

Multifunction 3-Phase Energy Metering IC

- Highly accurate:
 - ✓ Supports IEC 62053-21:2003, IEC 62053-22:2003 and IEC 62053-23:2003;
 - ✓ <0.1% error in active energy over a dynamic range of 10000:1;
 - ✓ <0.1% error in reactive energy over a dynamic range of 5000:1;
- Supplies Irms, Vrms, active/reactive/apparent power, active/reactive/apparent energy, line frequency, phase, and power factor of every phase and on the overall system;
- Supports neutral current input;
- Supplies raw waveform of current and voltage in DMA mode with updating frequency of 6.4kHz;
- Supports low power operating modes;
- Supports software calibration:
 - ✓ Phase compensation in 5 sections over the range of $\pm 2.8^\circ$;
 - ✓ Gain calibration in 3 sections and offset calibration of total active power;
 - ✓ Gain and offset calibration of total/fundamental reactive power and fundamental active power;
 - ✓ Accelerating calibration when weak current is applied;
 - ✓ Self-check of the configuration for the calibration;
- Supports programmable no-load detection threshold;
- Supports current transformer and di/dt current sensor;
- Supports 3-phase, 3-wire service, and 3-phase, 4-wire service;
- Single 3.3V supply, wide range: 2.5V~3.6V;
- Internal reference: 1.185V (drift 10ppm/°C);
- Supports SPI communication;
- Crystal frequency: 13.1072MHz;
- Operating temperature: -40~+85°C;
- Storage temperature: -40~+125°C;
- Package: 44 – LQFP.

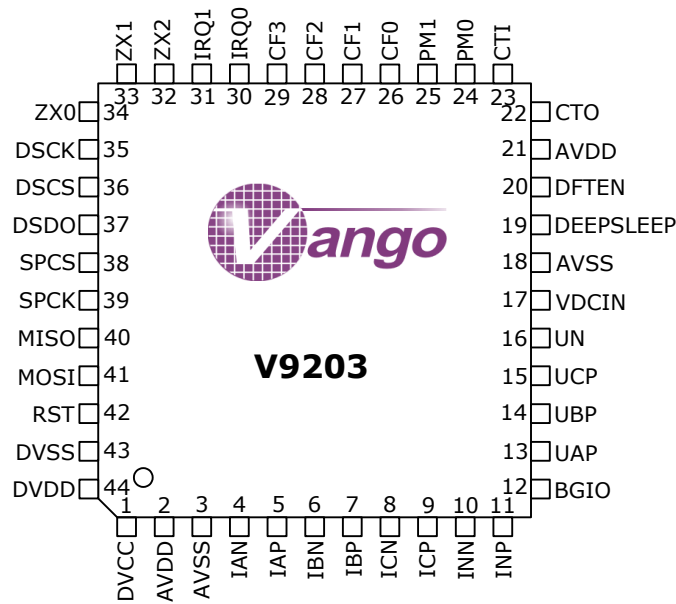
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Pin Description



*AVDD: Both Pin2 and Pin21 must be used for analog 3.3V voltage input simultaneously.

**AVSS: Both Pin3 and Pin18 must be grounded simultaneously.

No.	Mnemonic	Type	Description
1	DVCC	Power	Digital power supply. This pin must be connected to a parallel circuit combined by a 10 μ F capacitor and 0.1 μ F capacitor.
2	AVDD	Power	3.3-V power supply.
3	AVSS	Ground	Analog ground.
4~5	IAN, IAP	Input	Analog input pins for Current Channel A (IA).
6~7	IBN, IBP	Input	Analog input pins for Current Channel B (IB).
8~9	ICN, ICP	Input	Analog input pins for Current Channel C (IC).
10~11	INN, INP	Input	Analog input pins for Neutral Current Channel (IN).
12	BGIO	Input/Output	On-chip reference. This pin must be connected to a 1 μ F capacitor.
13	UAP	Input	Positive input pin for Voltage Channel A (UA).
14	UBP	Input	Positive input pin for Voltage Channel B (UB).
15	UCP	Input	Positive input pin for Voltage Channel C (UC).
16	UN	Input	Negative input pin for the three voltage channels.
17	VDCIN	Input	Power supply monitor input.

No.	Mnemonic	Type	Description
			<p>When the level on this pin is higher than 1.1-V, the power supply is in a normal state.</p> <p>When the level on this pin is lower than 1.0-V, the system is powered down.</p>
18	AVSS	Ground	Analog ground.
19	DEEPSLEEP	Input	<p>Deep sleep enable pin.</p> <p>Hold high logic for more than 4ms to enable the system entering the Deepsleep state.</p> <p>Hold low logic for more than 4ms to wake up and retrieve the system.</p>
20	DFTEN	Input	<p>DFT enable pin, high active.</p> <p>Hold low logic for proper operation.</p>
21	AVDD	Power	3.3-V power supply.
22	CTO	Output	<p>Crystal output.</p> <p>The load capacitance (CL) of the embedded oscillator is 10-pF.</p> <p>Both pins must be directly connected to a 13.1072-MHz crystal with about 8-pF CL for clock generation.</p>
23	CTI	Input	<p>Crystal input.</p> <p>Both pins must be connected to a 15-pF capacitor respectively, which increases the power consumption by about 36-μA, and then to a 13.1072-MHz crystal with about 18-pF CL.</p>
24~25	PM0, PM1	Input	<p>Operation mode select input.</p> <p>PM0, 0; PM1, 0: Sleep (not recommended). In this operation mode, only the RC oscillator, the crystal oscillator, the digital power circuit, the clock management circuit, the reset circuits, and the filters for input signals on the pins PM0/PM1/RST/DFTEN, are operating, other circuits stop working. The memory and register configuration hold the values.</p> <p>PM0, 1; PM1, 0: power-off/no-voltage pre-detection mode. In this operation mode, only the RC oscillator, the crystal oscillator, the digital power circuit, the current channels of Phase A/B/C, the clock scaler, the BandGap circuit, the clock management circuit, the reset circuits, the filters for input signals on the pins PM0/PM1/RST/DFTEN, the phase compensation circuit, the CIC filter, the current detection circuit, the interrupt circuits, and the SPI interfaces, are operating, other circuits stop working. In this</p>

No.	Mnemonic	Type	Description
			<p>mode, the SPI interfaces cannot communicate normally. Users can detect the current signal for energy metering via the no-voltage interrupt of the current channel.</p> <p>PM0, 0; PM1, 1: RMS mode. In this operation mode, only the RC oscillator, the crystal oscillator, the digital power circuit, the current channels of Phase A/B/C, the clock scaler, the BandGap circuit, the clock management circuit, the reset circuits, the filters for input signals on the pins PM0/PM1/RST/DFTEN, the phase compensation circuit, the CIC filter, the RMS/power/power factor calculation circuits, the normal and high-speed energy accumulation circuits, the pulse generation circuits, DC-stopping circuits, the current detection circuit, the frequency/phase measurement circuit, no-load detection circuit, the interrupt circuits, and the SPI interfaces, are operating, other circuits stop working. The master MCU can read the fundamental current RMS of each phase, and detect the no-load condition.</p> <p>PM0, 1; PM1, 1: normal operation mode. In this mode, all circuits can work according to the register configurations. All the registers, except the analog control registers, must be configured in this mode.</p>
26	CF0	Output	<p>CF pulse output.</p> <p>Via configuring the registers ZZPA0 (0xEC23) or ZZPA1 (0xEC24), this pin can be used to output total or fundamental active energy CF pulse of each phase or on the overall system.</p>
27	CF1	Output	<p>CF pulse output.</p> <p>Via configuring the registers ZZQA0 (0xEC47) or ZZQA1 (0xEC48), this pin can be used to output total or fundamental reactive energy CF pulse of each phase or on the overall system.</p>
28	CF2	Output	<p>CF pulse output.</p> <p>Via configuring the registers ZZPA0 (0xEC23) or ZZPA1 (0xEC24), this pin can be used to output total or fundamental active energy CF pulse of each phase or on the overall system.</p>
29	CF3	Output	<p>CF pulse output.</p> <p>Via configuring the registers ZZQA0 (0xEC47), ZZQA1 (0xEC48), or ZZAPPA (0xEC05), this pin can be used to output total reactive energy CF pulse, or total/fundamental apparent energy CF pulse of each phase or on the overall system.</p>
30	IRQ0	Output	<p>Interrupt Output 0.</p> <p>Configure the registers IRQEN0 or IRQEN1 to enable the interrupts generation and output on the pin IRQ0</p>

No.	Mnemonic	Type	Description
31	IRQ1	Output	Interrupt Output 1. or IRQ1.
32	ZX2	Output	<p>This pin outputs the sign of the Voltage/Current Channel C.</p> <p>1, negative; 0, positive.</p> <p>When the output of this pin is on the transition from logic "1" to "0", meaning the signal of Voltage/Current Channel C is crossing zero positively, the pins IRQ0 or IRQ1 will output zero-crossing interrupt.</p>
33	ZX1	Output	<p>This pin outputs the sign bit of the Voltage/Current Channel B.</p> <p>1, negative; 0, positive.</p> <p>When the output of this pin is on the transition from logic "1" to "0", meaning the signal of Voltage/Current Channel B is crossing zero positively, the pins IRQ0 or IRQ1 will output zero-crossing interrupt.</p>
34	ZX0	Output	<p>This pin outputs the sign bit of the Voltage/Current Channel A.</p> <p>1, negative; 0, positive.</p> <p>When the output of this pin is on the transition from logic "1" to "0", meaning the signal of Voltage/Current Channel A is crossing zero positively, the pins IRQ0 or IRQ1 will output zero-crossing interrupt.</p>
35	DSCK	Output	DMA_SPI interface in mater mode. This pin is used to output the serial communication clock.
36	DSCS	Output	<p>DMA_SPI interface in master mode. This pin is used to select the slave, active low.</p> <p>When this pin outputs high logic, the DMA_SPI circuit is reset, and DSDO output is in a high impedance state.</p>
37	DSDO	Output	DMA_SPI interface in master mode. This pin is used to output the serial communication data.
38	SPCS	Input	<p>SPI interface in slave mode. This pin is used for salve select, low active.</p> <p>When this pin holds high logic, the SPI circuit is reset, and enables the pin MISO to output logic "0".</p>
39	SPCK	Input	SPI interface in slave mode. This pin is used for clock input.
40	MISO	Output	SPI interface in slave mode. This pin is used for data output.
41	MOSI	Input	SPI interface in slave mode. This pin is used for data input.

No.	Mnemonic	Type	Description
42	RST	Input	Reset input, low active. Hold low logic for at least 5ms to reset the system.
43	DVSS	Ground	Digital ground.
44	DVDD	Power	3.3-V digital power supply.

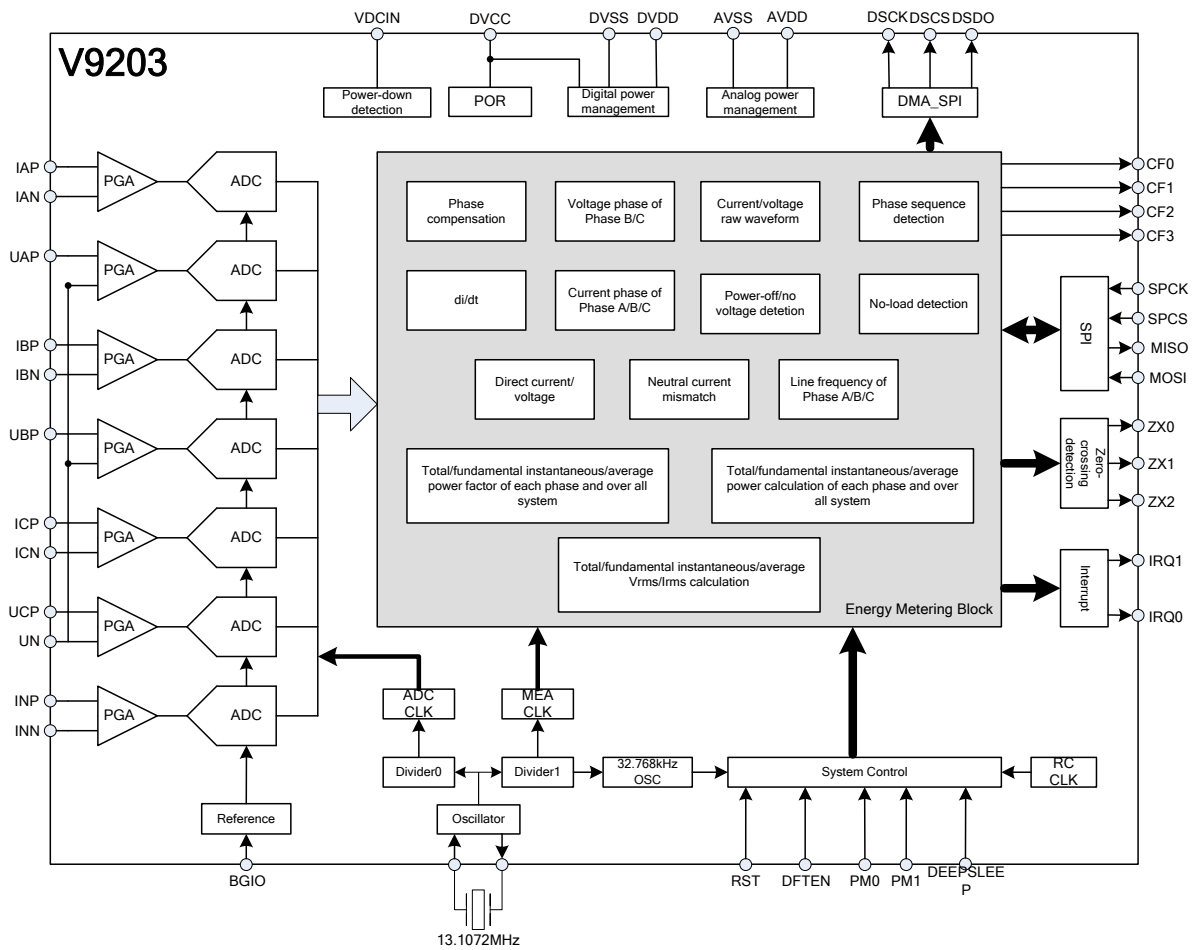
Parameters

Parameter	Min.	Typ.	Max.	Unit	Remark
Analog Input					
Maximum Signal Level			±200	mV	Peak value
Bandwidth (-3dB)		3.2		kHz	
ADC					
DC Offset			2	mV	
Resolution		22		Bit	Sign bit is excluded.
On-chip Reference					
Reference Error	-20		20	mV	
Power Supply Rejection Ratio		80		dB	
Temperature Coefficient		10		ppm/°C	
Output Voltage		1.185		V	
POR					
Detection Threshold (DVCC)	1.7	1.8	1.9	V	
VDCIN					
Input Voltage	0		VDD	V	
Impedance Input		1.5		MΩ	
Detection Threshold for Power-Down		1.0		V	
Detection Threshold for Power-UP		1.1		V	
Phase Error Between Channels					
PF=0.8 Capacitive		0.05		Degree	
PF=0.5 Inductive		0.05		Degree	
Total Active Energy Metering Error		0.1		%	Dynamic Range 10000:1 @ 25°C

Parameter	Min.	Typ.	Max.	Unit	Remark
Total Active Energy Metering Bandwidth		3.2		kHz	
Total Reactive Energy Metering Error		0.1		%	Dynamic Range 5000:1 @ 25°C
Total Reactive Energy Metering Bandwidth		3.2		kHz	
Fundamental Active Energy Metering Error		0.1		%	Dynamic Range 10000:1 @ 25°C
Fundamental Active Energy Metering Bandwidth		65		Hz	
Fundamental Reactive Energy Metering Error		0.1		%	Dynamic Range 5000:1 @ 25°C
Fundamental Reactive Energy Metering Bandwidth		65		Hz	
Total Apparent Energy Metering Error		0.5		%	Dynamic Range 2000:1 @ 25°C
Fundamental Apparent Energy Metering Error		0.5		%	Dynamic Range 2000:1 @ 25°C
VRMS Metering Error		0.5		%	Dynamic Range 2000:1 @ 25°C
VRMS Metering Bandwidth		3.2		kHz	
IRMS Metering Error		0.5		%	Dynamic Range 2000:1 @ 25°C
IRMS Metering Bandwidth		3.2		kHz	
CF Pulse Output					
Maximum Output Frequency		102.4		kHz	
Duty Cycle		50		%	160ms When the pulse period is less than 160ms.
Active High Pulse Width		80		ms	
Logic Output					

Parameter	Min.	Typ.	Max.	Unit	Remark
Output High Voltage, V _{OH}	2.4			V	Load of 16-mA current in a short time may not damage the chip, but load of 12-mA for a long time may damage the chip. If the pin DVDD33 is powered by the 3.3-V LDO, the total load on the IOs cannot exceed the maximum load of the 3.3-V LDO.
I _{SOURCE}		12	16	mA	
Output Low Voltage, V _{OL}			0.4	V	
I _{SINK}		12	16	mA	
Logic Input					
Input High Voltage, V _{INH}	2.0			V	
Input Low Voltage, V _{INL}			0.4	V	
SPI Interface	512		6553600	Hz	
DMA_SPI Interface		3.2768		MHz	
Power Input					
AVDD	2.5	3.3	3.6	V	
Digital Power Output					
Voltage	2.1	2.5	2.8	V	
Current			35	mA	
Operation Temperature	-40		+85	°C	
Storage Temperature	-40		+125	°C	

Functional Block Diagram



1. Analog Control Registers

All analog control registers of the V9203 will be reset to their default values when power-on reset or RST pin reset occurs. All the default values in the following tables are in hexadecimal form.

