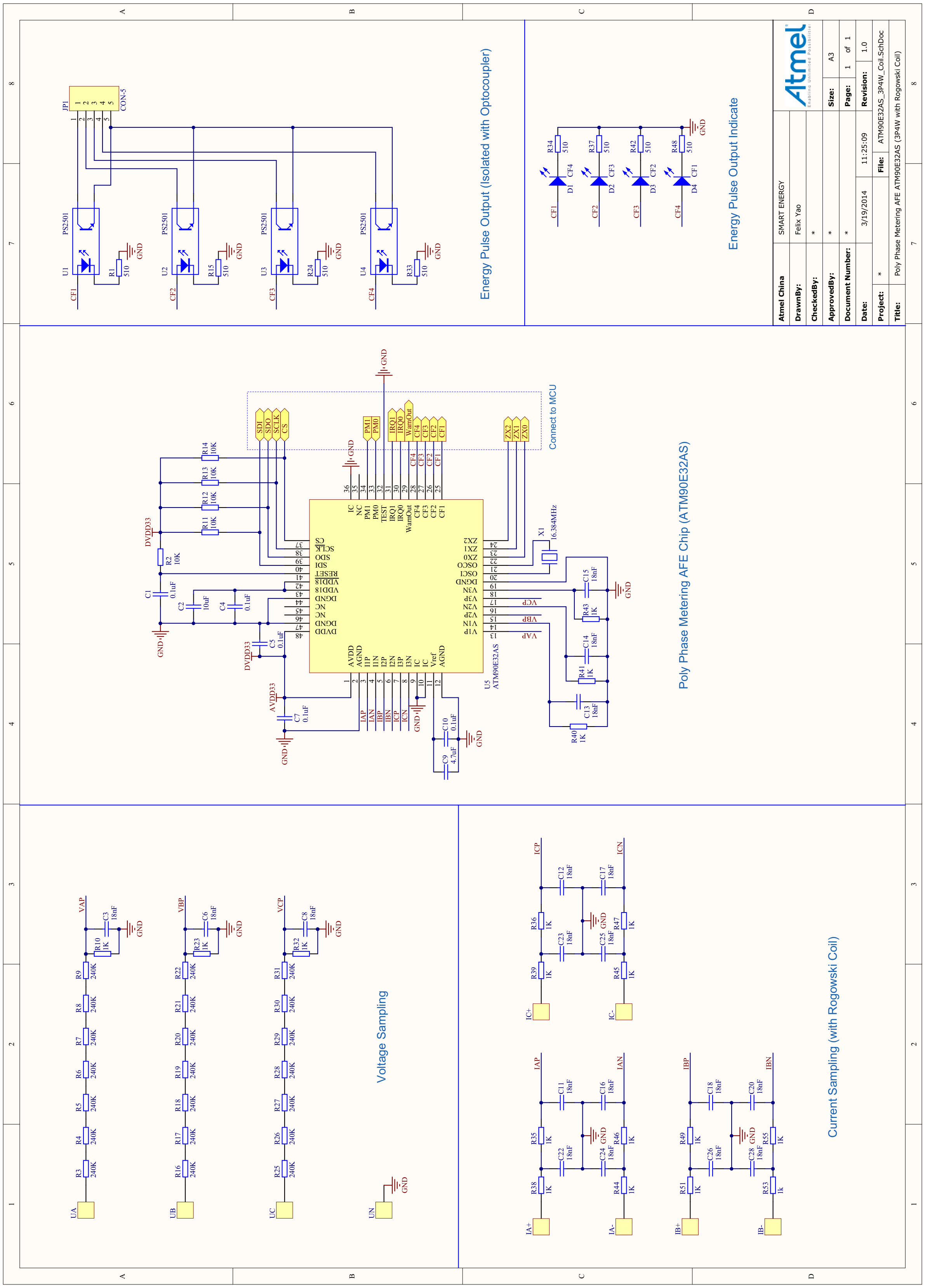


1.1.2 BOM (CT)

Table-1 3P4W BOM (CT)

Component Type	Designator	Quantity	Parameter	Tolerance
SMT Capacitor	C3 C6 C8 C11 C12 C13 C14 C15 C16 C17 C18 C20	12	18nF	±5% NP0 (anti-aliasing filter capacitor)
	C1 C4 C5 C7 C10	5	0.1µF	±10% X7R
	C9	1	4.7µF	±10% X7R
	C2	1	10µF	±10% X7R
SMT Resistor	R38 R39 R44 R45 R51 R53	6	2.4Ω	±1% 1/8W 25ppm
	R1 R15 R24 R33 R34 R37 R42 R48	8	510Ω	±5% 1/8W 100ppm
	R10 R23 R32 R35 R36 R40 R41 R43 R46 R47 R49 R55	12	1kΩ	±1% 1/8W 25ppm (anti-aliasing filter resistor)
	R2 R11 R12 R13 R14	5	10kΩ	±5% 1/8W 100ppm
	R3~R9, R16~R22, R25~R31	21	240kΩ	±1% 1/8W 25ppm
LED	D1 D2 D3 D4	4	-	-
SMT Optocoupler	U1 U2 U3 U4	4	PS2501	-
Crystal	X1	1	16.384MHz	±20ppm
IC	U5	1	M90E32AS	-
Connector	JP1	1	CON-5	-

1.1.3 Schematics (Rogowski)



1.1.4 BOM (Rogowski)

Table-2 3P4W BOM (Rogowski)

Component Type	Designator	Quantity	Parameter	Tolerance
SMT Capacitor	C3 C6 C8 C11 C12 C13 C14 C15 C16 C17 C18 C19 C20 C21 C22 C23 C24 C25 C26 C27 C28	21	18nF	±5% NP0 (anti-aliasing filter capacitor)
	C1 C4 C5 C7 C10	5	0.1µF	±10% X7R
	C9	1	4.7µF	±10% X7R
	C2	1	10µF	±10% X7R
SMT Resistor	R1 R15 R24 R33 R34 R37 R42 R48	8	510Ω	±5% 1/8W 100ppm
	R10 R23 R32 R35 R36 R38 R39 R40 R41 R43 R44 R45 R46 R47 R49 R51 R53 R55	18	1kΩ	±1% 1/8W 25ppm (anti-aliasing filter resistor)
	R2 R11 R12 R13 R14	5	10kΩ	±5% 1/8W 100ppm
	R3~R9, R16~R22, R25~R31	21	240kΩ	±1% 1/8W 25ppm
LED	D1 D2 D3 D4	4	-	-
SMT Optocoupler	U1 U2 U3 U4	4	PS2501	-
Crystal	X1	1	16.384MHz	±20ppm
IC	U5	1	M90E32AS	-
Connector	JP1	1	CON-5	-

1.1.5 Circuit Description

The recommended circuit for the M90E32AS three-phase four-wire (3P4W) application is as shown in 1.1.1 Schematics (Current Transformer (CT)). The M90E32AS can use CT and Rogowski coil in current sampling. The recommended circuit for 3P4W application with Rogowski coil is as shown in 1.1.3 Schematics (Rogowski).

It is recommended to use two-order filtering when sampling with Rogowski coil. The other parts are same with the CT application circuit. It is recommended to refer to the circuit of 1.2.1 Schematics when using Rogowski coil in 3P3W design, only need to change CT to Rogowski coil. The recommended type of Rogowski coil is: PA3202NL (Pulse Electronics).

Poly-phase voltage is sampled over resistor divider network with recommended ratio of 240KΩ x 7:1KΩ. The anti-aliasing filter capacitor is recommended to be 18nF. Poly-phase current and N line current are sampled over current transformer (CT). The CT ratio and load resistance should be selected based on the actual metering range. The anti-aliasing filter resistance/capacitor is suggested to be 1KΩ/18nF for the current sampling circuit.

The CF1~CF4 pins are provided with driving capacity of 8mA which can drive LED and optocoupler parallelly. The other digital pins are provided with driving capacity of 5mA which can drive optocoupler directly.

Application note: how to select CT and CT load resistance

Condition:

M90E32AS ADC input voltage range is 120µVrms ~ 720mVrms

M90E32AS ADC input gain PGA_GAIN = 1, 2, 4

Assume:

Metering range of the energy meter is Imin ~ Imax

CT current output ratio is N:1

CT load resistance is R_{CT}

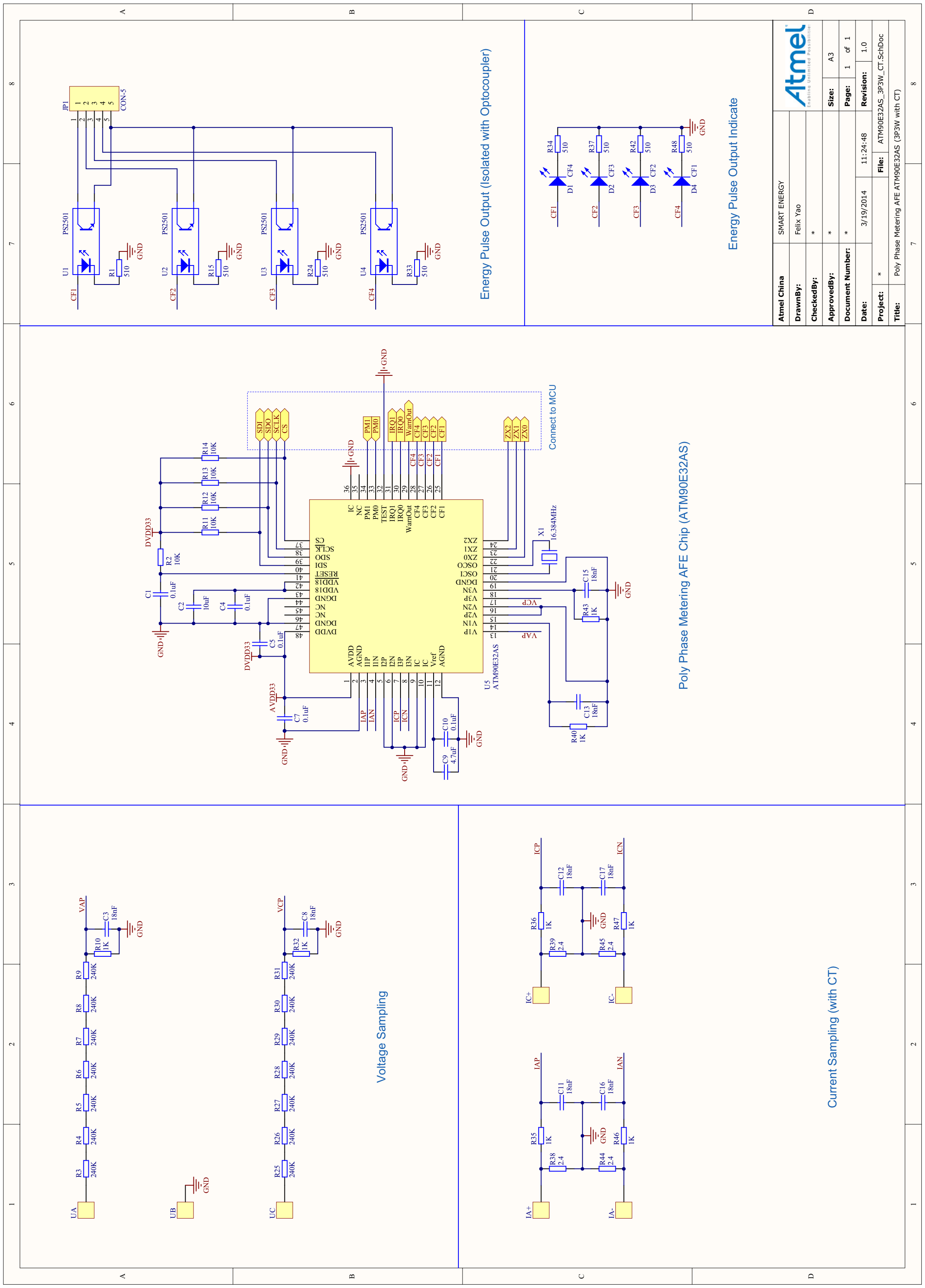
So the parameters meet the formula as below:

$$120\mu Vrms < \frac{PGA\_GAIN \times R_{CT} \times I_{min}}{N}$$

$$\frac{PGA\_GAIN \times R_{CT} \times I_{max}}{N} < 720mVrms$$

1.2 3P3W Application

1.2.1 Schematics



1.2.2 BOM

Table-3 3P3W BOM

Component Type	Designator	Quantity	Parameter	Tolerance
SMT Capacitor	C3 C8 C11 C12 C13 C15 C16 C17	8	18nF	±5% NP0 (anti-aliasing filter capacitor)
	C1 C4 C5 C7 C10	5	0.1µF	±10% X7R
	C9	1	4.7µF	±10% X7R
	C2	1	10µF	±10% X7R
SMT Resistor	R38 R39 R44 R45	4	2.4Ω	±1% 1/8W 25ppm
	R1 R15 R24 R33 R34 R37 R42 R48	8	510Ω	±5% 1/8W 100ppm
	R10 R32 R35 R36 R40 R43 R46 R47	8	1kΩ	±1% 1/8W 25ppm (anti-aliasing filter resistor)
	R2 R11 R12 R13 R14	5	10kΩ	±5% 1/8W 100ppm
	R3~R9, R25~R31	14	240kΩ	±1% 1/8W 25ppm
LED	D1 D2 D3 D4	4	-	-
SMT Optocoupler	U1 U2 U3 U4	4	PS2501	-
Crystal	X1	1	16.384MHz	±20ppm
IC	U5	1	M90E32AS	-
Connector	JP1	1	CON-5	-

1.2.3 Circuit Description

This circuit is the recommended circuit for the M90E32AS three-phase three-wire (3P3W) application.

Phase B is the reference ground in 3P3W application. In 3P3W system, Uab stands for Ua, Ucb stands for Uc and there is no Ub.

Phase B voltage, phase B current and N line sampling current are not needed in 3P3W application. Pin 5, 6, 15 and 16 should be connected to GND. All NC pins should be left open.

The other parts of 3P3W application circuit are similar to 3P4W and can be treated in the same way.

2 INTERFACE

The M90E32AS provides a four-wire SPI interface (CS, SCLK, SDI and SDO).

The SPI interface in Slave mode is mainly used for register read/write operation. A complete SPI read/write operation is of 32 bits, which contains 16-bit address and 16-bit data. In the 16-bit address, bit0 ~ bit9 correspond to valid register address A0 ~ A9, and bit10 ~ bit14 are reserved (these bits are don't-care). Bit15 indicates the SPI operation is read or write.

SPI Operation	Description	Highest Bit (Bit15)
Read	Read register data	1
Write	Write data to register	0

The transmission of address and data bits is from high to low, which means MSB first and LSB last. Note that the M90E32AS read/write only supports single address operation, rather than continuous read or write.

The M90E32AS has a special register LastSPIData [78H] for recording the last SPI read/write data. This register can be used for data check for SPI read/write operation. When the system is in strong interference situation, the disturbance signal may cause SPI communication disorder and result in SPI read/write error. In this case, LastSPIData can be used to check the correctness of SPI read/write and strengthen system robustness. For read-clear registers, if the read data is different from the LastSPIData data, the actual data can be obtained by reading the LastSPIData register repeatedly.

LastSPIData application is as shown in Figure-1 and Figure-2:

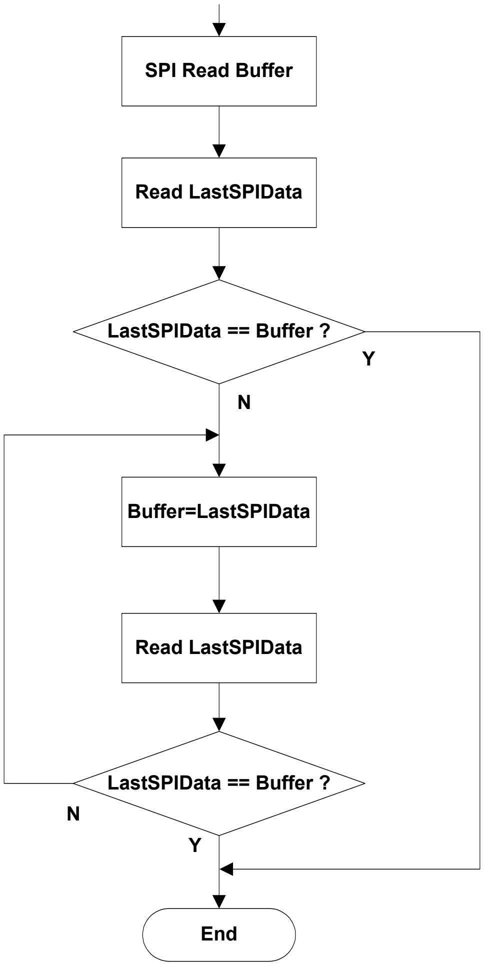


Figure-1 LastSPIData Application (Read)

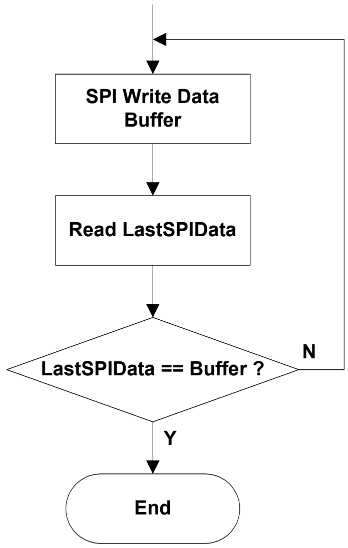


Figure-2 LastSPIData Application (Write)

3 POWER MODES

Four power modes are supported which correspond to four kinds of power consumption. The power mode is configured by PM1/PM0 pins.

<table>
<tr><th>PM1</th><th>PM0</th><th>Power Modes</th><th>Power Consumption</th></tr>
<tr><td>1</td><td>1</td><td>Normal mode</td><td rowspan="4">High
↓
Low</td></tr>
<tr><td>1</td><td>0</td><td>Partial Measurement mode</td></tr>
<tr><td>0</td><td>1</td><td>Detection mode</td></tr>
<tr><td>0</td><td>0</td><td>Idle mode</td></tr>
</table>

3.1 Normal Mode

In Normal mode, all function blocks are active except for the current detector block. All registers can be accessed.

3.2 Partial Measurement Mode

In Partial Measurement mode, the active measurement modules in Partial Measurement mode are the same as Normal mode.

In this mode, all the measurements are through the same hardware that does the measurement in the normal mode. To save power, the energy accumulation block and a portion of the DSP computation code will not be running in this mode.

In this mode, There are configuration bits in the PMPwrCtrl (0EH) register to get lower power if the application allows:

<table>
<tr><th>Address</th><th>Name</th><th colspan="8">Bit15 ~
Bit0</th></tr>
<tr><td rowspan="4">0EH</td><td rowspan="4">PMPwrCtrl</td><td>Bit15</td><td>Bit14</td><td>Bit13</td><td>Bit12</td><td>Bit11</td><td>Bit10</td><td>Bit9</td><td>Bit8</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>PMPwrDown-
Vch</td></tr>
<tr><td>Bit7</td><td>Bit6</td><td>Bit5</td><td>Bit4</td><td>Bit3</td><td>Bit2</td><td>Bit1</td><td>Bit0</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>-</td><td>ACTRL_CLK_
GATE</td><td>DSP_CLK_
GATE</td><td>MTMS_CLK_
GATE</td><td>PMClkLow</td></tr>
</table>

1. PMPwrDownVch: In Partial Measurement Mode the V0/V1/V2 analog channel can be powered off to save power
   0: Power on
   1: Power off (default)
2. ACTRL_CLK_GATE: Power off the clock of analog control block to save power.
   0: Power on
   1: Power off (default)
3. DSP_CLK_GATE: Power off the clock of DSP register to save power.
   0: Power on
   1: Power off (default)
4. MTMS_CLK_GATE: Power off the metering and measuring block to save power.
   0: Power on
   1: Power off (default)
5. PMClkLow: In Partial Measurement Mode the main clock can be reduced to 8.192MHz to save power.
   0: 16.384MHz
   1: 8.192MHz (default)

3.3 Detection Mode

In Detection mode, only the current detector is active and all the registers can not be accessed by external MCU. In this mode, each I/O is in specific state (for details refer to datasheet) and SPI is disabled. So the control and threshold registers for Detection mode need to be programmed in Normal mode before entering Detection mode. Once these related registers are written, there is no need to re-configure them when switching between different power modes. Detection mode related registers are listed as below:

Address	Name
10H	DetectCtrl
11H	DetectThA
12H	DetectThB
13H	DetectThC

Current detection is achieved with low power comparators. Two comparators are supplied for each phase on detecting positive and negative current. When any single-phase current or multiple-phase current exceeds the configured threshold, the IRQ0 pin is asserted high. When all three phase currents exceed the configured threshold, the IRQ1 pin is asserted high. The IRQ0/IRQ1 state is cleared when entering or exiting Detection mode.