Table 1-1 Analog Control Register 0 (ANCtrl0, 0x8000)

0x8000, R/W, Analog Control Register 0, ANCtrl0				
Bit		Default Value	Function Description	
Bit[31:19]	Reserved	0		These bits must be set to their default values for proper operation.
Bit18	GUC	0	To set analog PGA gain of UC input.	0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
Bit17	GUB	0	To set analog PGA gain of UB input.	0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
Bit16	GUA	0	To set analog PGA gain of UA input.	0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
Bit15	Reserved	0		This bit must be set to its default value for proper operation.
Bit[14:12]	GIN<2:0>	0	To set analog PGA gain of IN input.	000, $\times 2$; 001, $\times 4$; 010, $\times 16$; 011/100/101/110/111, $\times 32$ To ensure the output from the sensor matches the full scale of ADC, the default value should not be used.
Bit11	Reserved	0		This bit must be set to its default value for proper operation.
Bit[10:8]	GIC<2:0>	0	To set analog PGA gain of IC input.	000, $\times 2$; 001, $\times 4$; 010, $\times 16$; 011/100/101/110/111, $\times 32$ To ensure the output from the sensor matches the full scale of ADC, the default value should not be used. In the power-off/no-voltage pre-detection mode, it is recommended to set to $\times 32$.

0x8000, R/W, Analog Control Register 0, ANCtrl0				
Bit		Default Value	Function Description	
Bit7	Reserved	0		This bit must be set to its default value for proper operation.
Bit[6:4]	GIB<2:0>	0	To set analog PGA gain of IB input.	000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used. In the power-off/no-voltage pre-detection mode, it is recommended to set to ×32.
Bit3	Reserved	0		This bit must be set to its default value for proper operation.
Bit[2:0]	GIA<2:0>	0	To set analog PGA gain of IA input.	000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used. In the power-off/no-voltage pre-detection mode, it is recommended to set to ×32.
Note: The configuration of this register can be read out of the register ZZANA0 (0xEC01) which is used to calculate the checksum for system check.				

Table 1-2 Analog Control Register 1 (ANCtrl1, 0x8001)

0x8001, R/W, Analog Control Register 1, ANCtrl1				
Bit		Default Value	Function Description	
Bit[31:14]	Reserved	0		These bits must be set to their default values for proper operation.
Bit13	REFGIT	0	To adjust the bias current of the ADC reference generator.	0, ×1 (recommended); 1, ×1.5
Bit12	REFBIT	0	To adjust the bias current of the ADC	0, ×1 (recommended); 1, ×1.33

0x8001, R/W, Analog Control Register 1, ANCtrl1				
Bit		Default Value	Function Description	
			reference buffer.	
Bit[11:10]	ADIT2<1:0>	0	To adjust the 2 nd bias current of the ADC.	00, ×1 (recommended); 01, ×1.5; 10, ×2; 11, ×2.5
Bit[9:8]	ADIT1<1:0>	0	To adjust the 1 st bias current of the ADC.	00, ×1 (recommended); 01, ×1.5; 10, ×2; 11, ×2.5
Bit7	Reserved	0		This bit must be set to its default value for proper operation.
Bit6	ADRSTUC	0	To reset the integrator of the modulator of Channel UC.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit5	ADRSTUB	0	To reset the integrator of the modulator of Channel UB.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit4	ADRSTUA	0	To reset the integrator of the modulator of Channel UA.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit3	ADRSTIN	0	To reset the integrator of the modulator of Channel IN.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit2	ADRSTIC	0	To reset the integrator of the modulator of Channel IC.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit1	ADRSTIB	0	To reset the integrator of the modulator of Channel IB.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Bit0	ADRSTIA	0	To reset the integrator of the modulator of Channel IA.	When some ADC anomaly occurs, set this bit to 1 to reset the integrator. By default, it is set to 0 disabling the reset.
Note: The configuration of this register can be read out of the register ZZANA1 (0xEC02) which is used to calculate the checksum for system check.				

Table 1-3 Analog Control Register 2 (ANCtrl2, 0x8002)

0x8002, R/W, Analog Control Register 2, ANCtrl2				
Bit		Default Value	Function Description	
Bit31	Reserved	0		This bit must be set to its default value for proper operation. In immediately 976μs after reset, this bit is set to 1 automatically. So it must be cleared for proper operation.
Bit30	ADPDUCN	0	To enable the ADC of Channel UC.	0, disable; 1, enable. In immediately 976μs after reset, these bits are set to 0b11111111 automatically, to enable all ADCs of the channels.
Bit29	ADPDUBN	0	To enable the ADC of Channel UB.	
Bit28	ADPDUAN	0	To enable the ADC of Channel UA.	
Bit27	ADPDINN	0	To enable the ADC of Channel IN.	
Bit26	ADPDICN	0	To enable the ADC of Channel IC.	
Bit25	ADPDIBN	0	To enable the ADC of Channel IB.	
Bit24	ADPDIAN	0	To enable the ADC of Channel IA.	
Bit23	AMPITN	0	To adjust the bias current of the amplifier of Channel IN.	1, lower to 50%. The default value is recommended.
Bit22	AMPITI	0	To adjust the bias current of the amplifier of the current channels.	1, lower to 50%. The default value is recommended.
Bit21	Reserved	0		This bit must be set to its default value for proper operation.
Bit20	AMPITU	0	To adjust the bias current of the amplifier of the voltage channels.	1, lower to 50%. The default value is recommended.
Bit[19:18]	Reserved	0		These bits must be set to their default values for proper operation.

0x8002, R/W, Analog Control Register 2, ANCtrl2				
Bit		Default Value	Function Description	
Bit[17:16]	CURRIT<1:0>	0	To adjust the bias current of the analog circuits.	00, 100%; 01, -33%; 10, -66%; 11, -75%
Bit[15:13]	REST<2:0>	0	To finely adjust the temperature coefficient of the BandGap circuit.	000, 0; 001, +6ppm; 010, +12ppm (recommended); 011, +18ppm; 100, -24ppm; 101, -18ppm; 110, -12ppm; 111, -6ppm
Bit[12:11]	RESTL<1:0>	0	To roughly adjust the temperature coefficient of the BandGap circuit.	00, 0; 01, -60ppm; 10, -120ppm (recommended); 11, -180ppm
Bit10	CLKOSEL	0	To select the ADC clock output.	0, the same phase as the input clock; 1, the inverse of the input clock. This bit must be set to 1 for proper operation.
Bit9	Reserved	0		This bit must be set to its default value for proper operation.
Bit8	BGPCHOPN	0	To disable the chopper of the BandGap circuit.	1, disable; 0, enable (by default).
Bit[7:0]	Reserved	0		These bits must be set to their default values for proper operation.
Note: The configuration of this register can be read out of the register ZZANA2 (0xEC03) which is used to calculate the checksum for system check.				

Table 1-4 Analog Control Register 3 (ANCtrl3, 0x8003)

0x8003, R/W, Analog Control Register 3, ANCtrl3				
Bit		Default Value	Function Description	
Bit[31:20]	Reserved	0		These bits must be set to their default values for proper operation.
Bit[19:18]	ADCLKSEL<1:0>	0	To select the sampling	Base: 204.8kHz.

0x8003, R/W, Analog Control Register 3, ANCtrl3				
Bit		Default Value	Function Description	
			frequency for the oversampling ADC (ADC frequency).	00, ×4; 01, ×8; 10, ×1; 11, ×2 When logic high is input to both the pins PM0 and PM1, in which the V9203 works in OPM0 (normal operation mode), the metering frequency must be 8 times of the ADC frequency.
Bit[17:16]	MEACLKSEL<1:0>	0	To select the frequency for the energy metering block (metering frequency).	Base: 819.2kHz. 00, ×8; 01, ×4; 10, ×2; 11, ×1 When both the pins PM0 and PM1 are input high logic, in which the V9203 works in OPM0 (normal operation mode), the metering frequency must be 8 times of the ADC frequency.
Bit[15:11]	Reserved	0		These bits must be set to their default values for proper operation.
Bit10	REFBUFEN	0	To enable the reference buffer of the ADCs.	0, disable (default); 1, enable. This bit must be set to 1 for proper operation.
Bit[9:3]	Reserved	0		These bits must be set to their default values for proper operation.
Bit2	CLKPDN	0	To enable the clock scaler.	0, disable; 1, enable. In immediately 488μs after reset, these bits are set to 0b101 automatically, to enable the clock scaler and BandGap Circuit A and disable the BandGap Circuit B. Then, users must set these bits to 0b110 to enable the BandGap Circuit B and the clock scaler, and disable the BandGap Circuit A.
Bit1	BGPPDNB	0	To enable the BandGap Circuit B.	
Bit0	BGPPDNA	0	To enable the BandGap Circuit A.	
Note: The configuration of this register can be read out of the register ZZANA3 (0xEC04) which is used to calculate the checksum for system check.				

2. Reset

In the V9203, two events can reset the system: power-on and RST pin input.

2.1. Power-on Reset (POR)

In the V9203, the internal power-on reset circuit supervises the output voltage on the pin DVCC (Pin1) all the time. When the output voltage is higher than 1.8V, the reset signal is released, and the reset state holds 244 μ s. When the output voltage is lower than 1.8V, the system is in the reset state.

The threshold, 1.8V, a typical value, is associated with the chips.

2.2. RST Pin Reset

When the level on the pin RST holds low for more than 5ms, the system is reset, and the reset state holds at least 244 μ s.

To protect the RST pin input from the electrostatic interference, the input is filtered by the RC oscillator clock.

3. Clock Generation

The on-chip RC oscillator circuit and the crystal oscillator circuit provide clock for the V9203.

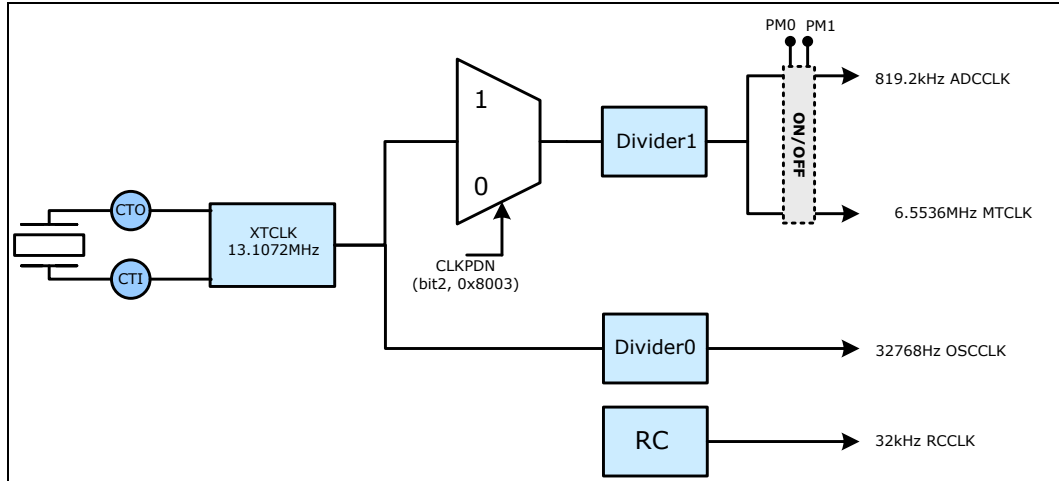


Figure 3-1 Clock Generation

3.1. RC Oscillator

The on-chip RC oscillator can generate a 32kHz RC clock (RCCLK) which can be used to filter the input signals on the pin PM0/PM1/RST/DFTEN. This oscillator cannot be turned off.

3.2. Crystal Oscillator

The on-chip crystal oscillator can be used with a 13.1072MHz crystal to generate 3 clock signals:

- **OSCCLK:** 32768Hz OSC clock. The OSCCLK is crystal oscillator clock source divided by 400. This clock signal is used by the reset circuits.
- **ADCCLK:** 819.2kHz ADC clock. The ADCCLK is crystal oscillator clock source divided by 16. This clock signal is used by the ADCs and the phase compensation circuits. This clock can be disabled via disabling the clock scaler via configuring bit[2:0] of register ANCtrl3 (0x8003).
- **MTCLK:** 6.5536MHz metering clock. The MTCLK is crystal oscillator clock source divided by 2. This clock signal is used as the system clock. This clock can be disabled via disabling the clock scaler via configuring bit[2:0] of register ANCtrl3 (0x8003). When this clock is disabled, OSCCLK is used as the system clock. When the system works in OPM0, or normal operating mode, the MTCLK must be 8 times of ADCCLK.

The load capacitance (CL) of the crystal oscillator is 10-pF. Both pins, CTI and CTO, must be directly connected to a 13.1072-MHz crystal with about 8-pF CL externally for clock generation. Both pins must be connected to a 15-pF capacitor respectively externally, which increases the power consumption by about 36-μA, and then to a 13.1072-MHz crystal with about 18-pF CL.

The crystal oscillator works all the time, consuming about 0.26mA.

4. Operating Mode

The POR or RST pin input event can reset the system to default state. Immediately after the reset, bit[31:24] of ANCtrl2 register (0x8002) are automatically set to 0b11111111 to enable the signal input of the 7 ADCs, and then bit[2:0] of ANCtrl3 register (0x8003) are automatically set to 0b101 to enable the clock scaler to generate 6.5536MHz MTCLK for the energy metering block and 819.2kHz ADCCLK for ADC sampling and phase compensation. 488μs later, the system is ready for the inputs on the pins PM0 (Pin24) and PM1 (Pin25) which determine the operating mode of the V9203.

Whatever operating mode the V9203 is in, an input of logic “1” on the pin DEEPSLEEP (Pin19) forces the system to enter into the deep sleep mode.

Table 4-1 PM0/PM1/DEEPSLEEP Determining the Operating Mode

PM0	PM1	DEEPSLEEP	Operating Mode
1	1	0	OPM0, normal operation mode.
1	0	0	OPM1, power-off/no-voltage pre-detection mode.
0	1	0	OPM2, RMS mode.
0	0	0	OPM3, sleep mode (not recommended).
X	X	1	OPM4, deep sleep mode.

4.1. OPM0

In OPM0, or normal operation mode, all analog circuits can work according to the analog control registers configurations, the digital circuits work, and the ADC sampling frequency is 819.2kHz and the metering frequency is 6.5536MHz by default.

All the registers, except for the analog control registers, must be configured in this mode.

In this mode, users can configure the registers ANCtrl2 and ANCtrl3 to reduce the ADC sampling and energy metering frequency to bring the system into underclocking operation to lower the power consumption.

Table 4-2 Configuration for Underclocking Operation in OPM0

Register	bit		Description
ANCtrl3, 0x8003	Bit[19:18]	ADCLKSEL<1:0>	0b10, 204.8kHz ADC sampling frequency.
	Bit[17:16]	MEACLKSEL<1:0>	0b10, 1.6384MHz metering frequency.
ANCtrl2, 0x8002	Bit[17:16]	CURRIT<1:0>	0b11, to lower the bias current of the analog circuits by 75%.

4.2. OPM1

In OPM1, or power-off/no-voltage pre-detection mode, only the RC oscillator, the crystal oscillator, the digital power circuit, the current channels of Phase A/B/C, the clock scaler, the BandGap circuit, the clock management circuit, the reset circuits, the filters for input signals on the pins PM0/PM1/RST/DFTEN, the phase compensation circuit, the CIC filter, the current detection circuit, the interrupt circuits, and the SPI interfaces, are operating, and other circuits stop working. In this mode, the SPI interfaces cannot communicate normally.

When any bit of bit[13:11] of the register IRQEN0 (0xA000) or IRQEN1 (0xA001) is set to logic 1, the current interrupt is enabled. When a current signal is caught, a current detection interrupt is triggered, the interrupt flag is set bit, a logic high is output on the pin IRQ0 or IRQ1 to signal the master MCU that the current is strong enough for energy metering.

In this mode, by default, the ADC sampling frequency is 819.2kHz, and the metering frequency is 6.5536MHz. But, users can configure the registers ANCtrl2 and ANCtrl3 to reduce the ADC sampling and energy metering frequency to bring the system into underclocking operation to lower the power consumption. In the underclocking operation, the settling time is less than 20ms.

Table 4-3 Configuration for Underclocking Operation in **OPM1 or OPM2**

Register	bit		Description
ANCtrl3, 0x8003	Bit[19:18]	ADCLKSEL<1:0>	0b10, 204.8kHz ADC sampling frequency
	Bit[17:16]	MEACLKSEL<1:0>	0b11, 819.2kHz metering frequency
ANCtrl2, 0x8002	Bit[17:16]	CURRIT<1:0>	0b11, to lower the bias current of the analog circuits by 75%.

4.3. OPM2

In OPM2, or RMS mode, that is accumulating current RMS for energy metering, only the RC oscillator, the crystal oscillator, the digital power circuit, the current channels of Phase A/B/C, the clock scaler, the BandGap circuit, the clock management circuit, the reset circuits, the filters for input signals on the pins PM0/PM1/RST/DFTEN, the phase compensation circuit, the CIC filter, the RMS/power/power factor calculation circuits, the normal and high-speed energy accumulation circuits, the pulse generation circuits, DC-stopping circuits, the current detection circuit, the frequency/phase measurement circuit, the no-load detection circuit, the interrupt circuits, and the SPI interfaces, are operating, and other circuits stop working.

In this mode, set the ZZCPSEL register (0xEC15) to 0x01, then the master MCU can read of the fundamental current RMS of each phase for no-load detection.

In this mode, by default, the ADC sampling frequency is 819.2kHz, and the metering frequency is 6.5536MHz. In full operation, the settling time is less than 135ms. But, users can configure the registers ANCtrl2 and ANCtrl3 to reduce the ADC sampling and energy metering frequency to bring the system into underclocking operation to lower the power consumption. Refer to the above table for details of the register configuration.

4.4. OPM3

When low level (00) is input to both pins PM0 and PM1 when the V9203 is working in the OPM0 (or normal operation mode), the system clock is switched to 32768Hz OSCCLK, and inputs to all ADCs are disabled. Immediately 488 μ s later, the system enters to OPM3, or sleep mode, which is not recommended.

In this mode, only the RC oscillator, the crystal oscillator, the digital power circuit, the clock management circuit, the reset circuits, and the filters for input signals on the pins PM0/PM1/RST/DFTEN, are operating, and other circuits stop working. The memory and register configuration hold the values. And the system is in a low-power state, consuming 273 μ A (typical). If high level is input to either PM0 or PM1, the system is awoken.

4.5. OPM4

Hold high logic on the pin DEEPSLEEP for more than 4ms to enable the system entering to the OPM4, or deep sleep mode.

In this mode, the digital power circuit is turned off, the power supply for the digital circuits is driven down to 0V, and only the RC oscillator is working. The system is in an ultralow power state, consuming 0.19 μ A (typical) only.

Hold low logic on the pin DEEPSLEEP for more than 4ms to wake up and retrieve the system.

4.6. Power Consumption

Table 4-4 Power Consumption of The V9203

Operating	Operating Mode	Power Consumption		Description
Full operating	OPM0	9.16	mA	Metering frequency is 6.5536MHz, ADC sampling frequency is 819.2kHz, ADCs of current and voltage of Phase A/B/C are enabled.
		9.9	mA	Metering frequency is 6.5536MHz, ADC sampling frequency is 819.2kHz, ADCs of current and voltage of Phase A/B/C and Channel IN are enabled.
	OPM2	5.1	mA	Metering frequency is 6.5536MHz, ADC sampling frequency is 819.2kHz, ADCs of current and voltage of Phase A/B/C are enabled.
Underclocking Operating	OPM0	3.21	mA	Metering frequency is 1.6384MHz, ADC sampling frequency is 204.8kHz, ADCs of current and voltage of Phase A/B/C are enabled.

Operating	Operating Mode	Power Consumption		Description
	OPM1	1.65	mA	Metering frequency is 819.2kHz, ADC sampling frequency is 204.8kHz, ADCs of current and voltage of Phase A/B/C are enabled.
	OPM2	2.2	mA	
	OPM4	0.19	μA	Deep sleep mode.

5. Power Supply Management

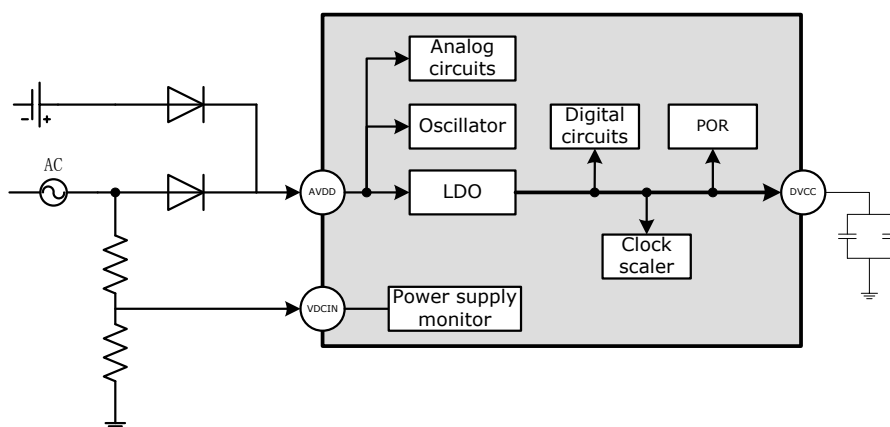


Figure 5-1 Power Supply Architecture

The V9203 has a power input 3.3V (2.5~3.6V). The analog circuits, such as the ADCs, BandGap circuits, and the oscillator, are powered by the input of AVDD. And the digital circuits, clock scaler and the power-on reset circuit are powered by the digital power supply circuit.

5.1. Digital Power Supply

The digital power supply for digital circuits, clock scaler and power-on reset circuit is derived by an on-chip LDO from power input (AVDD). This LDO keeps working even though the system is powered down.

The LDO has a driving capability of 35mA, which means when the load current on the digital circuits is less than 35mA, the LDO outputs stable voltage; but when the load current is higher than 35mA, the output reduces as the current increases.

The internal power-on reset circuit supervises the output voltage on the pin DVCC (Pin1) all the time. When the output voltage is higher than 1.8V, the reset signal is released, and the reset state holds 244μs. When the output voltage is lower than 1.8V, the system is in the reset state. The threshold, 1.8V, a typical value, is associated with the chips. It is recommended to decouple the pin externally with a 10μF capacitor in parallel with a 0.1μF capacitor.

5.2. Power Supply Monitor

The V9203 contains a power supply monitor circuit which monitors the input on the pin VDCIN (Pin17).

When the input level on the pin is less than 1-V, the monitor circuit outputs logic 1, signaling the master MCU that the V9203 has been powered down. If bit16 of either IRQEN0 register (0xA000) or IRQEN1 register (0xA001) is set to 1 to enable the power down interrupt, the interrupt flag, bit16 of the register IRQFLAG (0xA002), is set bit when the power-down event occurs, and either pin IRQ0 (Pin30) or

IRQ1 (Pin31) outputs logic 1.

6. BandGap Circuits

In the V9203, the BandGap Circuits output a reference voltage, about 1.185V with a typical temperature coefficient of 10ppm/°C, for ADCs. This circuit consumes about 0.1mA.

In immediately 488μs after reset, bit[2:0] of ANCtrl3 (0x8003) register is set to 0b101 automatically, to enable the clock scaler and BandGap Circuit A, and disable the BandGap Circuit B. Then, users must set these bits to 0b110 to enable the BandGap Circuit B and the clock scaler, and disable the BandGap Circuit A, because the BandGap Circuit B is characteristic of a better temperature performance.

Users can adjust the temperature performance as follows:

1. Set bit1 of ANCtrl3 register (0x8003) to 1, to enable the BandGap Circuit B;
2. Enable the chopper to eliminate the bias current of the BandGap circuits (by default). When the chopper is enabled, the output of the BandGap circuit varies in the range of -50~+50mV, and the temperature coefficient can be improved by 5ppm.
3. Configure bit[15:13] and bit[12:11] of ANCtrl2 register (0x8002) to adjust the temperature coefficient to kill the temperature coefficient introduced by the external components. It is recommended to configure the bits as follows:

Table 6-1 Adjusting the Temperature Coefficient

Register	bit		Configuration
Analog Control Register 2 (0x8002, ANCtrl2)	Bit[15:13]	REST<2:0>	0b010
	Bit[12:11]	RESTL<1:0>	0b10

7. SPI

The data frame received and transmitted via the SPI interfaces of the V9203 is composed of 32 bits, including 2-bit Start Bits (bit[31:30], "10"), 6-bit Command Bits (bit[29:24]), 16-bit Data (bit[23:16], DATAH, and bit[15:8], DATA L), and 8-bit Checksum (bit[7:0]), as shown in the following figure. When the V9203 receives or sends the frame, the most significant bit always is shifted in or out first.

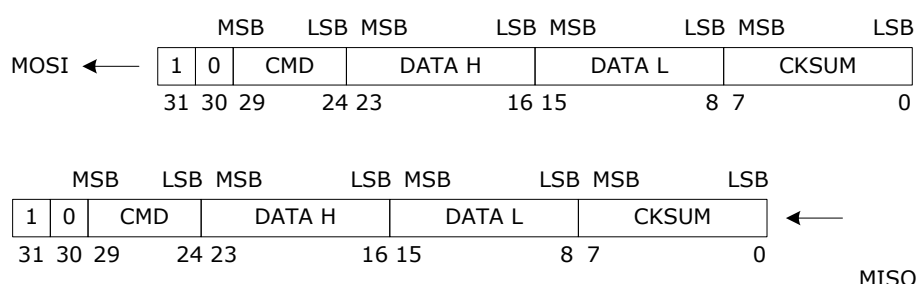


Figure 7-1 Data Frame Structure

Table 7-1 Description of Data Frame

Data Frame		Description
Start Bits, "10"	Bit31~bit30	On a low-to-high SCLK transition, the V9203 receives a bit on MOSI; and on a high-to-low SCLK transition, the V9203 transmits a bit on MISO. On two continuous low-to-high SCLK transition, the V9203 receives "1" and then "0", the Start Bits.
Command Bits, CMD	Bit29~bit24	To determine the function of the data frame. The most significant bit is shifted in or out first.
Data, DATA H, DATA L	Bit23~bit8	The data to be operated according to the command bits. The most significant bit is shifted in or out first.
Checksum, CKSUM	Bit7~bit0	CKSUM is the checksum. Checksum is the 2'-complement of the sum of the 3 bytes (Bit[31:24], bit[23:16] and bit[15:8]). The most significant bit is shifted in or out first.

Table 7-2 Description of Command Bits

CMD		Description
0b001000	0x08	To write of lower 16 bits of SPI buffer.
0b001010	0x0A	To write of higher 16 bits of SPI buffer.
0b001100	0x0C	To give the address of the target register to be write operated.
0b010000	0x10	To give the address of the target register to be read operated.
0b010010	0x12	To read out the lower 16 bits of the target register.

CMD		Description
0b010100	0x14	To read out the higher 16 bits of the target register.
0b001110	0x0E	To read out the last target address operated.
0b010110	0x16	To read out the lower 16 bits of the last target register operated.
0b011000	0x18	To read out the higher 16 bits of the last target register operated.

7.1. SPI Write Operation

The master must send 3 data frames to complete writing of a 32-bit datum using the SPI interface of the V9203, 2 data frames for a 16-bit datum, or 1 data frame for an 8-bit datum. For example, the following table shows the 3 data frames for the SPI write operation of a 32-bit datum.

Table 7-3 SPI Write Operation: Description of the CMD and DATA of the Frames

No. of Frame	CMD	DATA H & DATA L	Description
1	0x08	The lower 16 bits of the target data.	The master MCU sends the lower 16 bits of the target data, and the data is written to the lower 16 bits of SPI buffer of the V9203 on the last (the 32 nd) low-to-high SPCK transition.
2	0x0A	The higher 16 bits of the target data.	The master MCU sends the higher 16 bits of the target data, and the data is written to the higher 16 bits of SPI buffer of the V9203 on the last (the 32 nd) low-to-high SPCK transition.
3	0x0C	The address of the target register to be written.	The above 32-bit data is written into the target register after the last bit of the data frame is received.

The master sends the checksums of the above three data frames. If any error is detected in the received data frames, the data frames are invalid. If the SPI error interrupt is enabled (bit15 of IRQEN0 [0xA000] or IRQEN1[0xA001] is set to 1), the interrupt flag (bit15 of IRQFLAG[0xA002]) is set bit, and a logic high is output on the pin IRQ0 or IRQ1.

During the SPI write operation, the V9203 sends the content on the MISO pin that is shifted in on the MOSI pin on the high-to-low SPCK transition. So users can read the content sent on the MISO pin to detect whether the V9203 received the right data.