The all three phase currents are considered as the currents of three current channels I1~I3. As there is no phase B current in 3P3W application, IRQ1 will not be asserted high even if both phase A and phase C current exceed the configured threshold.

Current detection module can be enabled in Normal mode through configuring the DEtectCtrl(10H) register to facilitate the current detection threshold calibration.

3.4 Idle Mode

In Idle mode, all the modules are disabled and all the registers can not be accessed. In this mode, each I/O is in a specific state (for details refer to datasheet) and SPI is disabled. All register values are lost except for current detection related registers.

3.5 Transition And Application of Power Modes

The four power modes are controlled by the PM0 and PM1 pins. In application, any power mode transition goes through Idle mode to avoid register value confusion or system status uncertainty in mode transition. All function modules are disabled in Idle mode while the related modules will be enabled after switching from Idle mode to other mode, which is equivalent to reset to the function modules, thus ensuring normal operation of the function modules.

It needs to reload registers to ensure normal operation when switching from Idle mode to Normal mode or Partial Measurement mode, while no need to reload registers when switching from Idle mode to Detection mode. Power mode transition is shown as Figure-3:

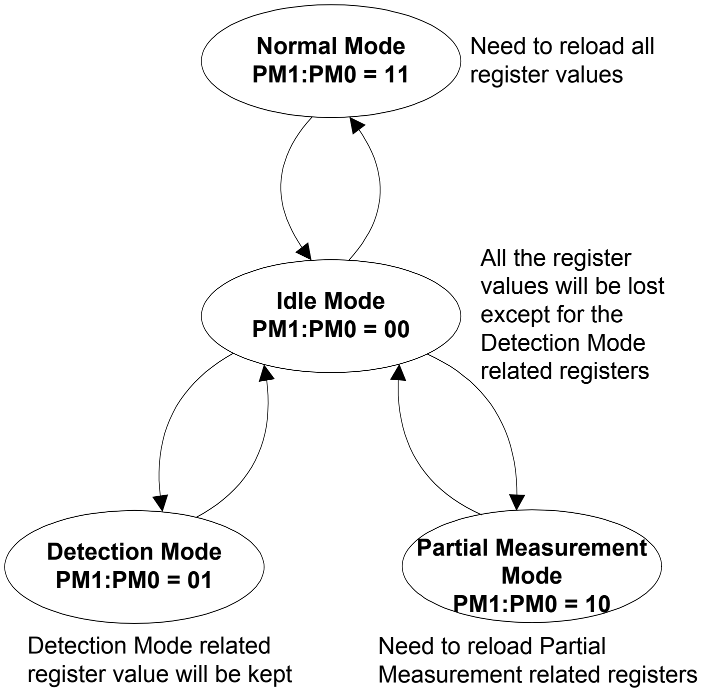


Figure-3   Power Mode Transition

Note: For description convenience, the intermediary Idle mode will be omitted when refering to power mode transition.

The most typical application of power mode transition is no-voltage detection for power meter.

The so-called no-voltage state is when all phase voltages are less than the voltage threshold but the load current is greater than the configured current value (such as 5% of rated current). In no-voltage state, the power meter usually uses backup battery for power supply. The system needs to enter low power mode and perform measurement and recording for no-voltage state periodically.

The recommended flow for power meter with the M90E32AS is as below:

1. Set the current detection threshold to be the minimum load current (such as 5% of rated current) required in no-voltage state.
2. When no-voltage happens, the system enters Idle mode;
3. The system enters Detection mode every once in a while (such as 5s);
4. Once the load current is greater than the configured value, the system enters Partial Measurement mode to measure and record the load current;
5. The system returns to Idle mode after measurement and recording are completed;
6. The system enters Partial Measurement mode every once in a while (such as 60s) to measure and record the load current.

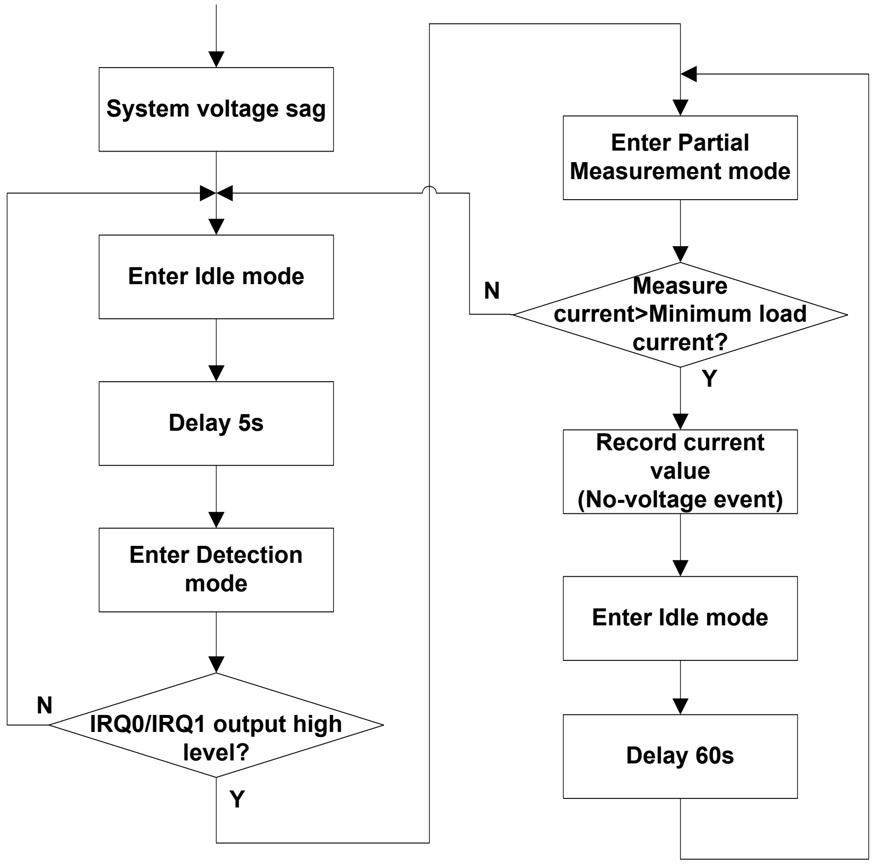


Figure-4 Application of Detection Mode and Partial Measurement Mode

<u>Application note: Design principle for current detection threshold</u>

It is recommended to do system design based on current detection threshold of 1.5mVrms.

Example:

Assume:

The requirement is that the minimum load current detected is 2.5% of rated current. Current specification is 5(60)A;

The minimum load current is Id, which corresponds to a 1.5mVrms ADC input signal.

The parameters meet the following relations:

	Minimum Detection Load Current Id	**Related Current In**	**Maximum Current Imax**
ratio to rated current	2.5% In	In	12In
corresponding A/D input signal	3mVrms	60mVrms	720mVrms
actual current	250mA	5A	60A

4 CALIBRATION

4.1 Calibration Method

Normally voltage, current, mean power, phase angle, frequency and so on are regarded as measurement values, while active energy, reactive energy and so on are regarded as metering values.

Measurement and metering function both need calibration before normal use as shown in below table.

Power Mode	Parameter	Need Calibration	Calibration Method
Normal mode	voltage/current	√	offset/gain calibration
	power/frequency/phase angle/ power factor	X	-
	full-wave energy metering	√	offset/gain/phase angle calibration
	fundamental energy metering	√	offset/gain calibration
	harmonic energy metering	X	-
Partial Measurement mode	voltage/ current/ power	X	-
Detection mode	current detection	√	threshold calibration

In typical application of three-phase power meter, voltage, current and full-wave energy must be calibrated. The others can be calibrated according to actual application, no need to calibrate if no use.

The calibration flow follows the sequence of measurement first then metering. Metering calibration is realized by first calibrating gain and then calibrating phase angle compensation, only single-point calibration is needed over the entire dynamic range. Reactive does not need to be calibrated since it is guaranteed by chip design.

Frequency, phase angle and power factor do not need calibration, since their accuracy is guaranteed by chip design.

4.2 Calibration in Normal Mode

The basic functions, such as measurement, metering, harmonic analysis and so on are only active in Normal mode. So calibration in Normal mode is basic and a must. The related registers need to be configured before calibration. Calibration flow is as shown in Figure-5.