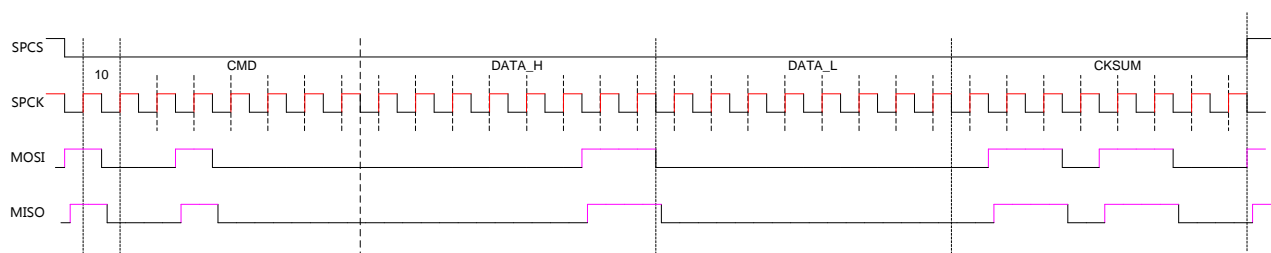


Figure 7-2 SPI Write Operation of a 32-bit Register

7.2. SPI Read Operation

The master must send 3 data frames to complete reading a 32-bit datum using the SPI interface of the V9203, 2 data frames for a 16-bit datum, or 1 data frame for an 8-bit datum. For example, the following table shows the 3 data frames for the SPI read operation of a 32-bit datum.

Table 7-4 SPI Read Operation: Description of the CMD and DATA of the Frames

No. of Frame	CMD	DATA H & DATA L	Description
1	0x10	The address of the target register to be read.	The master MCU sends the address of the target register to be read. The master MCU sends the checksum.
2	0x12	The lower 16 bits of the target register.	From the 1 st to 8 th high-to-low SPCK transition, the master MCU sends the start bits and command bits to the V9203 on the pin MOSI, and the V9203 sends the received bits to the mater MCU on the pin MISO. From the 9 th to 32 nd high-to-low SPCK transition, whatever is received on the MOSI pin of the V9203, from the 9 th to 24 th SPCK transition, the V9203 sends the lower 16 bits of the target register on the MISO pin, and then from the 25 th to 32 nd high-to-low SPCK transition, the V9203 sends the checksum calculated by the SPI module of the V9203 on the MISO pin. The master MCU can read the content sent from the MISO pin of the V9203 and combine them to be a data frame to detect whether the transfer operation is right.
3	0x14	The higher 16 bits of the target register.	From the 1 st to 8 th high-to-low SPCK transition, the master MCU sends the start bits and command bits to the V9203 on the pin MOSI, and the V9203 sends the received bits to the mater MCU on the pin MISO. From the 9 th to 32 nd high-to-low SPCK transition, whatever is received on the MOSI pin of the V9203, from the 9 th to 24 th SPCK transition, the V9203 sends the higher 16 bits of the target register on the MISO pin, and then from the 25 th to 32 nd high-to-low SPCK transition, the V9203 sends the checksum calculated by the SPI module of the V9203 on the MISO pin. The master MCU can read the content sent from the MISO pin of the V9203 and combine them to be a data frame to detect whether the transfer operation is right.

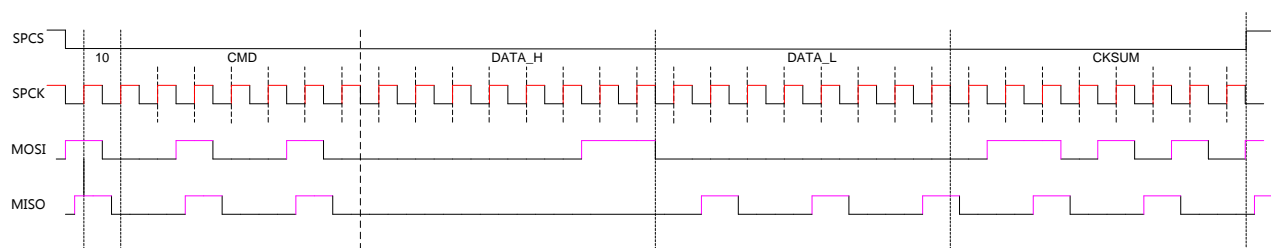


Figure 7-3 SPI Read Operation of a 32-bit Register

7.3. Check The Last Operation

The master MCU can check the last write or read operation via the SPI interface of the V9203. The master must send 3 data frames as follows to complete the checking.

Table 7-5 SPI Read Operation: Description of the CMD and DATA of the Frames

No. of Frame	CMD	DATA H & DATA L	Description
1	0x0E	The last address operated.	<p>From the 1st to 8th high-to-low SPCK transition, the master MCU sends the start bits and command bits to the V9203 on the pin MOSI, and the V9203 sends the received bits on the pin MISO.</p> <p>From the 9th to 32nd high-to-low SPCK transition, whatever is received on the MOSI pin of the V9203, from the 9th to 24th SPCK transition, the MISO sends address of the target register, and then from the 25th to 32nd high-to-low SPCK transition, the MISO sends the checksum calculated by the SPI module of the V9203.</p>
2	0x16	The lower 16 bits of the last target register operated.	<p>From the 1st to 8th high-to-low SPCK transition, the master MCU sends the start bits and command bits to the V9203 on the pin MOSI, and the V9203 sends the received bits to the mater MCU on the pin MISO.</p> <p>From the 9th to 32nd high-to-low SPCK transition, whatever is received on the MOSI pin of the V9203, from the 9th to 24th SPCK transition, the V9203 sends the lower 16 bits of the target register on the MISO pin, and then from the 25th to 32nd high-to-low SPCK transition, the V9203 sends the checksum calculated by the SPI module of the V9203 on the MISO pin.</p>
3	0x18	The higher 16 bits of the last target register operated.	<p>From the 1st to 8th high-to-low SPCK transition, the master MCU sends the start bits and command bits to the V9203 on the pin MOSI, and the V9203 sends the received bits to the mater MCU on the pin MISO.</p> <p>From the 9th to 32nd high-to-low SPCK transition, whatever is received on the MOSI pin of the V9203, from the 9th to 24th SPCK transition, the V9203 sends the higher 16 bits of the target register</p>

No. of Frame	CMD	DATA H & DATA L	Description
			on the MISO pin, and then from the 25 th to 32 nd high-to-low SPCK transition, the V9203 sends the checksum calculated by the SPI module of the V9203 on the MISO pin.

7.4. Reset

The SPI interfaces of the V9203 can be reset by 3 events:

- Holding low input on the RST pin for more than 5ms: the SPI buffer is cleared and the SPI interfaces are reset;
- High input on the SPCS pin: the SPI interfaces are reset, and the MISO pin stays in a high impedance state until the RST pin reset occurs. The SPI can work normally when a low logic is input on the SPCS pin and no RST pin reset occurs.
- High input on the MOSI pin during 32 continuous SPCK: the SPI interfaces get back to idle state, and the MISO pin output low logic.

7.5. Filters

4 optional filters can be used to adjust the communication rate. By default, the Filter 0 is used, and the communication rate is less than 409.6kHz.

Table 7-6 Select the Filters for Communication Rate Adjustment.

CMD	DATA H	DATA L	Description
0x10	0xFC	Do not care.	To use Filter 1.
0x10	0xFB	Do not care.	To use Filter 2.
0x10	0xFA	Do not care.	To use Filter 3.
0x10	0xF9	Do not care.	To use Filter 0.

Table 7-7 Relationships between Filter, Master Clock and SPI Communication Rate

Master Clock	Filter			
	Filter 0	Filter 1	Filter 2	Filter 3
6.5536MHz	409.6 kHz	6.5536 MHz	655.36 kHz	102.4 kHz
3.2768MHz	204.8 kHz	3.2768 MHz	327.68 kHz	51.2 kHz
1.6384MHz	102.4 kHz	1.6384 MHz	163.84 kHz	25.6 kHz
819.2kHz	51.2 kHz	819.2 kHz	81.92 kHz	12.8 kHz

Master Clock	Filter			
	Filter 0	Filter 1	Filter 2	Filter 3
32.768kHz	2.048 kHz	32.768 kHz	3.2768 kHz	512 Hz

8. Energy Metering Registers

All energy metering registers of the V9203 will be reset to their default values when power-on reset or RST pin reset happens. All the default values in the following tables are in hexadecimal form.

8.1. Energy Metering Configuration Registers

8.1.1. Metering Control Registers

Table 8-1 Metering Control Register 0 (0xC000, MTPARA0)

0xC000, R/W, Metering Control Register 0, MTPARA0					
Bit		Default Value	Function Description		
Bit[31:24]	MTRAM<7:0>	0	<p>To clear the data RAM located at addresses as followings in the energy metering block, or force the data RAM to go to the sleep:</p> <p>0xC800~0xC837</p> <p>0xC880~0xC8B7</p> <p>0xE000~0xE08F</p>	<p>Write of 0b10101010, 20ms later, the RAM located at addresses of the range of 0xE000~0xE08F/ 0xE800~0xEAB7/ 0xF800~0xF87F/ 0xF000~0xF1EF is cleared.</p> <p>Write of 0b01010101, the RAM located at addresses of the range of 0xE000~0xE08F/ 0xE800~0xEAB7/ 0xF800~0xF87F/ 0xF000~0xF1EF enters to sleep.</p> <p>Write of 0b00010000, and then write 0s in the RAM located at addresses of the range of 0xC800~0xC837 and 0xC880~0xC8B7 to clear the RAM.</p>	<p>Access bit [7:0] of the register located at address 0xC013 to access bit[31:24] of the register MTPARA0.</p>

0xC000, R/W, Metering Control Register 0, MTPARA0					
Bit		Default Value	Function Description		
			0xE800~0xEAB7 0xF800~0xF87F 0xF000~0xF1EF		
Bit[23:21]	Reserved	0			Access bit [7:0] of the register located at address 0xC012 to access bit[23:16] of the register MTPARA0.
Bit[20:16]	MSKP	0	To set the range of the hysteresis error of the fundamental current threshold for the total active power gain calibration in sections.	For example, if the value of MSKP is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of register of the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff, and the bottom threshold is 0xab00.	
Bit[15:13]	Reserved	0			Access bit [7:0] of the register located at address 0xC011 to access bit[15:8] of the register MTPARA0.
Bit[12:8]	MSKA	0	To set the range of the hysteresis error of the fundamental current threshold for the phase compensation in sections.	For example, if the value of MSKA is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of the register of the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff, and the bottom threshold is 0xab00.	
Bit7	Reserved	0			Access bit [7:0] of the register located at address 0xC010 to access bit[7:0] of the register MTPARA0.
Bit6	ADCIC	0	To enable digital signal input of Channel IC for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.	
Bit5	ADCIB	0	To enable digital signal	1, enable.	

0xC000, R/W, Metering Control Register 0, MTPARA0

Bit		Default Value	Function Description	
			input of Channel IB for digital signal processing.	0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.
Bit4	ADCIA	0	To enable digital signal input of Channel IA for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.
Bit3	ADCIN	0	To enable digital signal input of Channel IN for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.
Bit2	ADCUC	0	To enable digital signal input of Channel UC for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.
Bit1	ADCUB	0	To enable digital signal input of Channel UB for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.
Bit0	ADCUA	0	To enable digital signal input of Channel UA for digital signal processing.	1, enable. 0, disable. When this bit is set to 0, a constant "0" is input for digital signal processing.

Note: The configuration of this register can be read out of the register ZZPARA0 (0xEC27) which is to calculate the checksum for system check.

Table 8-2 Metering Control Register 1 (0xC001, MTPARA1)

0xC001, R/W, Metering Control Register 1, MTPARA1				
Bit		Default Value	Function Description	
Bit[31:27]	Reserved	0		
Bit[26:24]	ATXIN	0	To set digital PGA gain of IN input.	$\times 1 \sim \times 128$ (2^{ATXIN})
Bit23	Reserved	0		
Bit[22:20]	ATXIC	0	To set digital PGA gain of IC input.	$\times 1 \sim \times 128$ (2^{ATXIC})
Bit19	Reserved	0		
Bit[18:16]	ATXUC	0	To set digital PGA gain of UC input.	$\times 1 \sim \times 128$ (2^{ATXUC}) If the voltage multiplying the set analog PGA gain is still far smaller than the full scale of the ADC, it is recommended to set the digital PGA gain to $\times 8$ or $\times 16$, to improve the performance.
Bit15	Reserved	0		
Bit[14:12]	ATXIB	0	To set digital PGA gain of IB input.	$\times 1 \sim \times 128$ (2^{ATXIB})
Bit11	Reserved	0		
Bit[10:8]	ATXUB	0	To set digital PGA gain of UB input.	$\times 1 \sim \times 128$ (2^{ATXUB}) If the voltage multiplying the set analog PGA gain is still far smaller than the full scale of the ADC, it is recommended to set the digital PGA gain to $\times 8$ or $\times 16$, to improve the performance.
Bit7	Reserved	0		
Bit[6:4]	ATXIA	0	To set digital PGA gain of IA input.	$\times 1 \sim \times 128$ (2^{ATXIA})

0xC001, R/W, Metering Control Register 1, MTPARA1

Bit		Default Value	Function Description	
Bit3	Reserved	0		
Bit[2:0]	ATXUA	0	To set digital PGA gain of UA input.	$\times 1 \sim \times 128 (2^{ATXUA})$ If the voltage multiplying the set analog PGA gain is still far smaller than the full scale of the ADC, it is recommended to set the digital PGA gain to $\times 8$ or $\times 16$, to improve the performance.

Note: The configuration of this register can be read out of the register ZZPARA1 (0xEC28) which is to calculate the checksum for system check.

Table 8-3 Metering Control Register 2 (0xC002, MTPARA2)

0xC002, R/W, Metering Control Register 2, MTPARA2					
Bit		Default Value	Function Description		
Bit[31:28]	Reserved				Access bit [7:0] of the register located at address 0xC01B to access bit[31:24] of the register MTPARA2.
Bit27	DSPICK	0	To select the parity type for the output data from the DMA_SPI interfaces.	0, even parity; 1, odd parity.	
Bit26	DSPIMD	0	To select the frame format of the output data from the DMA_SPI interfaces.	0, 32-bit, one frame for a 32-bit data output; 1, 16-bit, two frames for a 32-bit data output.	
Bit25	PECEN	0	To disable gain calibrate the total active power in sections.	1, disable; 0, enable.	
Bit24	AECEN	0	To disable phase compensation in	1, disable; 0, enable.	

0xC002, R/W, Metering Control Register 2, MTPARA2					
Bit		Default Value	Function Description		
			sections.		
Bit23	Reserved				Access bit [7:0] of the register located at address 0xC01A to access bit[23:16] of the register MTPARA2.
Bit[22:16]	DSPIEN	0	To enable the raw waveform output of the channels from the DMA_SPI interfaces.	1, enable; 0, disable. Bit22, raw waveform of IN; Bit21, raw waveform of IC; Bit20, raw waveform of UC; Bit19, raw waveform of IB; Bit18, raw waveform of UB; Bit17, raw waveform of IA; Bit16, raw waveform of UA.	
Bit15	EGYEN	0	To enable accumulating energy in normal mode.	0, disable; 1, enable.	Access bit [7:0] of the register located at address 0xC019 to access bit[15:8] of the register MTPARA2.
Bit14	MTMODE	0	To select the 3-wire or 4-wire application.	0, 3-phase, 4-wire; 1, 3-phase, 3-wire.	
Bit13	APPMODE	0	To select the apparent power calculation method.	0, to calculate the apparent power based on the current RMS; 1, to calculate the apparent power based on the active and reactive power.	
Bit12	DIDTEN	0	To enable the digital integrator	0, disable; 1, enable.	