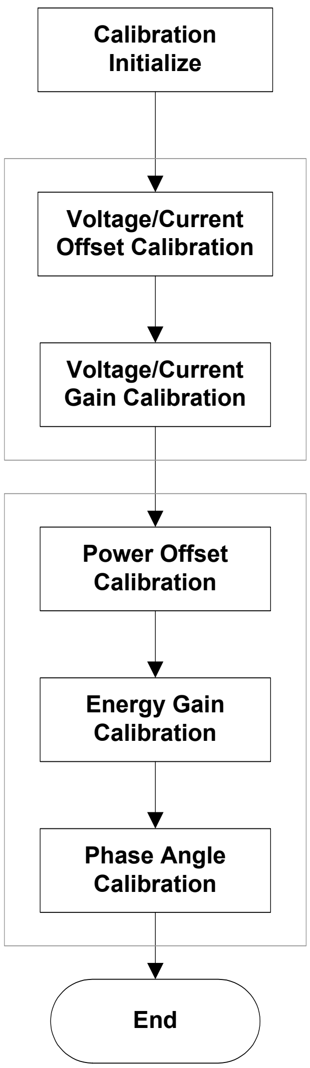


Figure-5 Active Energy Metering Calibration Flow in Normal Mode

4.2.1 Metering Enable and CRC Calibration

The device can automatically monitor the CRC changes versus a golden CRC which is latched after the first time the CRC computation is done. The latching event is triggered by none "0x55AA" value written to the CfgRegAccEn register (which means configuration done), followed by a new C C result available event. Once golden CRC is latched, the CRC_CMP signal is enabled. Subsequent CRC result will be compared with the latched CRC to generate the CRC error status. CRC error status can be read, and if configured, can goes to WARN or IRQ0 pins to alert the MCU in the case of CRC error.

4.2.2 PL Constant Configuration (PL_Constant)

Energy accumulation and metering are usually referenced by energy unit, such as kWh. However, within the M90E32AS, energy calculation or accumulation are based on energy pulse (CF). kWh and CF are connected by Meter Constant (MC, such as 3200 imp/kWh, which means each kWh corresponds to 3200 energy pulses). The chip's PL_Constant is a parameter related to MC. One PL_Constant corresponds to 0.01CF. PL_Constant should be configured according to different MC in application.

The M90E32AS provides four energy pulse outputs: active energy pulse CF1, reactive energy pulse or apparent energy pulse CF2, fundamental energy pulse CF3 and harmonic energy pulse CF4. Their Meter Constants are all set by PL_Constant in union rather than separately.

The PL_Constant registers consist of the PLconstH[31H] and PLconstL[32H] registers, corresponding to high word and low word of PL_Constant respectively.

PL_Constant is calculated as below:

PL_constant = 450,000,000,000 / MC

450,000,000,000: Constant

MC: Meter Constant, unit is imp/KWh, imp/Kvarh or imp/KVA

<u>Example: Calculation of PL_constant</u> Assume: Meter Constant MC = 3200 Thus: PL_constant = 450,000,000,000 / 3200= 140,625,000 (Hex is 8614C68H) so the registers are set as below: PLconstH[31H] = 0861H PLconstL[32H] = 4C68H

4.2.3 Metering Method Configuration (MMode0)

The M90E32AS can be used in difference systems and metering modes, which can be configured by the MMode0[33H] register.

Address	Name	Bit15 ~ Bit0							
33H	MMode0	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		-	-	-	Freq60Hz	HPFOff	didtEn	-	3P3W
		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		CF2varh	-	-	ABSEnQ	ABSEnP	EnPA	EnPB	EnPC

1. Freq60Hz: grid operating line reference frequency
   0: 50Hz (default)
   1: 60Hz
   The M90E32AS is applicable in 50 Hz or 60 Hz power grid. The M90E32AS uses different calculation parameters in data processing according to different grid frequency. To improve the accuracy of measurement and metering, please set this control bit according to the real power grid frequency.
2. HPFOff: HPF enable control bit
   0: enable HPF (default)
   1: disable HPF
   Besides measuring the voltage/current RMS in 50Hz or 60Hz (AC) power grid, the M90E32AS can also measure the mean current value of DC condition. HPF should be disabled when using DC measurement functions.
3. didtEn: enable integrator for didt current sensor
   0: disable integrator for didt current sensor; use CT sampling for current channel (default)
   1: enable integrator for didt current sensor; use Rogowski coil sampling for current channel
   The M90E32AS supports sampling over CT or Rogowski coil. Please set this control bit according to the real current sampling means. Note that different sampling circuit should be adopted when using Rogowski coil.
4. 3P3W: connection type for three-phase energy meter
   0: 3P4W connection (default)
   1: 3P3W connection
   The M90E32AS uses different phase sequence judgment for different connection. Please set this control bit according to the real connection type.
5. CF2varh: CF2 pin source configuration
   0: apparent energy
   1: reactive energy (default)
6. ABSEnQ: configure the calculation method of total (all-phase-sum) reactive energy and power
   0: total reactive energy equals to all-phase reactive energy arithmetic sum (default)
   1: total reactive energy equals to all-phase reactive energy absolute sum
7. ABSEnP: configure the calculation method of total (all-phase-sum) active energy and power
   0: total active energy equals to all-phase active energy arithmetic sum (default)
   1: total active energy equals to all-phase active energy absolute sum
8. EnPA: this bit configures whether Phase A is counted into the all-phase sum energy/power (P/Q/S)
   0: Corresponding Phase A not counted into the all-phase sum energy/power (P/Q/S)
   1: Corresponding Phase A to be counted into the all-phase sum energy/power (P/Q/S) (default)
9. EnPB: this bit configures whether Phase B is counted into the all-phase sum energy/power (P/Q/S)
   0: Corresponding Phase B not counted into the all-phase sum energy/power (P/Q/S)
   1: Corresponding Phase B to be counted into the all-phase sum energy/power (P/Q/S) (default)
10. EnPC: this bit configures whether Phase C is counted into the all-phase sum energy/power (P/Q/S)
    0: Corresponding Phase C not counted into the all-phase sum energy/power (P/Q/S)
    1: Corresponding Phase C to be counted into the all-phase sum energy/power (P/Q/S) (default)

Application note: Common configuration of MMode0

1. 3P4W, grid frequency 50Hz, MMode0 = 0087H
2. 3P3W, grid frequency 50Hz, MMode0 = 0185H

4.2.4 PGA Gain Configuration (MMode1)

The MMode1 register is used to configure PGA gain of ADC sampling channel, making chips applicable to meter designs of different current specifications.

Address	Name	Bit15 ~ Bit0							
34H	MMode1	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		-		PGA_GAIN (V3)		PGA_GAIN (V2)		PGA_GAIN (V1)	
		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		-		PGA_GAIN (I3)		PGA_GAIN (I2)		PGA_GAIN (I1)	

PGA_GAIN (V1~V3, I1~I4): analog PGA gain for seven ADC channels

00: 1X (default)

01: 2X

10: 4X

11: N/A

Application note: Configuration principle of PGA gain

1. Ensure that the ADC channel analog input signal should be within the dynamic range of 0~720mVrms
2. Configure PGA gain to be the maximum value within the whole dynamic range

4.2.5 Offset Calibration of Voltage/ Current/ Power

In application, the input signal is often influenced by the interference signal. This interference will enter data processing module through ADC and high-pass filter, not only producing errors to the voltage/current RMS and power calculation, but also affecting accuracy of the energy metering. The M90E32AS provides offset calibration function to voltage, current and power, reducing the influence of the interference signal to measurement/metering accuracy.

Every phase's voltage/current offset calibration should be proceeded individually. Take phase A for example, the signal source is: Ub=Uc=Un, Ua=0, Ia=0. The calibration flow of voltage/current offset is as below:

1. Read measurement registers (32 bits). It is suggested to read several times to get the average value;
2. Right shift the 32-bit data by 7 bits (ignore the lowest 7 bits);
3. Invert all bits and add 1 (2's complement);
4. Write the lower 16-bit result to the offset register

Every phase's power offset calibration should be proceeded individually. Take phase A for example, the signal source is: Ua=Ub=Uc=Un, Ia=0. The calibration flow of power offset is as below:

1. Read measurement registers (32 bits). It is suggested to read several times to get the average value;
2. Invert all bits and add 1 (2's complement);
3. Write the lower 16-bits result to the offset register

The corresponding offset register and measurement value registers are shown as below:

	Offset Registers		Measurement Value Registers			
	Address	Register Name	Address	Register Name	Address	Register Name
Voltage	63H	UoffsetA	0D9H	UrmsA	0E9H	UrmsALSB
	67H	UoffsetB	0DAH	UrmsB	0EAH	UrmsBLSB
	6BH	UoffsetC	0DBH	UrmsC	0EBH	UrmsCLSB
Current	64H	IoffsetA	0DDH	IrmsA	0EDH	IrmsALSB
	68H	IoffsetB	0DEH	IrmsB	0EEH	IrmsBLSB
	6CH	IoffsetC	0DFH	IrmsC	0EFH	IrmsCLSB
	6EH	IoffsetN	0D8H	IrmsN1	-	-
All-wave Power	41H	PoffsetA	0B1H	PmeanA	0C1H	PmeanALSB
	42H	QoffsetA	0B5H	QmeanA	0C5H	QmeanALSB
	43H	PoffsetB	0B2H	PmeanB	0C2H	PmeanBLSB
	44H	QoffsetB	0B6H	QmeanB	0C6H	QmeanBLSB
	45H	PoffsetC	0B3H	PmeanC	0C3H	PmeanCLSB
	46H	QoffsetC	0B7H	QmeanC	0C7H	QmeanCLSB
fundamental power	51H	PoffsetAF	0D1H	PmeanAF	0E1H	PmeanAFLSB
	52H	PoffsetBF	0D2H	PmeanBF	0E2H	PmeanBFLSB
	53H	PoffsetCF	0D3H	PmeanCF	0E3H	PmeanCFLSB

4.2.6 Voltage/ Current Measurement Calibration

Measurement calibration means the calibration of voltage rms (Urms) gain and current rms (Irms) gain. Measurement calibration is the premise of energy metering calibration.

1. Voltage/current offset (Uoffset/Ioffset) calibration:
   For calibration method, please refer to 4.2.5 Offset Calibration of Voltage/ Current/ Power. No need of calibration if the voltage/current offset is very small in general application.

2 Voltage/current gain calibration:
   The three phases' calibration can be proceeded simultaneously. The signal source is: Ua=Ub=Uc=Un, Ia=Ib=Ic=In(Ib). The calibration method is as below:

   a. Read voltage/current value of the external reference meter, and also read the voltage/current measurement value from chip registers;

   b. Calculate the voltage/current gain;

$$\text{Voltage Gain} = \frac{\text{reference voltage value}}{\text{Voltage measurement value}} \times 32768$$

$$\text{Current Gain} = \frac{\text{reference current value}}{\text{current measurement value}} \times 32768$$

   c. Write the result to the corresponding voltage/current gain registers

Note: voltage/current gain calibration is not necessarily proceeded when gain register is the default value. That is, when the first calibration result is not ideal, there is no need to reset the gain register to the default value. Calibration can be performed again based on the current value. The formula is as below:

$$\text{New Voltage Gain} = \frac{\text{reference voltage value}}{\text{voltage measurement value}} \times \text{existing voltage gain}$$

$$\text{New Current Gain} = \frac{\text{reference current value}}{\text{current measurement value}} \times \text{existing current gain}$$

The corresponding voltage/current gain register and measurement value registers are shown as below:

	Gain Register		Measurement Value Registers			
	Address	**Register Name**	**Address**	**Register Name**	**Address**	**Register Name**
Voltage	61H	UgainA	0D9H	UrmsA	0E9H	UrmsALSB
	65H	UgainB	0DAH	UrmsB	0EAH	UrmsBLSB
	69H	UgainC	0DBH	UrmsC	0EBH	UrmsCLSB
Current	62H	IgainA	0DDH	IrmsA	0EDH	IrmsALSB
	66H	IgainB	0DEH	IrmsB	0EEH	IrmsBLSB
	6AH	IgainC	0DFH	IrmsC	0EFH	IrmsCLSB

Application Note:

1. Voltage rms is unsigned and the minimum unit 1LSB of the UrmsA/UrmsB/UrmsC registers is 0.01V. Only the higher 8 bits of the UrmsALSB/ UrmsBLSB/UrmsCLSB registers are valid, the lower 8 bits are always 0, and 1LSB is 0.01/256 V.
2. Current rms is unsigned and the minimum unit 1LSB of the IrmsA/IrmsB/IrmsC registers is 0.001A; Only the higher 8 bits of the IrmsALSB/ IrmsBLSB/IrmsCLSB registers are valid, the lower 8 bits are always 0, and 1LSB is 0.001/256 A.
3. Power is signed complement. Whole 32-bit register value should be read before caculation in power value caculation. 1LSB is 0.00032 (W/var/ VA).

Example: Voltage gain calibration

Assume:

The initial value of phase A voltage gain register UgainA is 8000H (32768)

Reference meter output voltage is 220.00V

Voltage rms register readout UrmsA = 3039H (12345)

The higher 8 bits of voltage LSB register readout UrmsALSB = 43H (67)

Thus:

voltage measured value = (UrmsA x 0.01) + (UrmsALSB x 0.01 / 256)

= (12345 x 0.01) + (67 x 0.01 / 256)

=123.453 V

voltage gain = 220.00 / 123.453 x 32768 = 58395 = 0E41BH

So the register can be set to:

UgainA = 0E41BH

4.2.7 Energy Metering Calibration

Only active energy is required for energy calibration. There is no need to calibrate reactive energy, the accuracy of which is guaranteed by chip design. Metering calibration flow is gain first then phase angle. Active energy pulse output (CF1) should be connected to the pulse input port of the calibration bench during calibration.

Energy metering should be calibrated at In (Ib).

1. Power offset (Poffset/Qoffset) calibration
   For calibration method please refer to 4.2.5 Offset Calibration of Voltage/ Current/ Power. No need of calibration if the power offset is very small in general application.
2. Gain calibration
   Every phase's gain calibration should be proceeded individually. Take phase A for example, the signal source is: Ua=Ub=Uc=Un, IA=In(Ib),
   Ib=Ic=0, PF=1.0. The calibration method is as below:
   a. Read the energy error value ε from calibration bench;
   b. Calculate the gain;

   $$Gain = \text{Complementary}\left(\frac{-\varepsilon}{1+\varepsilon} \text{ x } 2^{15}\right)$$

   c. Write the result to the corresponding gain registers.
3. Phase angle calibration. Take phase A for example, the signal source is: Ua=Ub=Uc=Un, Ia=In(Ib), Ib=Ic=0, PF=0.5L.The calibration method is as below:
   a. Read the energy error value εp from calibration bench;
   b. Calculate the phase angle error;

   $$\text{AngleError} = \varepsilon_{p} \times \text{Gphase}$$

   Gphase is a constant. When grid frequency is 50Hz, Gphase=3763.739. When grid frequency is 60Hz, Gphase=3136.449
   c. Write the result to the corresponding phase angle error registers. The phase angle registers are signed and MSB of 1 indicates a negative value.

The corresponding gain register and phase angle registers are shown as below:

	Address	**Register Name**
Phase A	47H	GainA
	48H	PhiA
Phase B	49H	GainB
	4AH	PhiB
Phase C	4BH	GainC
	4CH	PhiC

Example: Energy gain and phase angle calculation
The condition is that power factor PF=1.0, current is Ib, energy error ε is -13.78%, so:
-ε/(1+ε)=0.159823707,
gain = int(0.159823707* 2^15)=5237.10=1475H
Write 1475H to the gain register.
After gain calibration, energy error εP is 0.95% in the condition of PF=0.5L, current is Ib and frequency is 50Hz, so:
phase angle = εP*3763.739
=0.0095*3763.739=35.75553=24H;
Write 24H to the phase angle register.

4.2.8 Fundamental Energy Metering Calibration

For fundamental energy metering calibration, only gain and offset calibration is needed. There is no need to calibrate phase angle. Fundamental energy pulse output (CF3) should be connected to the pulse input port of the calibration bench during calibration. Only sigle-point calibration in In(Ib) is needed for fundamental energy metering calibration.

Fundamental energy metering calibration is similar to energy metering calibration.

1. Fundamental power offset (PoffsetxF) calibration
   For calibration method please refer to 4.2.5 Offset Calibration of Voltage/ Current/ Power. No need of calibration if the power offset is very small in general application.
2. Fundamental energy gain calibration
   Every phase's fundamental energy calibration should be proceeded individually. Take phase A for example, the signal source is: Ua=Ub=Uc=Un,
   Ia=In(Ib), Ib=Ic=0, PF=1.0. The calibration method is as below:
   a. Read the error value ε from the external reference meter;
   b. Calculate the gain;

$$Gain = \text{Complementary}\left(\frac{-\varepsilon}{1+\varepsilon} \text{ x } 2^{15}\right)$$

   c. Write the result to the corresponding gain registers.

The corresponding fundamental energy gain registers are shown as below:

Address	Register Name
54H	PGainAF
55H	PGainBF
56H	PGainCF

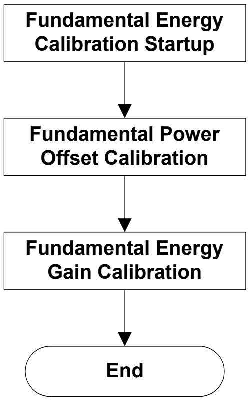


Figure-6 Fundamental Energy Metering Calibration Flow

4.3 Calibration in Partial Measurement Mode

The same measurement modules are used in Partial measurement mode as Normal mode, so no need to do special calibration for Partial measurement mode.

4.4 Calibration in Detection Mode

Current detection is realized by low power consumption comparators. The comparator outputs low level when the external current is lower than the configured threshold; The comparator outputs high level when the external current is higher than the configured threshold, as shown in Figure-7.

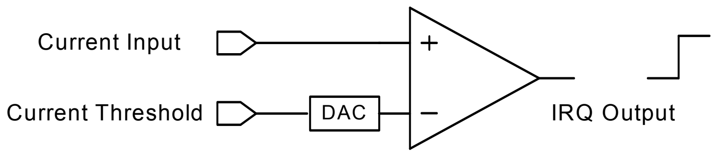


Figure-7 Current Detection Principle

4.4.1 Current Detection Module Configuration

Current detection module can be enabled in Normal mode to facilitate the current detection threshold calibration.

Six current threshold comparators can be configured for the current detection module to detect positive and negative current of three phases. These six threshold comparators can be enabled and disabled by the control bits, as shown below:

Address	**Register Name**	**Bit15 ~ Bit0**							
10H	DetectCtrl	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		-	-	-	-	-	-	-	-
		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		-	DetCalEn	PDN3	PDN2	PDN1	PDP3	PDP2	PDP1

1. DetCalEn: Enable detector calibration in Normal mode;
   0: Detector disable (default)
   1: Detectors enabled
2. PDN3/2/1: Control bits for negative detector of channel 3/2/1;
   0: Detector enable (default)
   1: Detector disable
3. PDP3/2/1: Control bits for positive detector of channel 3/2/1;
   0: Detector enable (default)
   1: Detector disable

Each of the six current threshold comparators has its own register configuration as shown below:

Address	**Register Name**	**Bit15 ~ Bit0**							
11H 12H 13H	DetectTh1 DetectTh2 DetectTh3	Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
		CalCodeN							
		Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
		CalCodeP							

1. CalCodeN: negative detector threshold, 8-bit width.
   8’b0000-0000 corresponds to minimum threshold Vc=-1.2mV=-0.85mVrms
   8’b1111-1111 corresponds to maximum threshold Vc=9mV=6.35mVrms
2. CalcodeP: positive detector threshold, definition is the same as CalCodeN.

4.4.2 Current Detection Threshold Calibration

Because of the low power consumption consideration and the manufacturing process, the current detection threshold is different from different chips. Therefore, calibration is needed due to the offset of chip's DAC output (less than ±5mVrms). The threshold current range is 2mVrms ~ 4mVrms within which the current detection module (low power consumption comparator) can detect accurately. It is recommended to proceed system design according to current detection threshold of 3mVrms.

Dichotomy is suggested in current detection threshold calibration. The recommended calibration flow is as shown in Figure-8.