0xC002, R/W, Metering Control Register 2, MTPARA2					
Bit		Default Value	Function Description		
			when a Rogowski coil is used for analog current input.		
Bit11	DCBYPASS	0	To switch on the direct current/voltage.	1, enable. When the direct current/voltage is switched on, no high-pass filter is applied to the raw waveform. And the signal composed of direct and alternating components is used for RMS calculation and energy metering.	
Bit[10:8]	CFFAST	0	To accelerate the pulse generation speed.	000~011, ×1; 100, ×4; 101, ×16; 110, ×64; 111, ×128.	
Bit[7:4]	CFCALC	0	To enable accumulating the total/fundamental active/reactive/apparent energy in high-speed mode.	1, enable; 0, disable. Bit7, total/fundamental apparent energy on the overall system, or total reactive energy on the overall system (CF3); Bit6, total/fundamental active energy on the overall system (CF2); Bit5, total/fundamental reactive energy on the overall system (CF1); Bit4, total/fundamental active energy on the overall system (CF0).	Access bit [7:0] of the register located at address 0xC018 to access bit[7:0] of the register MTPARA2.
Bit[3:0]	CFON	0	To enable CF pulse output.	1, enable; 0, disable.	

0xC002, R/W, Metering Control Register 2, MTPARA2					
Bit		Default Value	Function Description		
				Bit3, pulse output on the pin CF3; Bit2, pulse output on the pin CF2; Bit1, pulse output on the pin CF1; Bit0, pulse output on the pin CF0.	
Note: The configuration of this register can be read out of the register ZZPARA2 (0xEC29) which is to calculate the checksum for system check.					

Table 8-4 Metering Control Register 3 (0xC003, MTPARA3)

0xC003, R/W, Metering Control Register 3, MTPARA3					
Bit		Default Value	Function Description		
Bit[31:0]	CHECKSUM	0	<p>The configuration of this register can be read out of the register ZZPARA3 (0xEC2A) which is to calculate the checksum for system check.</p> <p>The sum of the values of the register ZZPARA3 (0xEC2A), on behalf of this register, and the other 109 registers for system check, is the checksum. If the checksum is equal to 0xFFFFFFFF, the configuration is accurate; otherwise, some error happens, and an interrupt is generated and output from the pin IRQ0 all the time, or from the pin IRQ0 when it is enabled.</p>		

8.1.2. No-Load Detection Mode Register

Table 8-5 No-Load Detection Mode Register (0xEC15, ZZCPSEL)

Address	Mnemonic	R/W	Length	Default Value	Function Description
0xEC15	ZZCPSEL	R/W	1-bit	0	<p>To set the mode for no-load detection.</p> <p>1, to detect the no-load condition based on the instantaneous fundamental current RMS;</p> <p>0, to detect the no-load condition based on the absolute value of the instantaneous total or fundamental active/reactive power.</p> <p>This register is to calculate the checksum for system check as a 32-bit register with the 31 most significant bits padded with 0s.</p>

8.1.3. Registers for Power On The Overall System Calculation Mode

Table 8-6 Register for Total/Fundamental Active Power on The Overall System Calculation Mode 0 (0xEC23, ZZPA0)

0xEC23, R/W, Register for Total/Fundamental Active Power on The Overall System Calculation Mode 0, ZZPA0					
Bit		Default Value	Function Description		
Bit[31:6]	Reserved				
Bit5	PCABS0	0	<p>To select three power values to calculate the total or fundamental active power on the overall system.</p> <p>1, select; 0, clear.</p> <p>Bit5, the absolute value of the instantaneous active power of Phase C;</p> <p>Bit4, the algebra value of the instantaneous active power of Phase C;</p>		
Bit4	PC0	0			
Bit3	PBABS0	0			
Bit2	PB0	0			

0xEC23, R/W, Register for Total/Fundamental Active Power on The Overall System Calculation Mode 0, ZZPA0			
Bit		Default Value	Function Description
Bit1	PAABS0	0	Bit3, the absolute value of the instantaneous active power of Phase B; Bit2, the algebra value of the instantaneous active power of Phase B; Bit1, the absolute value of the instantaneous active power of Phase A; Bit0, the algebra value of the instantaneous active power of Phase A. For example, if the register is set to 0b100001, the total or fundamental active power on the overall system is the sum of the absolute value of the instantaneous active power of Phase C, 0, and the algebra value of the instantaneous active power of Phase A. It is recommended to set to 0x15. The selection of the absolute and algebra value of the instantaneous active power of one phase cannot concur. This register is used to calculate the checksum for system check as a 32-bit register with the 26 most significant bits padded with 0s.
Bit0	PA0	0	

Table 8-7 Register for Total/Fundamental Active Power On The Overall System Calculation Mode 1 (0xEC24, ZZPA1)

0xEC24, R/W, Register for Total/Fundamental Active Power On The Overall System Calculation Mode 1, ZZPA1					
Bit		Default Value	Function Description		
Bit[31:6]	Reserved				
Bit5	PCABS1	0	To select three power values to calculate the total or fundamental active power on the overall system. 1, select; 0, clear.		
Bit4	PC1	0			
Bit3	PBABS1	0	Bit5, the absolute value of the instantaneous active power of Phase C;		

0xEC24, R/W, Register for Total/Fundamental Active Power On The Overall System Calculation Mode 1, ZZPA1			
Bit		Default Value	Function Description
Bit2	PB1	0	Bit4, the algebra value of the instantaneous active power of Phase C; Bit3, the absolute value of the instantaneous active power of Phase B;
Bit1	PAABS1	0	
Bit0	PA1	0	Bit2, the algebra value of the instantaneous active power of Phase B; Bit1, the absolute value of the instantaneous active power of Phase A; Bit0, the algebra value of the instantaneous active power of Phase A. For example, if the register is set to 0b000110, the total or fundamental active power on the overall system is the sum of 0, the algebra value of the instantaneous active power of Phase B, and the absolute value of the instantaneous active power of Phase A. It is recommended to set to 0x2A. The selection of the absolute and algebra value of the instantaneous active power of one phase cannot concur. This register is used to calculate the checksum for system check as a 32-bit register with the 26 most significant bits padded with 0s.

Table 8-8 Register for Total/Fundamental Reactive Power On The Overall System Calculation Mode 0 (0xEC47, ZZQA0)

0xEC47, R/W, Register for Total/Fundamental Reactive Power on the overall system Calculation Mode 0, ZZQA0			
Bit		Default Value	Function Description
Bit[31:6]	Reserved	-	To select three power values to calculate the total or fundamental reactive power on the overall system. 1, select; 0, clear. Bit5, the absolute value of the instantaneous reactive power of Phase C;
Bit5	QCABS0	0	
Bit4	QC0	0	

0xEC47, R/W, Register for Total/Fundamental Reactive Power on the overall system Calculation Mode 0, ZZQA0			
Bit		Default Value	Function Description
Bit3	QBABS0	0	Bit4, the algebra value of the instantaneous reactive power of Phase C; Bit3, the absolute value of the instantaneous reactive power of Phase B; Bit2, the algebra value of the instantaneous reactive power of Phase B; Bit1, the absolute value of the instantaneous reactive power of Phase A; Bit0, the algebra value of the instantaneous reactive power of Phase A. For example, if the register is set to 0b100001, the total or fundamental reactive power on the overall system is the sum of the absolute value of the instantaneous reactive power of Phase C, 0, and the algebra value of the instantaneous reactive power of Phase A. It is recommended to set to 0x15. The selection of the absolute and algebra value of the instantaneous reactive power of one phase cannot concur. This register is used to calculate the checksum for system check as a 32-bit register with the 26 most significant bits padded with 0s.
Bit2	QB0	0	
Bit1	QAABS0	0	
Bit0	QA0	0	

Table 8-9 Register for Total/Fundamental Reactive Power On The Overall System Calculation Mode 1 (0xEC48, ZZQA1)

0xEC48, R/W, Register for Total/Fundamental Reactive Power On The Overall System Calculation Mode 1, ZZQA1			
Bit		Default Value	Function Description
Bit[31:6]	Reserved	-	To select three power values to calculate the total or fundamental reactive power on the overall system. 1, select; 0, clear. Bit5, the absolute value of the instantaneous reactive power of Phase C;
Bit5	QCABS1	0	
Bit4	QC1	0	

0xEC48, R/W, Register for Total/Fundamental Reactive Power On The Overall System Calculation Mode 1, ZZQA1			
Bit		Default Value	Function Description
Bit3	QBABS1	0	Bit4, the algebra value of the instantaneous reactive power of Phase C; Bit3, the absolute value of the instantaneous reactive power of Phase B; Bit2, the algebra value of the instantaneous reactive power of Phase B; Bit1, the absolute value of the instantaneous reactive power of Phase A; Bit0, the algebra value of the instantaneous reactive power of Phase A. For example, if the register is set to 0b000110, the total or fundamental reactive power on the overall system is the sum of 0, the algebra value of the instantaneous reactive power of Phase B, and the absolute value of the instantaneous reactive power of Phase A. It is recommended to set to 0x2A. The selection of the absolute and algebra value of the instantaneous reactive power of one phase cannot concur. This register is used to calculate the checksum for system check as a 32-bit register with the 26 most significant bits padded with 0s.
Bit2	QB1	0	
Bit1	QAABS1	0	
Bit0	QA1	0	

Table 8-10 Register for Total/Fundamental Apparent Power On The Overall System Calculation Mode (0xEC05, ZZAPPA)

0xEC05, R/W, Register for Total/Fundamental Apparent Power over All System Calculation Mode, ZZAPPA			
Bit		Default Value	Function Description
Bit[31:3]	Reserved	-	To select three power values to calculate the total or fundamental apparent power on the overall system. 1, select; 0, clear. Bit2, the instantaneous apparent power of Phase C;
Bit2	APPC	0	
Bit1	APPB	0	

Bit0	APPA	0	<p>Bit1, the instantaneous apparent power of Phase B;</p> <p>Bit0, the instantaneous apparent power of Phase A;</p> <p>For example, if the register is set to 0b110, the total or fundamental apparent power on the overall system is the sum of the instantaneous apparent power of Phase C, the instantaneous apparent power of Phase B, and 0.</p> <p>It is recommended to set to 0x07.</p> <p>This register is used to calculate the checksum for system check as a 32-bit register with the 29 most significant bits padded with 0s.</p>
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8.1.4. Register for CF Pulse Source Selection

Table 8-11 Register for CF Pulse Source Selection (0xEC34, ZZPCF0A)

0xEC34, R/W, Register for CF Pulse Source Selection, ZZPCF0A				
Bit		Default Value	Function Description	
Bit[31:16]	Reserved	-	-	
Bit[15:12]	CF3PS	0	<p>To set the source for the CF pulse output on the pin CF3.</p> <p>1000~1111, the fundamental apparent power on the overall system;</p> <p>0100~0111, the total apparent power on the overall system;</p> <p>0010~0011, the absolute value of the total reactive power on the overall system in Mode 1;</p> <p>0001, the absolute value of the total reactive power on the overall system in Mode 0;</p> <p>0000, a non-zero random value.</p> <p>Via configuring the registers ZZQA0 (0xEC47), ZZQA1 (0xEC48), and ZZAPPA (0xEC05), the pin CF3 can be used to output CF pulse sourced the total reactive power or total/fundamental</p>	

0xEC34, R/W, Register for CF Pulse Source Selection, ZZPCF0A				
Bit		Default Value	Function Description	
				apparent power of each phase or on the overall system.
Bit[11:8]	CF2PS	0	To set the source for the CF pulse output on the pin CF2.	<p>1000~1111, the absolute value of the fundamental active power on the overall system in Mode 1;</p> <p>0100~0111, the absolute value of the fundamental active power on the overall system in Mode 0;</p> <p>0010~0011, the absolute value of the total active power on the overall system in Mode 1;</p> <p>0001, the absolute value of the total active power on the overall system in Mode 0;</p> <p>0000, a non-zero random value.</p> <p>Via configuring the registers ZZPA0 (0xEC23) and ZZPA1 (0xEC24), the pin CF2 can be used to output CF pulse sourced the total/fundamental active power of each phase or on the overall system.</p>
Bit[7:4]	CF1PS	0	To set the source for the CF pulse output on the pin CF1.	<p>1000~1111, the absolute value of the fundamental reactive power on the overall system in Mode 1;</p> <p>0100~0111, the absolute value of the fundamental reactive power on the overall system in Mode 0;</p> <p>0010~0011, the absolute value of the total reactive power on the overall system in Mode 1;</p> <p>0001, the absolute value of the total reactive power on the overall system in Mode 0;</p> <p>0000, a non-zero random value.</p> <p>Via configuring the registers ZZQA0 (0xEC47) and ZZQA1 (0xEC48), the pin CF1 can be used to output CF pulse sourced the total/fundamental reactive power of each phase or on the</p>

0xEC34, R/W, Register for CF Pulse Source Selection, ZZPCF0A				
Bit		Default Value	Function Description	
				overall system.
Bit[3:0]	CFOPS	0	To set the source for the CF pulse output on the pin CF0.	<p>1000~1111, the absolute value of the fundamental active power on the overall system in Mode 1;</p> <p>0100~0111, the absolute value of the fundamental active power on the overall system in Mode 0;</p> <p>0010~0011, the absolute value of the total active power on the overall system in Mode 1;</p> <p>0001, the absolute value of the total active power on the overall system in Mode 0;</p> <p>0000, a non-zero random value.</p> <p>Via configuring the registers ZZPA0 (0xEC23) and ZZPA1 (0xEC24), the pin CF0 can be used to output CF pulse sourced the total/fundamental active power of each phase or on the overall system.</p>
This register is used to calculate the checksum for system check as a 32-bit register with the 16 most significant bits padded with 0s.				

8.2. Metering Data Registers

8.2.1. Registers for DC Component

Table 8-12 Registers for DC Component (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
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Address	Mnemonic	Description	R/W	Format	Remark
0xF02C	DCUA	The instantaneous direct voltage of Phase A.	R/W	24-bit, 2'-complement	<p>These registers, with bit23 being the sign bit, are accessed as a 32-bit register with sign extended to 32 bits.</p> <p>When the metering frequency is 6.5536MHz, these registers are updated once every 20ms, and the settling time is 100ms.</p>
0xF02D	DCIA	The instantaneous direct current of Phase A.	R/W	24-bit, 2'-complement	
0xF02E	DCUB	The instantaneous direct voltage of Phase B.	R/W	24-bit, 2'-complement	
0xF02F	DCIB	The instantaneous direct current of Phase B.	R/W	24-bit, 2'-complement	
0xF030	DCUC	The instantaneous direct voltage of Phase C.	R/W	24-bit, 2'-complement	
0xF031	DCIC	The instantaneous direct current of Phase C.	R/W	24-bit, 2'-complement	
0xF032	DCIN	The instantaneous direct current of Channel IN.	R/W	24-bit, 2'-complement	

8.2.2. Registers for Line Frequency and Phase Angle of Each Phase

Table 8-13 Registers for Line Frequency and Phase Angle of Each Phase (R)

Address	Mnemonic	Description	R/W	Format	Default Value	Remark
0xC008	FA	The line frequency of Phase A.	R	17-bit, 2'-complement	0	<p>Positive, constantly.</p> <p>These registers are accessed as 32-bit registers with the 15 most significant bits padded with 0s.</p> <p>The measurement resolution is 0.0008Hz.</p> <p>When the metering frequency is 6.5536MHz, these registers are updated once every 640ms, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 1s.</p>
0xC009	FB	The line frequency of Phase B.	R	17-bit, 2'-complement	0	
0xC00A	FC	The line frequency of Phase C.	R	17-bit, 2'-complement	0	

Address	Mnemonic	Description	R/W	Format	Default Value	Remark
0xC00B	PHSUB	The voltage phase angle of Phase B.	R	12-bit, 2'-complement	0	<p>The phase angle of each signal is measured relative to the voltage phase angle of Phase A. So, the voltage phase angle of Phase A is 0, constantly.</p> <p>These registers are accessed as a 32-bit register with the 20 most significant bits padded with 0s.</p> <p>The measurement resolution is 0.175°.</p> <p>When the metering frequency is 6.5536MHz, these registers is updated once every 20ms, and the settling time is associated with the signal strength. The smaller the signal is, the longer the settling time is, usually more than 1s.</p>
0xC00C	PHSUC	The voltage phase angle of Phase C.	R	12-bit, 2'-complement	0	
0xC00D	PHSIA	The current phase angle of Phase A.	R	12-bit, 2'-complement	0	
0xC00E	PHSIB	The current phase angle of Phase B.	R	12-bit, 2'-complement	0	
0xC00F	PHSIC	The current phase angle of Phase C.	R	12-bit, 2'-complement	0	

8.2.3. Registers for Power Factor

Table 8-14 Registers for Total Power Factor (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE811	AFA	The instantaneous total power factor of Phase A.	R/W	32-bit, unsigned	<p>Power factor is calculated following the equation:</p> $\text{Powerfactor} = \frac{ \text{instantaneous active power} }{\text{instantaneous apparent power}}$ <p>When the ratio of the value of these registers to the number 2^31 is more than 1, the power factor is 1.</p>
0xE812	AFB	The instantaneous total power factor of Phase B.	R/W	32-bit, unsigned	
0xE813	AFC	The instantaneous total power factor of Phase C.	R/W	32-bit, unsigned	

Address	Mnemonic	Description	R/W	Format	Remark
0xE814	AFS	The instantaneous total power factor on the overall system.	R/W	32-bit, unsigned	<p>When the metering frequency is 6.5536MHz, the updating time of the instantaneous power factor registers is 80ms, and the settling time is 400ms; the updating time of the average power factor registers is 640ms, and the settling time is 1s.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the instantaneous power factor registers is 320ms, and the settling time is 1.6s; the updating time of the average power factor registers is 2.56s, and the settling time is 4s.</p> <p>When the metering frequency is 819.2kHz, the updating time of the instantaneous power factor registers is 640ms, and the settling time is 3.2s; the updating time of the average power factor registers is 5.12s, and the settling time is 8s.</p>
0xE8E4	MAFA	The average total power factor of Phase A.	R/W	32-bit, unsigned	
0xE8E5	MAFB	The average total power factor of Phase B.	R/W	32-bit, unsigned	
0xE8E6	MAFC	The average total power factor of Phase C.	R/W	32-bit, unsigned	
0xE8E7	MAFS	The average total power factor on the overall system.	R/W	32-bit, unsigned	

Table 8-15 Registers for Fundamental Power Factor (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE857	BFA	The instantaneous fundamental power factor of Phase A.	R/W	32-bit, unsigned	<p>Power factor is calculated following the equation:</p> $\text{Powerfactor} = \frac{\text{instantaneousactivepower}}{\text{instantaneousapparentpower}}$ <p>When the ratio of the value of these registers to the number 2³¹ is more than 1, the power factor is 1.</p> <p>When the metering frequency is 6.5536MHz, the updating time of the instantaneous power factor registers is 80ms, and the settling time is 450ms; the updating time of the average power factor registers is 640ms, and the settling time is 1s.</p>
0xE858	BFB	The instantaneous fundamental power factor of Phase B.	R/W	32-bit, unsigned	
0xE859	BFC	The instantaneous fundamental power factor of Phase C.	R/W	32-bit, unsigned	

Address	Mnemonic	Description	R/W	Format	Remark
0xE85A	BFS	The instantaneous fundamental power factor on the overall system.	R/W	32-bit, unsigned	When the metering frequency is 1.6384MHz, the updating time of the instantaneous power factor registers is 320ms, and the settling time is 1.8s; the updating time of the average power factor registers is 2.56s, and the settling time is 4s. When the metering frequency is 819.2kHz, the updating time of the instantaneous power factor registers is 640ms, and the settling time is 3.6s; the updating time of the average power factor registers is 5.12s, and the settling time is 8s.
0xE8F9	MBFA	The average fundamental power factor of Phase A.	R/W	32-bit, unsigned	
0xE8FA	MBFB	The average fundamental power factor of Phase B.	R/W	32-bit, unsigned	
0xE8FB	MBFC	The average fundamental power factor of Phase C.	R/W	32-bit, unsigned	
0xE8FC	MBFS	The average fundamental power factor on the overall system.	R/W	32-bit, unsigned	

8.2.4. Registers for RMS

All the RMS registers are in the format of 32-bit 2'-complement, and positive constantly.

Table 8-16 Registers for Total Current/Voltage RMS (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE83E	ARTIA	The instantaneous total current RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 6.5536MHz, the updating time of the registers is 20ms, and the settling time is 150ms.
0xE83F	ARTIB	The instantaneous total current RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE840	ARTIC	The instantaneous total current RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE841	ARTIN	The instantaneous total current RMS of Channel	R/W	32-bit, 2'-complement	When the metering frequency is 1.6384MHz, the updating time of the registers is 80ms,

Address	Mnemonic	Description	R/W	Format	Remark
		IN.			and the settling time is 600ms.
0xE842	ARTUA	The instantaneous total voltage RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 819.2kHz, the updating time of content of the registers is 160ms, and the settling time is 1.2s.
0xE843	ARTUB	The instantaneous total voltage RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE844	ARTUC	The instantaneous total voltage RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE944	MUA	The average total voltage RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 6.5536MHz, the updating time of the registers is 640ms, and the settling time is 1s.
0xE945	MUB	The average total voltage RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE946	MUC	The average total voltage RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE90E	MIA	The average total current RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 1.6384MHz, the updating time of the registers is 2.56s, and the settling time is 4s.
0xE90F	MIB	The average total current RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE910	MIC	The average total current RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE911	MIN	The average total current RMS of Channel IN.	R/W	32-bit, 2'-complement	When the metering frequency is 819.2kHz, the updating time of content of the registers is 5.12s, and the settling time is 8s.
0xE94B	MUM	The algebra sum of the total current RMS on the overall system.	R/W	32-bit, 2'-complement	

Table 8-17 Registers for Fundamental Current/Voltage RMS (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE880	BRTIA	The instantaneous fundamental current RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 6.5536MHz, the updating time of the registers is 20ms, and the settling time is 200ms.
0xE881	BRTIB	The instantaneous fundamental current RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE882	BRTIC	The instantaneous fundamental current RMS of	R/W	32-bit, 2'-complement	When the metering frequency is 1.6384MHz, the updating time of the registers is 80ms,

Address	Mnemonic	Description	R/W	Format	Remark
		Phase C.			and the settling time is 800ms.
0xE883	BRTUA	The instantaneous fundamental voltage RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 819.2kHz, the updating time of content of the registers is 160ms, and the settling time is 1.6s.
0xE884	BRTUB	The instantaneous fundamental voltage RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE885	BRTUC	The instantaneous fundamental voltage RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE8FD	MBIA	The average fundamental current RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 6.5536MHz, the updating time of the registers is 640ms, and the settling time is 1s.
0xE8FE	MBIB	The average fundamental current RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE8FF	MBIC	The average fundamental current RMS of Phase C.	R/W	32-bit, 2'-complement	
0xE90B	MBUA	The average fundamental voltage RMS of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 1.6384MHz, the updating time of the registers is 2.56s, and the settling time is 4s.
0xE90C	MBUB	The average fundamental voltage RMS of Phase B.	R/W	32-bit, 2'-complement	
0xE90D	MBUC	The average fundamental voltage RMS of Phase C.	R/W	32-bit, 2'-complement	
					When the metering frequency is 819.2kHz, the updating time of content of the registers is 5.12s, and the settling time is 8s.

8.2.5. Power Registers

Table 8-18 Total Active/Reactive/Apparent Power Registers (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE801	AABSPSUM0	The absolute value of the instantaneous total active power on the overall system in	R/W	32-bit, 2'-complement	Positive, constantly.

Address	Mnemonic	Description	R/W	Format	Remark
		Calculation Mode 0.			<p>When the metering frequency is 6.5536MHz, the updating time of the registers is 80ms, and the settling time is 400ms.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the registers is 320ms, and the settling time is 1.6s.</p> <p>When the metering frequency is 819.2kHz, the updating time of content of the registers is 640ms, and the settling time is 3.2s.</p>
0xE802	AABSPSUM1	The absolute value of the instantaneous total active power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE803	AABSQSUM0	The absolute value of the instantaneous total reactive power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE804	AABSQSUM1	The absolute value of the instantaneous total reactive power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE805	ABSAPA	The absolute value of the instantaneous total active power of Phase A.	R/W	32-bit, 2'-complement	
0xE806	ABSAPB	The absolute value of the instantaneous total active power of Phase B.	R/W	32-bit, 2'-complement	
0xE807	ABSAPC	The absolute value of the instantaneous total active power of Phase C.	R/W	32-bit, 2'-complement	
0xE808	ABSAQA	The absolute value of the instantaneous total reactive power of Phase A.	R/W	32-bit, 2'-complement	
0xE809	ABSAQB	The absolute value of the instantaneous total reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE80A	ABSAQC	The absolute value of the instantaneous total reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE81F	APPA	The instantaneous total apparent power of Phase A.	R/W	32-bit, 2'-complement	When the metering frequency is 6.5536MHz, the updating time of the registers is 80ms,

Address	Mnemonic	Description	R/W	Format	Remark
0xE820	APPB	The instantaneous total apparent power of Phase B.	R/W	32-bit, 2'-complement	<p>and the settling time is 400ms.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the registers is 320ms, and the settling time is 1.6s.</p> <p>When the metering frequency is 819.2kHz, the updating time of content of the registers is 640ms, and the settling time is 3.2s.</p>
0xE821	APPC	The instantaneous total apparent power of Phase C.	R/W	32-bit, 2'-complement	
0xE822	APSUM0	The algebra value of the instantaneous total active power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE823	APSUM1	The algebra value of the instantaneous total active power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE824	APTLA	The algebra value of the instantaneous total active power of Phase A.	R/W	32-bit, 2'-complement	
0xE825	APTLB	The algebra value of the instantaneous total active power of Phase B.	R/W	32-bit, 2'-complement	
0xE826	APTLC	The algebra value of the instantaneous total active power of Phase C.	R/W	32-bit, 2'-complement	
0xE831	AQSUM0	The algebra value of the instantaneous total reactive power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE832	AQSUM1	The algebra value of the instantaneous total reactive power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE833	AQTLA	The algebra value of the instantaneous total reactive power of Phase A.	R/W	32-bit, 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xE834	AQTLB	The algebra value of the instantaneous total reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE835	AQTLC	The algebra value of the instantaneous total reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE84E	ASSUM	The instantaneous total apparent power on the overall system.	R/W	32-bit, 2'-complement	
0xE8E8	MAPA	The average total active power of Phase A.	R/W	32-bit, 2'-complement	<p>When the metering frequency is 6.5536MHz, the updating time of the registers is 640ms, and the settling time is 1s.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the registers is 2.56s, and the settling time is 4s.</p> <p>When the metering frequency is 819.2kHz, the updating time of content of the registers is 5.12s, and the settling time is 8s.</p>
0xE8E9	MAPB	The average total active power of Phase B.	R/W	32-bit, 2'-complement	
0xE8EA	MAPC	The average total active power of Phase C.	R/W	32-bit, 2'-complement	
0xE8EB	MAPPA	The average total apparent power of Phase A.	R/W	32-bit, 2'-complement	
0xE8EC	MAPPB	The average total apparent power of Phase B.	R/W	32-bit, 2'-complement	
0xE8ED	MAPPC	The average total apparent power of Phase C.	R/W	32-bit, 2'-complement	
0xE8EE	MAPSUM0	The average total active power on the overall system 0.	R/W	32-bit, 2'-complement	
0xE8EF	MAPSUM1	The average total active power on the overall system 1.	R/W	32-bit, 2'-complement	
0xE8F0	MAQA	The average total reactive power of Phase A.	R/W	32-bit, 2'-complement	
0xE8F1	MAQB	The average total reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE8F2	MAQC	The average total reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE8F3	MAQSUM0	The average total reactive power on the overall system 0.	R/W	32-bit, 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xE8F4	MAQSUM1	The average total reactive power on the overall system 1.	R/W	32-bit, 2'-complement	
0xE8F5	MASSUM	The average total apparent power on the overall system.	R/W	32-bit, 2'-complement	

Table 8-19 Fundamental Active/Reactive/Apparent Power Registers (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE80B	ABSBPA	The absolute value of the instantaneous fundamental active power of Phase A.	R/W	32-bit, 2'-complement	Positive, constantly. When the metering frequency is 6.5536MHz, the updating time of the registers is 80ms, and the settling time is 450ms. When the metering frequency is 1.6384MHz, the updating time of the registers is 320ms, and the settling time is 1.8s. When the metering frequency is 819.2kHz, the updating time of content of the registers is 640ms, and the settling time is 3.6s.
0xE80C	ABSBPB	The absolute value of the instantaneous fundamental active power of Phase B.	R/W	32-bit, 2'-complement	
0xE80D	ABSBPC	The absolute value of the instantaneous fundamental active power of Phase C.	R/W	32-bit, 2'-complement	
0xE80E	ABSBQA	The absolute value of the instantaneous fundamental reactive power of Phase A.	R/W	32-bit, 2'-complement	
0xE80F	ABSBQB	The absolute value of the instantaneous fundamental reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE810	ABSBQC	The absolute value of the instantaneous fundamental reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE850	BABSPSUM0	The absolute value of the instantaneous fundamental active power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE851	BABSPSUM1	The absolute value of the instantaneous fundamental active power on the overall system	R/W	32-bit, 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
		in Calculation Mode 1.			
0xE852	BABSQSUM0	The absolute value of the instantaneous fundamental reactive power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE853	BABSQSUM1	The absolute value of the instantaneous fundamental reactive power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE854	BAPPA	The instantaneous fundamental apparent power of Phase A.	R/W	32-bit, 2'-complement	<p>When the metering frequency is 6.5536MHz, the updating time of the registers is 80ms, and the settling time is 450ms.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the registers is 320ms, and the settling time is 1.8s.</p> <p>When the metering frequency is 819.2kHz, the updating time of content of the registers is 640ms, and the settling time is 3.6s.</p>
0xE855	BAPPB	The instantaneous fundamental apparent power of Phase B.	R/W	32-bit, 2'-complement	
0xE856	BAPPC	The instantaneous fundamental apparent power of Phase C.	R/W	32-bit, 2'-complement	
0xE864	BPSUM0	The algebra value of the instantaneous fundamental active power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE865	BPSUM1	The algebra value of the instantaneous fundamental active power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE866	BPTLA	The algebra value of the instantaneous fundamental active power of Phase A.	R/W	32-bit, 2'-complement	
0xE867	BPTLB	The algebra value of the instantaneous fundamental active power of Phase B.	R/W	32-bit, 2'-complement	
0xE868	BPTLC	The algebra value of the instantaneous	R/W	32-bit, 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
		fundamental active power of Phase C.			
0xE875	BQSUM0	The algebra value of the instantaneous fundamental reactive power on the overall system in Calculation Mode 0.	R/W	32-bit, 2'-complement	
0xE876	BQSUM1	The algebra value of the instantaneous fundamental reactive power on the overall system in Calculation Mode 1.	R/W	32-bit, 2'-complement	
0xE877	BQTLA	The algebra value of the instantaneous fundamental reactive power of Phase A.	R/W	32-bit, 2'-complement	
0xE878	BQTLB	The algebra value of the instantaneous fundamental reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE879	BQTLC	The algebra value of the instantaneous fundamental reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE88C	BSSUM	The instantaneous fundamental apparent power on the overall system.	R/W	32-bit, 2'-complement	
0xE8F6	MBAPPA	The average fundamental apparent power of Phase A.	R/W	32-bit, 2'-complement	<p>When the metering frequency is 6.5536MHz, the updating time of the registers is 640ms, and the settling time is 1s.</p> <p>When the metering frequency is 1.6384MHz, the updating time of the registers is 2.56s, and the settling time is 4s.</p> <p>When the metering frequency is 819.2kHz, the updating time of content of the registers</p>
0xE8F7	MBAPPB	The average fundamental apparent power of Phase B.	R/W	32-bit, 2'-complement	
0xE8F8	MBAPPC	The average fundamental apparent power of Phase C.	R/W	32-bit, 2'-complement	
0xE900	MBPA	The average fundamental active power of Phase A.	R/W	32-bit, 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xE901	MBPB	The average fundamental active power of Phase B.	R/W	32-bit, 2'-complement	is 5.12s, and the settling time is 8s.
0xE902	MBPC	The average fundamental active power of Phase C.	R/W	32-bit, 2'-complement	
0xE903	MBPSUM0	The average fundamental active power on the overall system 0.	R/W	32-bit, 2'-complement	
0xE904	MBPSUM1	The average fundamental active power on the overall system 1.	R/W	32-bit, 2'-complement	
0xE905	MBQA	The average fundamental reactive power of Phase A.	R/W	32-bit, 2'-complement	
0xE906	MBQB	The average fundamental reactive power of Phase B.	R/W	32-bit, 2'-complement	
0xE907	MBQC	The average fundamental reactive power of Phase C.	R/W	32-bit, 2'-complement	
0xE908	MBQSUM0	The average fundamental reactive power on the overall system 0.	R/W	32-bit, 2'-complement	
0xE909	MBQSUM1	The average fundamental reactive power on the overall system 1.	R/W	32-bit, 2'-complement	
0xE90A	MBSSUM	The average fundamental apparent power on the overall system.	R/W	32-bit, 2'-complement	