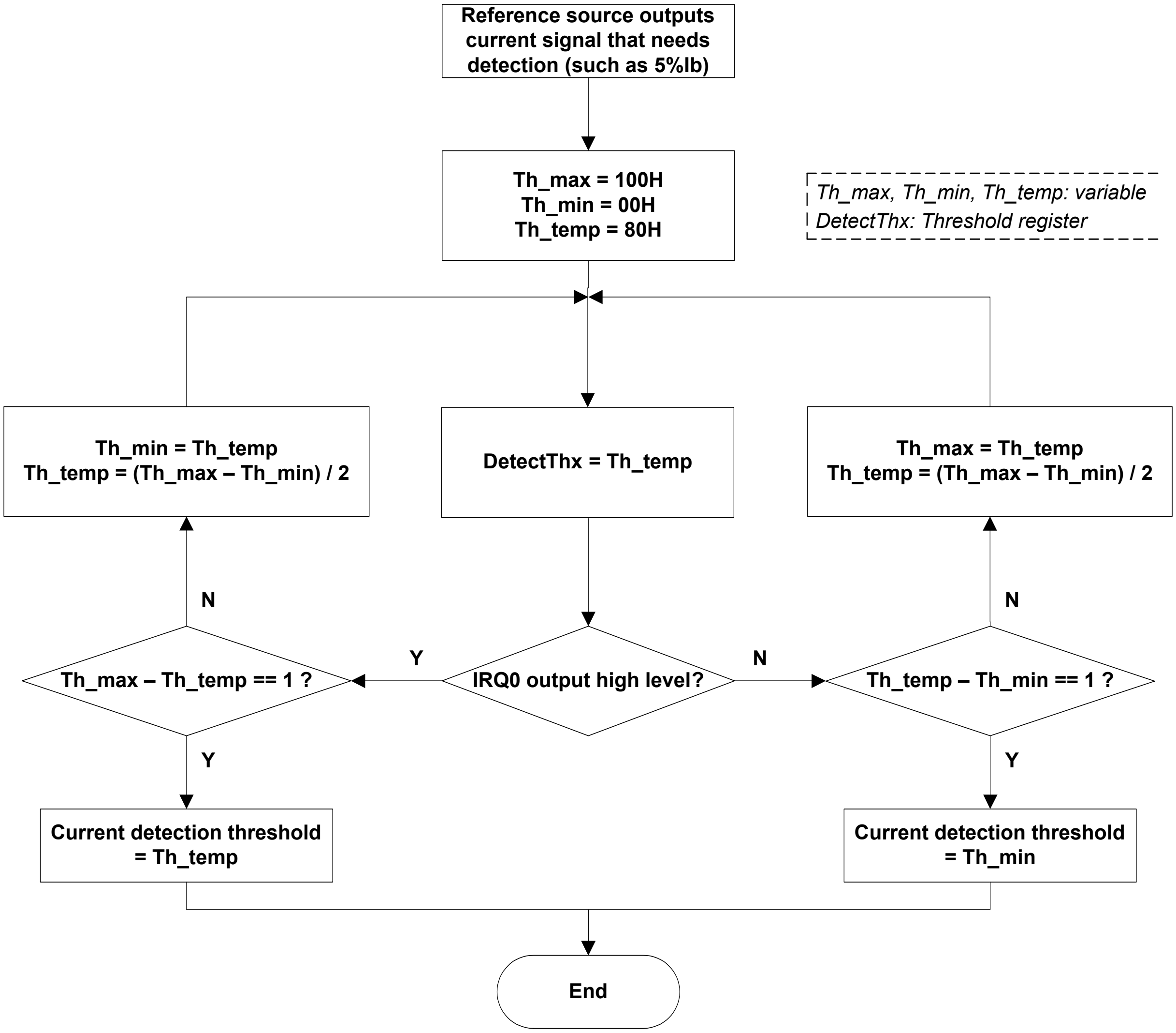


Figure-8 Current Detection Threshold Calibration Flow

5 FUNCTION REGISTERS CONFIGURATION

5.1 Startup Current Configuration

The registers which related to startup current configuration is shown as below:

Address	Register Name	Description
35H	PStartTh	All-phase Active Startup Power Threshold.
36H	QStartTh	All-phase Reactive Startup Power Threshold.
37H	SStartTh	All-phase Apparent Startup Power Threshold.
38H	PPhaseTh	Each-phase Active Startup Power Threshold.
39H	QPhaseTh	Each-phase Reactive Startup Power Threshold.
3AH	SPhaseTh	Each-phase Apparent Startup Power Threshold.

1. Due to system interference when current is 0, small signal may be gernerated in current sampling channel, producing a certain amount of energy and affecting the measurement and metering accuracy. To avoid this, the M90E32AS provides the each-phase startup power configuration/judgment function.
2. PPhaseTh, QPhaseTh and SPhaseTh are used to judge the startup power of each phase (A/B/C). Take active power for example, when a single phase input power is smaller than the configured PPhaseTh value, the input active power of that phase will be set to 0 by force, that means input to the next process is 0. Otherwise the signal will be streamed to the next process.
   Note that the threshold are configured separately to active(P), reactive(Q) and apparent (S). The compared value is (|P|+|Q|).
3. PStartTh, QStartTh and SStartTh are used to judge all-phase startup power. Take active power for example, when all-phase-sum power is less than the configured PStartTh value, energy accumulation will not start. Otherwise energy accumulation will start.
4. Calculation methods of the two register groups are the same. The formula is as below:
   Register value = N / 0.00032, (N is the configured power threshold).

<u>Example: Startup Current Configuration</u>

Assume:

meter voltage is 220V, current specification 5(100)A, active startup current is 0.1%

considering the accuracy of current measurement in small-current state, it is recommended to configure the all-phase startup current threshold to be 50% of startup current (also can configure based the actual conditions).

Assume the startup threshold of each-phase power is configured to be 10% of startup current.

so:

All-phase Active Startup Power Threshold = 3 x 5 x 0.1% x 50% x 220 = 1.65W

Each-phase Active Startup Power Threshold = 5 x 0.1% x 10% x 220 = 0.11W

register values are:

PStartTh[35H] = 1.65 / 0.00032 = 5156 = 1424H

PPhaseTh[38H] = 0.11 / 0.00032 = 344 = 158H

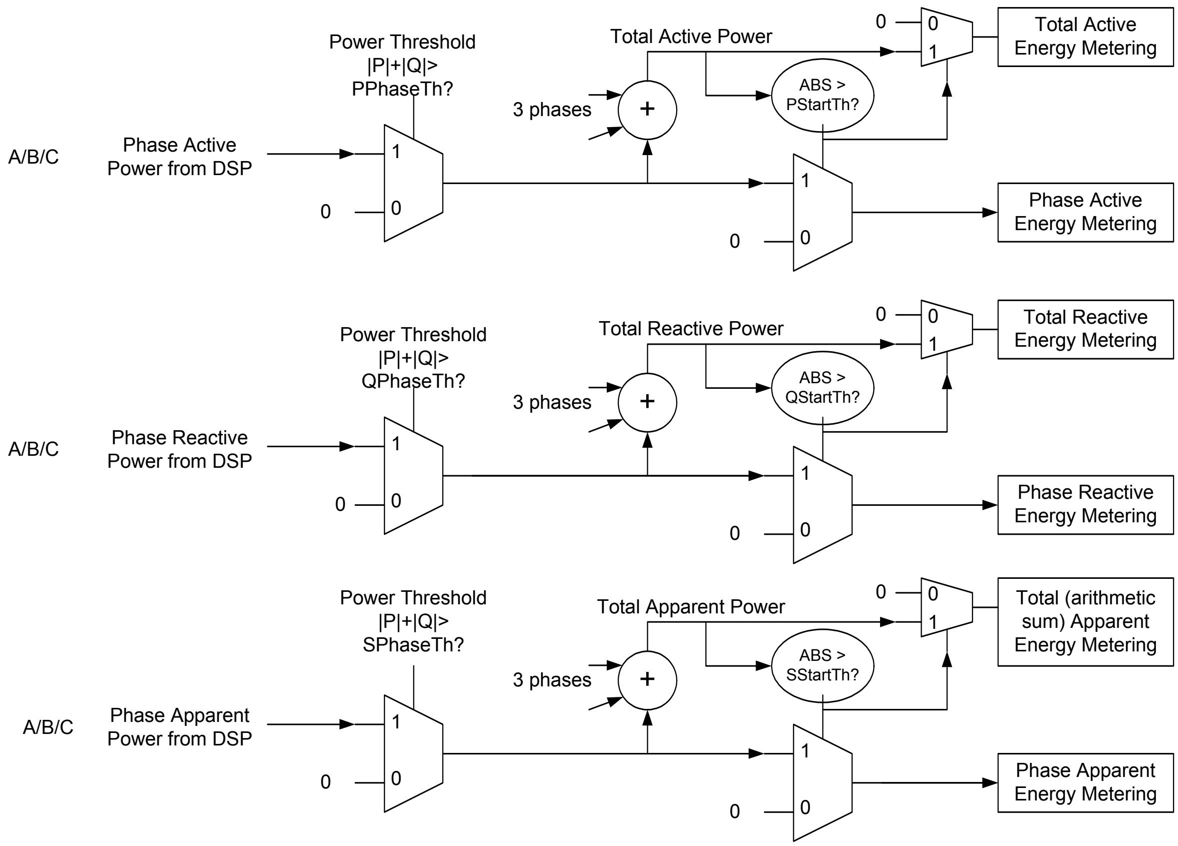


Figure-9 Metering Startup Handling

5.2 Sag Function

Sag detect function is provided in M90E32AS. The threshold of sag detection is configured through the SagTh register (08H). All three voltage phases use the same threshold. The threshold equation is as below:

$$SagTh = \frac{Vth \times 100 \times \sqrt{2}}{2 \times Ugain / 32768}$$

Vth: the voltage threshold to be configured;

Ugain: the gain after calibration

6 COMPENSATION METHOD

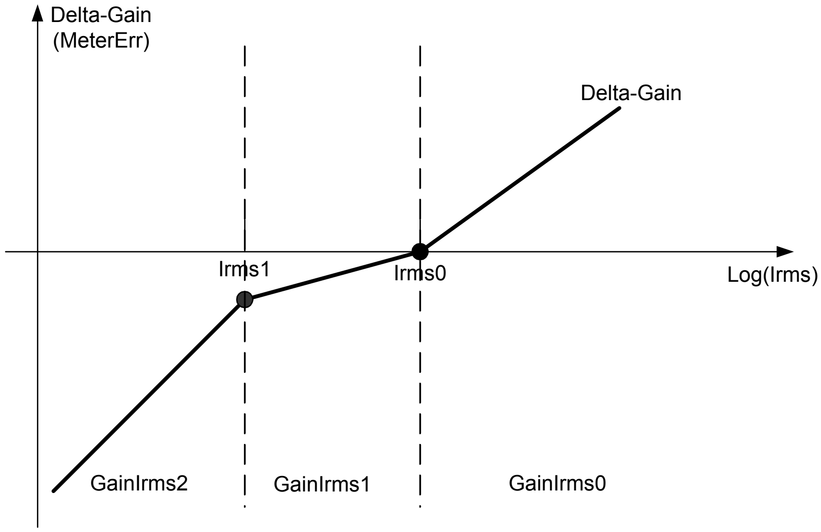
M90E32AS provids excellent metering accuracy over a dynamic range of 6000:1 and industrial temperature range.