8.2.6. Registers for Energy Accumulation and Pulse Generation in Normal Mode

Table 8-20 Registers for Total Active/Reactive/Apparent Energy Accumulation (R/W)

Address	Mnemonic	Description	R/W	Format
0xE8AC	EGYAPPAH	Higher 32 bits of the register for the total apparent energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8AD	EGYAPPAL	Lower 32 bits of the register for the total apparent energy of Phase A.	R/W	
0xE8AE	EGYAPPBH	Higher 32 bits of the register for the total apparent energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8AF	EGYAPPBL	Lower 32 bits of the register for the total apparent energy of Phase B.	R/W	
0xE8B0	EGYAPPCH	Higher 32 bits of the register for the total apparent energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8B1	EGYAPPCL	Lower 32 bits of the register for the total apparent energy of Phase C.	R/W	
0xE8B2	EGYAPPSH	Higher 32 bits of the register for the total apparent energy on the overall system.	R/W	64-bit, unsigned, positive
0xE8B3	EGYAPPSL	Lower 32 bits of the register for the total apparent energy on the overall system.	R/W	
0xE8D0	EGYPAH	Higher 32 bits of the register for the total active energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8D1	EGYPAL	Lower 32 bits of the register for the total active energy of Phase A.	R/W	
0xE8D2	EGYPBH	Higher 32 bits of the register for the total active energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8D3	EGYPBL	Lower 32 bits of the register for the total active energy of Phase B.	R/W	
0xE8D4	EGYPCH	Higher 32 bits of the register for the total active energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8D5	EGYPCL	Lower 32 bits of the register for the total active energy of Phase C.	R/W	
0xE8D6	EGYPS0H	Higher 32 bits of the register for the total active energy 0, accumulated by the total active power on the overall system in Calculation Mode 0.	R/W	64-bit, unsigned, positive
0xE8D7	EGYPS0L	Lower 32 bits of the register for the total active energy 0, accumulated by the total active power	R/W	

Address	Mnemonic	Description	R/W	Format
		on the overall system in Calculation Mode 0.		
0xE8D8	EGYPS1H	Higher 32 bits of the register for the total active energy 1, accumulated by the total active power on the overall system in Calculation Mode 1.	R/W	64-bit, unsigned, positive
0xE8D9	EGYPS1L	Lower 32 bits of the register for the total active energy 1, accumulated by the total active power on the overall system in Calculation Mode 1.	R/W	
0xE8DA	EGYQAH	Higher 32 bits of the register for the total reactive energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8DB	EGYQAL	Lower 32 bits of the register for the total reactive energy of Phase A.	R/W	
0xE8DC	EGYQBH	Higher 32 bits of the register for the total reactive energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8DD	EGYQBL	Lower 32 bits of the register for the total reactive energy of Phase B.	R/W	
0xE8DE	EGYQCH	Higher 32 bits of the register for the total reactive energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8DF	EGYQCL	Lower 32 bits of the register for the total reactive energy of Phase C.	R/W	
0xE8E0	EGYQS0H	Higher 32 bits of the register for the total reactive energy 0, accumulated by the total reactive power on the overall system in Calculation Mode 0.	R/W	64-bit, unsigned, positive
0xE8E1	EGYQS0L	Lower 32 bits of the register for the total reactive energy 0, accumulated by the total reactive power on the overall system in Calculation Mode 0.	R/W	
0xE8E2	EGYQS1H	Higher 32 bits of the register for the total reactive energy 1, accumulated by the total reactive power on the overall system in Calculation Mode 1.	R/W	64-bit, unsigned, positive
0xE8E3	EGYQS1L	Lower 32 bits of the register for the total reactive energy 1, accumulated by the total reactive power on the overall system in Calculation Mode 1.	R/W	
When the metering frequency is 6.5536MHz, the energy accumulation frequency in normal mode is 12.5Hz.				

Table 8-21 Pulse Counters of the Total Active/Reactive/Apparent Energy (R/W)

Address	Mnemonic	Description	R/W	Format
0xE88D	CFAPPA	Pulse counter of the total apparent energy of Phase A.	R/W	32-bit, unsigned, positive
0xE88E	CFAPPB	Pulse counter of the total apparent energy of Phase B.	R/W	32-bit, unsigned, positive
0xE88F	CFAPPC	Pulse counter of the total apparent energy of Phase C.	R/W	32-bit, unsigned, positive
0xE890	CFAPPS	Pulse counter of the total apparent energy on the overall system.	R/W	32-bit, unsigned, positive
0xE89F	CFPA	Pulse counter of the total active energy of Phase A.	R/W	32-bit, unsigned, positive
0xE8A0	CFPB	Pulse counter of the total active energy of Phase B.	R/W	32-bit, unsigned, positive
0xE8A1	CFPC	Pulse counter of the total active energy of Phase C.	R/W	32-bit, unsigned, positive
0xE8A2	CFPS0	Pulse counter of the total active energy 0 on the overall system.	R/W	32-bit, unsigned, positive
0xE8A3	CFPS1	Pulse counter of the total active energy 1 on the overall system.	R/W	32-bit, unsigned, positive
0xE8A4	CFQA	Pulse counter of the total reactive energy of Phase A.	R/W	32-bit, unsigned, positive
0xE8A5	CFQB	Pulse counter of the total reactive energy of Phase B.	R/W	32-bit, unsigned, positive
0xE8A6	CFQC	Pulse counter of the total reactive energy of Phase C.	R/W	32-bit, unsigned, positive
0xE8A7	CFQS0	Pulse counter of the total reactive energy 0 on the overall system.	R/W	32-bit, unsigned, positive
0xE8A8	CFQS1	Pulse counter of the total reactive energy 1 on the overall system.	R/W	32-bit, unsigned, positive

Table 8-22 Registers for Fundamental Active/Reactive/Apparent Energy Accumulation (R/W)

Address	Mnemonic	Description	R/W	Format
0xE8B4	EGYBAPPAH	Higher 32 bits of the register for the fundamental apparent energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8B5	EGYBAPPAL	Lower 32 bits of the register for the fundamental apparent energy of Phase A.	R/W	

Address	Mnemonic	Description	R/W	Format
0xE8B6	EGYBAPPBH	Higher 32 bits of the register for the fundamental apparent energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8B7	EGYBAPPBL	Lower 32 bits of the register for the fundamental apparent energy of Phase B.	R/W	
0xE8B8	EGYBAPPCH	Higher 32 bits of the register for the fundamental apparent energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8B9	EGYBAPPCL	Lower 32 bits of the register for the fundamental apparent energy of Phase C.	R/W	
0xE8BA	EGYBAPPSH	Higher 32 bits of the register for the fundamental apparent energy on the overall system.	R/W	64-bit, unsigned, positive
0xE8BB	EGYBAPPSL	Lower 32 bits of the register for the fundamental apparent energy on the overall system.	R/W	
0xE8BC	EGYBPAH	Higher 32 bits of the register for the fundamental active energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8BD	EGYBPAL	Lower 32 bits of the register for the fundamental active energy of Phase A.	R/W	
0xE8BE	EGYBPBH	Higher 32 bits of the register for the fundamental active energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8BF	EGYBPBL	Lower 32 bits of the register for the fundamental active energy of Phase B.	R/W	
0xE8C0	EGYBPCH	Higher 32 bits of the register for the fundamental active energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8C1	EGYBPCL	Lower 32 bits of the register for the fundamental active energy of Phase C.	R/W	
0xE8C2	EGYBPS0H	Higher 32 bits of the register for the fundamental active energy 0, accumulated by the fundamental active power on the overall system in Calculation Mode 0.	R/W	64-bit, unsigned, positive
0xE8C3	EGYBPS0L	Lower 32 bits of the register for the fundamental active energy 0, accumulated by the fundamental active power on the overall system in Calculation Mode 0.	R/W	
0xE8C4	EGYBPS1H	Higher 32 bits of the register for the fundamental active energy 1, accumulated by the fundamental active power on the overall system in Calculation Mode 1.	R/W	64-bit, unsigned, positive
0xE8C5	EGYBPS1L	Lower 32 bits of the register for the fundamental active energy 1, accumulated by the fundamental active power on the overall system in Calculation Mode 1.	R/W	

Address	Mnemonic	Description	R/W	Format
0xE8C6	EGYBQAH	Higher 32 bits of the register for the fundamental reactive energy of Phase A.	R/W	64-bit, unsigned, positive
0xE8C7	EGYBQAL	Lower 32 bits of the register for the fundamental reactive energy of Phase A.	R/W	
0xE8C8	EGYQB BH	Higher 32 bits of the register for the fundamental reactive energy of Phase B.	R/W	64-bit, unsigned, positive
0xE8C9	EGYQB L	Lower 32 bits of the register for the fundamental reactive energy of Phase B.	R/W	
0xE8CA	EGYBQCH	Higher 32 bits of the register for the fundamental reactive energy of Phase C.	R/W	64-bit, unsigned, positive
0xE8CB	EGYBQCL	Lower 32 bits of the register for the fundamental reactive energy of Phase C.	R/W	
0xE8CC	EGYBQS0H	Higher 32 bits of the register for the fundamental reactive energy 0, accumulated by the fundamental reactive power on the overall system in Calculation Mode 0.	R/W	64-bit, unsigned, positive
0xE8CD	EGYBQS0L	Lower 32 bits of the register for the fundamental reactive energy 0, accumulated by the fundamental reactive power on the overall system in Calculation Mode 0.	R/W	
0xE8CE	EGYBQS1H	Higher 32 bits of the register for the fundamental reactive energy 1, accumulated by the fundamental reactive power on the overall system in Calculation Mode 1.	R/W	64-bit, unsigned, positive
0xE8CF	EGYBQS1L	Lower 32 bits of the register for the fundamental reactive energy 1, accumulated by the fundamental reactive power on the overall system in Calculation Mode 1.	R/W	

When the metering frequency is 6.5536MHz, the energy accumulation frequency in normal mode is 12.5Hz.

Table 8-23 Pulse Counters of the Fundamental Active/Reactive/Apparent Energy (R/W)

Address	Mnemonic	Description	R/W	Format
0xE891	CFBAPPA	Pulse counter of the fundamental apparent energy of Phase A.	R/W	32-bit, unsigned, positive
0xE892	CFBAPPB	Pulse counter of the fundamental apparent energy of Phase B.	R/W	32-bit, unsigned, positive
0xE893	CFBAPPC	Pulse counter of the fundamental apparent energy of Phase C.	R/W	32-bit, unsigned, positive

Address	Mnemonic	Description	R/W	Format
0xE894	CFBAPPS	Pulse counter of the fundamental apparent energy on the overall system.	R/W	32-bit, unsigned, positive
0xE895	CFBPA	Pulse counter of the fundamental active energy of Phase A.	R/W	32-bit, unsigned, positive
0xE896	CFBPB	Pulse counter of the fundamental active energy of Phase B.	R/W	32-bit, unsigned, positive
0xE897	CFBPC	Pulse counter of the fundamental active energy of Phase C.	R/W	32-bit, unsigned, positive
0xE898	CFBPS0	Pulse counter of the fundamental active energy 0 on the overall system.	R/W	32-bit, unsigned, positive
0xE899	CFBPS1	Pulse counter of the fundamental active energy 1 on the overall system.	R/W	32-bit, unsigned, positive
0xE89A	CFBQA	Pulse counter of the fundamental reactive energy of Phase A.	R/W	32-bit, unsigned, positive
0xE89B	CFBQB	Pulse counter of the fundamental reactive energy of Phase B.	R/W	32-bit, unsigned, positive
0xE89C	CFBQC	Pulse counter of the fundamental reactive energy of Phase C.	R/W	32-bit, unsigned, positive
0xE89D	CFBQS0	Pulse counter of the fundamental reactive energy 0 on the overall system.	R/W	32-bit, unsigned, positive
0xE89E	CFBQS1	Pulse counter of the fundamental reactive energy 1 on the overall system.	R/W	32-bit, unsigned, positive

8.2.7. Registers for Energy Accumulation and Pulse Generation in High-Speed Mode

Table 8-24 Registers for Power for Energy Accumulation in High-Speed Mode (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xEC33	ZZPCF0	The total/fundamental active power on the overall system for energy accumulation in high-speed mode.	R/W	32-bit 2'-complement	Positive, constantly. When the metering frequency is 6.5536MHz, the updating time of these registers is 80ms, and the settling time is 400ms.
0xEC38	ZZPCF1	The total/fundamental reactive power on the overall system for energy accumulation in high-speed mode.	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xEC3D	ZZPCF2	The total/fundamental active power on the overall system for energy accumulation in high-speed mode.	R/W	32-bit 2'-complement	When the metering frequency is 1.6384MHz, the updating time of these registers is 320ms, and the settling time is 1.6s. When the metering frequency is 819.2kHz, the updating time of these registers is 640ms, and the settling time is 3.2s.
0xEC42	ZZPCF3	The total/fundamental apparent power or the total reactive power on the overall system for energy accumulation in high-speed mode.	R/W	32-bit 2'-complement	

Table 8-25 Energy Accumulation Registers in High-Speed Mode (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xD000	EGY0L	Lower 32 bits of the register for the total/fundamental active energy on the overall system in high-speed mode (CF0).	R/W	64-bit, unsigned, positive	When the metering frequency is 6.5536MHz, the energy accumulation frequency in high-speed mode is 204.8kHz.
0xD001	EGY0H	Higher 32 bits of the register for the total/fundamental active energy on the overall system in high-speed mode (CF0).	R/W		
0xD002	EGY1L	Lower 32 bits of the register for the total/fundamental reactive energy on the overall system in high-speed mode (CF1).	R/W	64-bit, unsigned, positive	
0xD003	EGY1H	Higher 32 bits of the register for the total/fundamental reactive energy on the overall system in high-speed mode (CF1).	R/W		
0xD004	EGY2L	Lower 32 bits of the register for the total/fundamental active energy on the overall system in high-speed mode (CF2).	R/W	64-bit, unsigned, positive	
0xD005	EGY2H	Higher 32 bits of the register for the total/fundamental active energy on the overall system in high-speed mode (CF2).	R/W		
0xD006	EGY3L	Lower 32 bits of the register for the total/fundamental apparent energy or the total reactive energy on the overall system in high-speed mode (CF3).	R/W	64-bit, unsigned, positive	