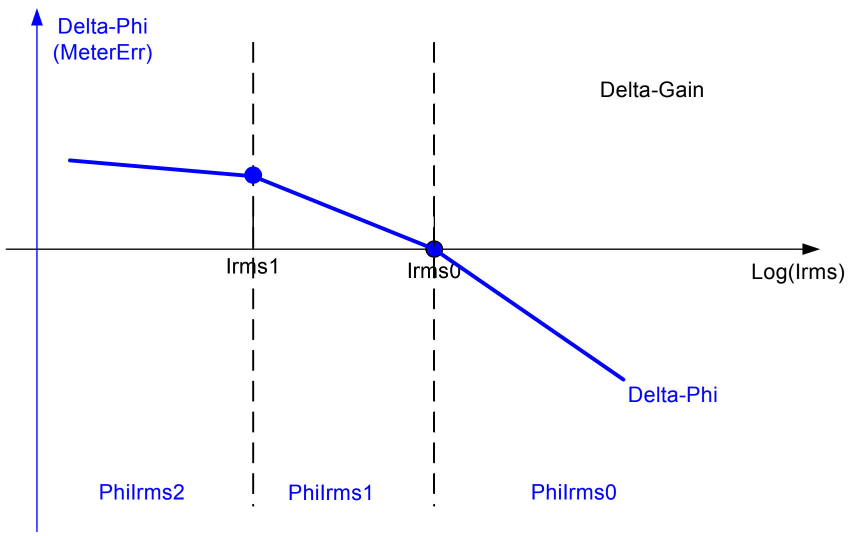
But in application of power meter, system metering accuracy would be infulenced by the performance difference of peripheral devices. So M90E32AS provides compensation function for system metering error considering the system application of power meter.

M90E32AS provides three compensation functions based on different correspondences:

1. Current besed Compensation (per phase), it goes to Gain and Phi;
2. Frequency based compensation(all phases are the same), it goes to Phi;
3. Temperature based compensation (per phase), it goes to UGain

6.1 Current Segment Compensation Descriprion



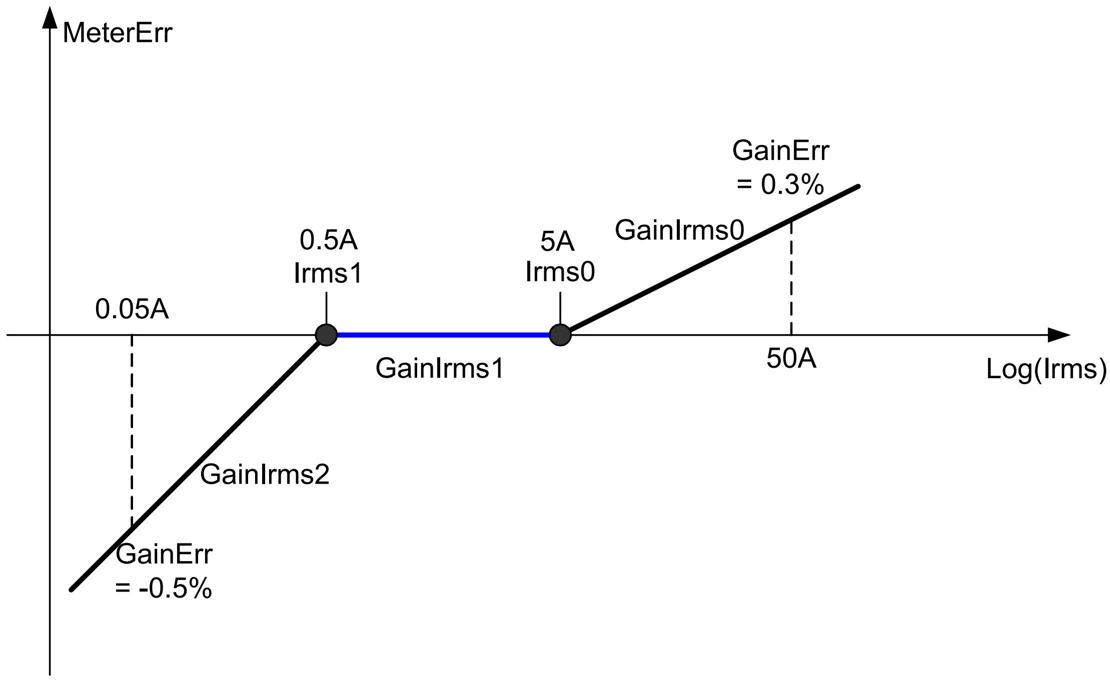


1. Irms0 and Irms1 are the current points of segments, through which the whole current range can be divided to three segments in calibration; gain and phi use the same current points in segment compensation;
2. GainIrms0, GainIrms1 and GainIrms2 are gain compensation coefficients for every current segment; Log(Irms) is the X axis, and delta-gain value when PF=1.0 is the Y axis value;
3. PhiIrms0, PhiIrms1 and PhiIrms2 are phi compensation coefficients for every current segment; Log(Irms) is the X axis, and delta- phi value when PF=1.0 is the Y axis value.

Note: Log(X)=Log2(X)*6 in the following description, for example Log(2)=16 and Log(16)=64.

6.2 GainIrms Segment Compensation Example

Per-phase compensation, take phase-A for example:



1. Irms0=5A
   register value is 5000, Log(Irms0) = Log2(5000)*16 = 197 (=0xC5), that is the LOGIrms0[0x20]register value should be set to 0xC5;
2. Irms1=0.5A
   register value is 500, Log(Irms1) = Log2(500)*16 = 143 (=0x8F), that is the LOGIrms1[0x21] register value should be 0x8F;
3. GainIrms0
   X axis difference ΔX is:
   Log(50000) - Log(5000) = Log(50000/5000) = Log(10) = Log2(10)*16 = 53
   Y axis difference ΔY is: 0.3% - 0 = 0.003,

   Then $CompensationValue = -2^{19} \times \frac{\Delta Y}{\Delta X} = -2^{19} \times \frac{0.003}{53} = -30$ (Note: 2^{19} is constant)

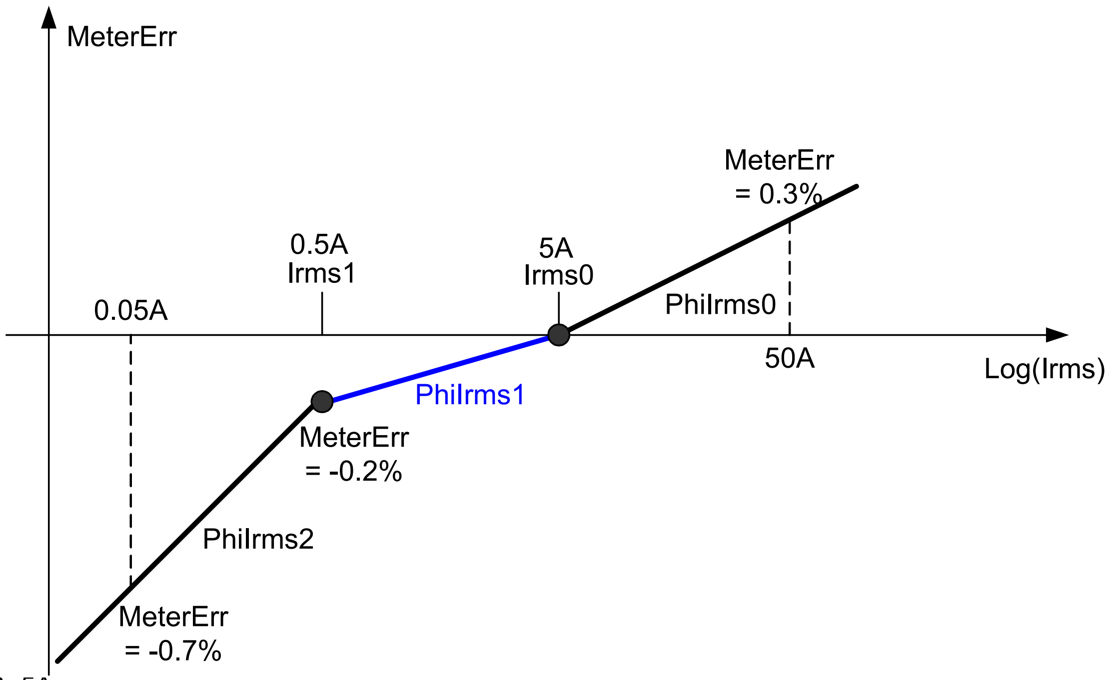
   that is IGainAIrms01[0x26, Bit7:0] =-30 (=0xE2) (Note: complement);
4. GainIrms1
   no compensation
   that is IGainAIrms01[0x26, Bit15:8]=0;
5. GainIrms2
   difference ΔX is: Log(500) - Log(50) = Log(500/50) = Log(10) = Log2(10)*16 = 53,
   difference ΔY is: 0 - (-0.5%) = 0.005,

   Then $CompensationValue = -2^{19} \times \frac{\Delta Y}{\Delta X} = -2^{19} \times \frac{0.005}{53} = -49$ (Note: 2^{19} is constant)

   that is IGainAIrms2[0x27] =-49 (=0xCF)(Note: complement)

6.3 PhiIrms Segment Compensation Example

Per-phase compensation, take phase-A for example:



1. Irms0=5A
   register value is 5000, Log(Irms0) = Log2(5000)*16 = 197 (=0xC5)
   that is LOGIrms0[0x20] register value should be set to 0xC5
2. Irms1=0.5A
   register vaue is 500, Log(Irms1) = Log2(500)*16 = 143 (=0x8F)
   that is LOGIrms1[0x21] register value should be set to 0x8F
3. PhiIrms0
   X axis difference ΔX is:
   Log(50000) - Log(5000) = Log(50000/5000) = Log(10) = Log2(10)*16 = 53,
   Y axis differece ΔY:0.3% - 0 = 0.003,

   then $CompensationValue = 3764 \times 2^8 \times \frac{\Delta Y}{\Delta X} = 3764 \times 2^8 \times \frac{0.003}{53} = 55$ (Note: 3764×2^8 is constant),

   that is PhiAIrms01[0x24] Bit7:0=55 (=0x37) (Note: complement);
4. PhiIrms1
   X axis differenceΔ is:
   Log(5000) - Log(500) = Log(5000/500) = Log(10) = Log2(10)*16 = 53
   Y axis difference ΔY: 0 - (-0.2%) = 0.002,

   then $CompensationValue = 3764 \times 2^8 \times \frac{\Delta Y}{\Delta X} = 3764 \times 2^8 \times \frac{0.002}{53} = 36$ (Note: 3764×2^8 is constant),

   that is PhiAIrms01[0x24] Bit15:8=36 (=0x24) (Note: complement);
5. PhiIrms2
   X axis difference ΔX is:
   Log(500) - Log(50) = Log(500/50) = Log(10) = Log2(10)*16 = 53,
   Y axix difference ΔY: (-0.2%) - (-0.7%) = 0.005,

   then $CompensationValue = 3764 \times 2^8 \times \frac{\Delta Y}{\Delta X} = 3764 \times 2^8 \times \frac{0.005}{53} = 91$ (Note: 3764×2^8 is constant),

   that is PhiAIrms2[0x25] Bit7:0=91 (=0x5A) (Note: complement).

6.4 Frequency-Phase Compensation (PhiFreqComp)

Example (all phases use the same compensation):

1. Assume reference frequency is 50Hz, that means the F0[0x22] register value is set to 5000 (=0x1388);
2. Assume offset is 0% when 50Hz(PF=0.5L) and 0.1% when 52Hz(PF=0.5L),

   then $CompensationValue = -3764 \times 2^{9} \times \frac{0.1\% - 0\%}{5200 - 5000} = -10$ (Note: 3764×2^{9} is constant),

   That is PhiFreqComp[0x1C]=-10 (=0xF6)(Note: complement)

7 TEMPERATURE COMPENSATION

The M90E32AS itself embodies good temperature characteristic. Considering that the external components might be affected by temperature in application, the M90E32AS also provides compensation function for external temperature drift.

A series of special registers should be configured for temperature compensation. These registers are located in special addresses, and access to these registers should be strictly carried out as the following.

7.1 On-chip Temperature Sensor Configuration

The M90E32AS provides a built-in temperature sensor. Due to the manufacturing process, the temperature sensor might be somewhat different for different chips. Therefore the on-chip temperature sensor should be configured before temperature compensation.

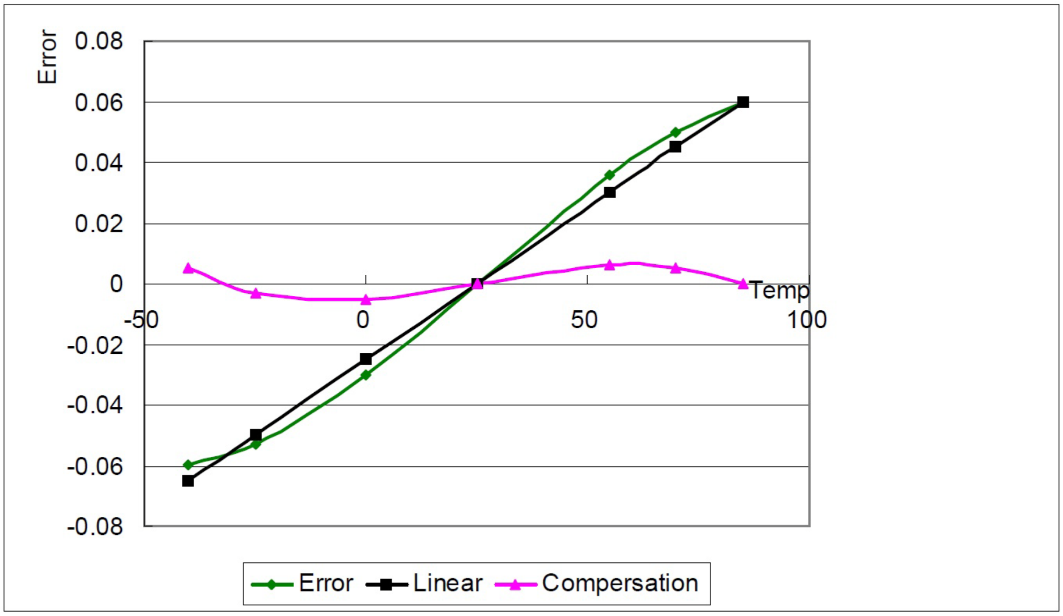
The configuration method is as below:

1. Write 55AAH to address 2FFH
2. Write 5183H to address 216H
3. Write 01C1H to address 219H
4. Write 0000H to address 2FFH

Read the Temp[0FCH] register directly to get the current temperature after configuration completed. Please note that, the temperature sensor will sense the temperature of the chip and it may have a few degrees of difference between the chip junction temperature and ambient temperature.

7.2 Temperature Compensation Based on Ugaint Example

Test data before temperature compensation is as below:



After linearization:

The reference temperature (temperature in calibrating) is 25 ℃ , which means setting the T0[0x23] register value to 25 (=0x19) (complement), metering error is 0.0000%;

The error at 85 ℃ point is 0.06%

So the temperature coefficient is calculated as below:

then $Compensati\ onValue = -2^{20} \times \frac{0.6\% - 0\%}{85 - 25} = -105$ (Note: 2^{20} is constant),

That is UGainTA[0x1A,Bit15:8]=-10 (=0xF6)(note: complement)

7.3 Temperature Compensation Based on Reference Voltage

On-chip high-precision reference voltage is provided with excellent low temperature coefficient. But in application, what should be considered is the temperature drift of the whole system. Therefore, the M90E32AS specially provides temperature compensation based on reference voltage to minimize temperature drift caused by the on-board components.

Note that, as voltage and current ADC sampling adopt the same reference voltage, compensation on the reference voltage will bring double effect on power and energy.

Temperature compensation on reference voltage is proceeded with every 8 ℃ as a segment. In application, it is suggested to test on a small batch of components from the same lot to get the best temperature compensation coefficient. And then use this compensation coefficient as a fixed value to be written directly to register in production.

The temperature compensation method is as below:

1. Write 55AAH to address 2FFH
2. Write the reference voltage coefficient of segment compensation to addresses 202H~209H
3. Write the curvature of segment compensation curve to address 201H
4. Write 0000H to address 2FFH

In normal condition, reference voltage is 1200mV. The unit of reference voltage compensation is 0.020mV in this compensation method.

The default value of the corresponding compensation registers is the ideal value in chip design. In application, only incremental adjustment is needed.

Address	Register Name	Bit	Read/Write	Default Value	Description
201H	BGCurveK	15:4	-	-	Reserved bit, readout value is 0
		3:0	Read/Write	0	Reference voltage temperature compensation curve. The bit3 is assumed as sign bit, range is -8 to +7. Scaling factor = 1+ register value*1/8. So the scaling factor will be from 0, with step of 1/8, all the way to 1+7/8.
202H	BG_TEMP_P12	15:8	Read/Write	0	Compensation coefficient on the 25 ℃ temperature point
		7:0	Read/Write	1	Compensation coefficient on the 17 ℃ temperature point
203H	BG_TEMP_P34	15:8	Read/Write	6	Compensation coefficient on the 41 ℃ temperature point
		7:0	Read/Write	2	Compensation coefficient on the 33 ℃ temperature point
204H	BG_TEMP_P56	15:8	Read/Write	25	Compensation coefficient on the 57 ℃ temperature point
		7:0	Read/Write	13	Compensation coefficient on the 49 ℃ temperature point
205H	BG_TEMP_P78	15:8	Read/Write	53	Compensation coefficient on the 73 ℃ temperature point
		7:0	Read/Write	39	Compensation coefficient on the 65 ℃ temperature point
206H	BG_TEMP_N12	15:8	Read/Write	16	Compensation coefficient on the 1 ℃ temperature point
		7:0	Read/Write	6	Compensation coefficient on the 9 ℃ temperature point
207H	BG_TEMP_N34	15:8	Read/Write	54	Compensation coefficient on the -15 ℃ temperature point
		7:0	Read/Write	34	Compensation coefficient on the -7 ℃ temperature point
208H	BG_TEMP_N56	15:8	Read/Write	117	Compensation coefficient on the -31 ℃ temperature point
		7:0	Read/Write	79	Compensation coefficient on the -23 ℃ temperature point
209H	BG_TEMP_N78	15:8	Read/Write	205	Compensation coefficient on the -47 ℃ temperature point
		7:0	Read/Write	159	Compensation coefficient on the -39 ℃ temperature point

Revision History

Doc. Rev.	Date	Comments
46103A	5/5/2014	Initial release.

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Atmel Corporation 1600 Technology Drive, San Jose, CA 95110 USA **T:** (+1)(408) 441.0311 **F:** (+1)(408) 436.4200 | **www.atmel.com**