Address	Mnemonic	Description	R/W	Format	Remark
0xD007	EGY3H	Higher 32 bits of the register for the total/fundamental apparent energy or the total reactive energy on the overall system in high-speed mode (CF3).	R/W		

Table 8-26 Pulse Counter in High-Speed Mode (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xD008	CF0	Pulse counter of the total/fundamental active energy on the overall system in high-speed mode (CF0).	R/W	64-bit, unsigned, positive	When the CF pulse output is enabled, one CF pulse is output when the pulses counter increments by 2.
0xD009	CF1	Pulse counter of the total/fundamental reactive energy on the overall system in high-speed mode (CF1).	R/W	64-bit, unsigned, positive	
0XD00A	CF2	Pulse counter of the total/fundamental active energy on the overall system in high-speed mode (CF2).	R/W	64-bit, unsigned, positive	
0XD00B	CF3	Pulse counter of the total/fundamental apparent energy or thte total reactive energy on the overall system in high-speed mode (CF3).	R/W	64-bit, unsigned, positive	

8.3. Registers for Calibration

8.3.1. Registers for Presetting Bias for Direct Current/Voltage

Table 8-27 Registers for Presetting Bias for Direct Current/Voltage

Address	Mnemonic	Description	R/W	Format	Remark
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Address	Mnemonic	Description	R/W	Format	Remark
0xEC16	ZZDCIA	To preset the bias for the current of Phase A.	R/W	24-bit 2'-complement	<p>These registers, with bit23 being the sign bit, are accessed as 32-bit registers with sign extended to 32 bits.</p> <p>These registers are used to calculate the checksum for system check as 32-bit registers with sign extended to 32 bits.</p>
0xEC17	ZZDCIB	To preset the bias for the current of Phase B.	R/W	24-bit 2'-complement	
0xEC18	ZZDCIC	To preset the bias for the current of Phase C.	R/W	24-bit 2'-complement	
0xEC19	ZZDCIN	To preset the bias for the current of Channel IN.	R/W	24-bit 2'-complement	
0xEC1A	ZZDCUA	To preset the bias for the voltage of Phase A.	R/W	24-bit 2'-complement	
0xEC1B	ZZDCUB	To preset the bias for the voltage of Phase B.	R/W	24-bit 2'-complement	
0xEC1C	ZZDCUC	To preset the bias for the voltage of Phase C.	R/W	24-bit 2'-complement	

8.3.2. Registers for Phase Compensation

Table 8-28 Phase Compensation Registers in Sections (R/W)

Address	Mnemonic	Description	R/W	Format	bit31	...	Bit24	Bit23	...	Bit16	Bit15	...	Bit8	Bit7	...	Bit0
0xE954	WAEC0	Section 0	R/W	32-bit 2'-complement	Reserved			To set the phase compensation for Phase C.			To set the phase compensation for Phase B.			To set the phase compensation for Phase A.		
0xE955	WAEC1	Section 1	R/W	32-bit 2'-complement	Reserved			To set the phase compensation for Phase C.			To set the phase compensation for Phase B.			To set the phase compensation for Phase A.		
0xE956	WAEC2	Section 2	R/W	32-bit 2'-complement	Reserved			To set the phase compensation for Phase C.			To set the phase compensation for Phase B.			To set the phase compensation for Phase A.		

Address	Mnemonic	Description	R/W	Format	bit31	...	Bit24	Bit23	...	Bit16	Bit15	...	Bit8	Bit7	...	Bit0
0xE957	WAE3	Section 3	R/W	32-bit 2'-complement	Reserved			To set the phase compensation for Phase C.			To set the phase compensation for Phase B.			To set the phase compensation for Phase A.		
0xE958	WAE4	Section 4	R/W	32-bit 2'-complement	Reserved			To set the phase compensation for Phase C.			To set the phase compensation for Phase B.			To set the phase compensation for Phase A.		

Note: bit23/bit15/bi7 is the sign bit of the phase compensation. 1, negative; 0, positive. The phase compensation resolution is 0.022 %lsb, and the compensation is over the range -2.8°~+2.8°. When the function of phase compensation in sections is disabled, only the registers of Section 0 are used, and it is recommended to write the content of the Section 0 registers to the other registers.

All the registers are used to calculate the checksum for system check.

Table 8-29 Current Threshold for Phase Compensation in Sections (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE97C	WTPA0A	To set Current Threshold 0 for Phase A	R/W	32-bit 2'-complement	<p>Compare the instantaneous fundamental current RMS after calibration (IRMS) to the set current thresholds for each phase, and then decide to use the register for phase compensation in sections for calibrating phase angle error.</p> <p>Take Phase A for example,</p> <p>When $IRMS < WTPA0A$, WAE0 register is used;</p> <p>When $WTPA0A < IRMS < WTPA1A$, WAE1 register is used;</p> <p>When $WTPA1A < IRMS < WTPA2A$, WAE2 register is used;</p> <p>When $WTPA2A < IRMS < WTPA3A$, WAE3 register is used;</p>
0xE97D	WTPA0B	To set Current Threshold 0 for Phase B	R/W	32-bit 2'-complement	
0xE97E	WTPA0C	To set Current Threshold 0 for Phase C	R/W	32-bit 2'-complement	
0xE97F	WTPA1A	To set Current Threshold 1 for Phase A	R/W	32-bit 2'-complement	
0xE980	WTPA1B	To set Current Threshold 1 for Phase B	R/W	32-bit 2'-complement	
0xE981	WTPA1C	To set Current Threshold 1 for Phase C	R/W	32-bit 2'-complement	
0xE982	WTPA2A	To set Current Threshold 2 for Phase A	R/W	32-bit 2'-complement	
0xE983	WTPA2B	To set Current Threshold 2 for Phase B	R/W	32-bit 2'-complement	
0xE984	WTPA2C	To set Current Threshold 2 for Phase C	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xE985	WTPA3A	To set Current Threshold 3 for Phase A	R/W	32-bit 2'-complement	When IRMS>WTPA3A, WAEC4 register is used. All the registers are used to calculate the checksum for system check.
0xE986	WTPA3B	To set Current Threshold 3 for Phase B	R/W	32-bit 2'-complement	
0xE987	WTPA3C	To set Current Threshold 3 for Phase C	R/W	32-bit 2'-complement	

8.3.3. Registers for RMS Calibration

Table 8-30 Registers for Calibrating Total Voltage/Current RMS (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE968	WARTIA	To set gain calibration of the total current RMS of Phase A.	R/W	32-bit 2'-complement	The read of the registers in decimal form is obtained via dividing the read in hexadecimal form by 2 ³¹ .
0xE969	WARTIB	To set gain calibration of the total current RMS of Phase B.	R/W	32-bit 2'-complement	
0xE96A	WARTIC	To set gain calibration of the total current RMS of Phase C.	R/W	32-bit 2'-complement	
0xE96B	WARTIN	To set gain calibration of the total current RMS of Channel IN.	R/W	32-bit 2'-complement	The value of RMS before and after calibration have a relationship as follows: $\text{RMS} = \text{RMS}' \times (1 + S) + C$ Where, RMS is the value of RMS after calibration; RMS' is the value of RMS before calibration; S is the gain calibration of the RMS;
0xE96C	WARTUA	To set gain calibration of the total voltage RMS of Phase A.	R/W	32-bit 2'-complement	
0xE96D	WARTUB	To set gain calibration of the total voltage RMS of Phase B.	R/W	32-bit 2'-complement	
0xE96E	WARTUC	To set gain calibration of the total voltage RMS of Phase C.	R/W	32-bit 2'-complement	
0xE994	WWARTIA	To set offset calibration of the total current RMS of Phase A.	R/W	32-bit 2'-complement	
0xE995	WWARTIB	To set offset calibration of the total current RMS of Phase B.	R/W	32-bit 2'-complement	
0xE996	WWARTIC	To set offset calibration of the total current RMS of Phase C.	R/W	32-bit 2'-complement	
0xE997	WWARTIN	To set offset calibration of the total current RMS of Channel	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
		IN.			C is the offset calibration of the RMS.
0xE998	WWARTUA	To set offset calibration of the total voltage RMS of Phase A.	R/W	32-bit 2'-complement	
0xE999	WWARTUB	To set offset calibration of the total voltage RMS of Phase B.	R/W	32-bit 2'-complement	
0xE99A	WWARTUC	To set offset calibration of the total voltage RMS of Phase C.	R/W	32-bit 2'-complement	All the registers are used to calculate the checksum for system check.

Table 8-31 Registers for Calibrating Fundamental Voltage/Current RMS (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE976	WBRTIA	To set gain calibration of the fundamental current RMS of Phase A.	R/W	32-bit 2'-complement	The read of the registers in decimal form is obtained via dividing the read in hexadecimal form by 2^{31} .
0xE977	WBRTIB	To set gain calibration of the fundamental current RMS of Phase B.	R/W	32-bit 2'-complement	
0xE978	WBRTIC	To set gain calibration of the fundamental current RMS of Phase C.	R/W	32-bit 2'-complement	
0xE979	WBRTUA	To set gain calibration of the fundamental voltage RMS of Phase A.	R/W	32-bit 2'-complement	The value of RMS before and after calibration have a relationship as follows: $RMS = RMS' \times (1 + S) + C$
0xE97A	WBRTUB	To set gain calibration of the fundamental voltage RMS of Phase B.	R/W	32-bit 2'-complement	
0xE97B	WBRTUC	To set gain calibration of the fundamental voltage RMS of Phase C.	R/W	32-bit 2'-complement	
0xE9A2	WWBRTIA	To set offset calibration of the fundamental current RMS of Phase A.	R/W	32-bit 2'-complement	Where, RMS is the value of RMS after calibration; RMS' is the value of RMS before calibration; S is the gain calibration of the RMS; C is the offset calibration of the
0xE9A3	WWBRTIB	To set offset calibration of the fundamental current RMS of Phase B.	R/W	32-bit 2'-complement	
0xE9A4	WWBRTIC	To set offset calibration of the fundamental current RMS of Phase C.	R/W	32-bit 2'-complement	
0xE9A5	WWBRTUA	To set offset calibration of the fundamental voltage RMS of Phase A.	R/W	32-bit 2'-complement	
0xE9A6	WWBRTUB	To set offset calibration of the fundamental voltage RMS of Phase B.	R/W	32-bit 2'-complement	
0xE9A7	WWBRTUC	To set offset calibration of the fundamental voltage RMS of Phase C.	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
					RMS. All the registers are used to calculate the checksum for system check.

8.3.4. Registers for Power Calibration

Table 8-32 Registers for Calibrating Total Active/Reactive Power (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE959	WAPTA	To set gain calibration of the total active power of Phase A.	R/W	32-bit 2'-complement	<p>The read of the registers in decimal form is obtained via dividing the read in hexadecimal form by 2^{31}.</p> <p>The value of power before and after calibration have a relationship as follows: $P = P' \times (1 + S) + C$ </p> <p>Where, P is the active or reactive power after calibration; P' is the active or reactive power before calibration; S is the gain calibration of the power; C is the offset calibration of the power.</p> <p>When the power calibration in sections is enabled, the content of the register gain calibration Section</p>
0xE95A	WAPTAK0	To set gain calibration Section 0 of the total active power of Phase A.	R/W	32-bit 2'-complement	
0xE95B	WAPTAK1	To set gain calibration Section 1 of the total active power of Phase A.	R/W	32-bit 2'-complement	
0xE95C	WAPTAK2	To set gain calibration Section 2 of the total active power of Phase A.	R/W	32-bit 2'-complement	
0xE95D	WAPTB	To set gain calibration of the total active power of Phase B.	R/W	32-bit 2'-complement	
0xE95E	WAPTBK0	To set gain calibration Section 0 of the total active power of Phase B.	R/W	32-bit 2'-complement	
0xE95F	WAPTBK1	To set gain calibration Section 1 of the total active power of Phase B.	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
0xE960	WAPTBK2	To set gain calibration Section 2 of the total active power of Phase B.	R/W	32-bit 2'-complement	<p>X of the power of each phase being used will be written in the register of power gain calibration. For example, if WAPTAK1 register is being used, its content will be written in the WAPTA register for power calibration of Phase A.</p> <p>When the function of power calibration in sections is disabled, only the registers of Section 0 are used, and it is recommended to write the content of the Section 0 register in the other registers.</p> <p>All the registers are used to calculate the checksum for system check.</p>
0xE961	WAPTC	To set gain calibration of the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE962	WAPTCK0	To set gain calibration Section 0 of the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE963	WAPTCK1	To set gain calibration Section 1 of the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE964	WAPTCK2	To set gain calibration Section 2 of the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE965	WAQTA	To set gain calibration of the total reactive power of Phase A.	R/W	32-bit 2'-complement	
0xE966	WAQTB	To set gain calibration of the total reactive power of Phase B.	R/W	32-bit 2'-complement	
0xE967	WAQTC	To set gain calibration of the total reactive power of Phase C.	R/W	32-bit 2'-complement	
0xE98E	WWAPTA	To set offset calibration of the total active power of Phase A.	R/W	32-bit 2'-complement	
0xE98F	WWAPTB	To set offset calibration of the total active power of Phase B.	R/W	32-bit 2'-complement	
0xE990	WWAPTC	To set offset calibration of the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE991	WWAQTA	To set offset calibration of the total reactive	R/W	32-bit 2'-complement	

Address	Mnemonic	Description	R/W	Format	Remark
		power of Phase A.			
0xE992	WWAQTb	To set offset calibration of the total reactive power of Phase B.	R/W	32-bit 2'-complement	
0xE993	WWAQTc	To set offset calibration of the total reactive power of Phase C.	R/W	32-bit 2'-complement	

Table 8-33 Current Threshold for Calibrating Total Active Power in Sections (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE988	WTPP0A	To set Current Threshold 0 for calibrating the total active power of Phase A.	R/W	32-bit 2'-complement	Compare the instantaneous current RMS after calibration (IRMS) to the set current thresholds for each phase, and then decide to use the register for power calibration in sections to calibrate the total active power of each phase. Take Phase A for example, When $IRMS < WTPP0A$, WAPTAK0 register is used; When $WTPP0A < IRMS < WTPP1A$, WAPTAK1 register is used; When $WTPP1A < IRMS$, WAPTAK2 register is used; All the registers are used to calculate the checksum for system check.
0xE989	WTPP0B	To set Current Threshold 0 for calibrating the total active power of Phase B.	R/W	32-bit 2'-complement	
0xE98A	WTPP0C	To set Current Threshold 0 for calibrating the total active power of Phase C.	R/W	32-bit 2'-complement	
0xE98B	WTPP1A	To set Current Threshold 1 for calibrating the total active power of Phase A.	R/W	32-bit 2'-complement	
0xE98C	WTPP1B	To set Current Threshold 1 for calibrating the total active power of Phase B.	R/W	32-bit 2'-complement	
0xE98D	WTPP1C	To set Current Threshold 1 for calibrating the total active power of Phase C.	R/W	32-bit 2'-complement	

Table 8-34 Registers for Calibrating Fundamental Active/Reactive Power (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE970	WBPTA	To set gain calibration of the fundamental	R/W	32-bit	The read of the registers in decimal form is

Address	Mnemonic	Description	R/W	Format	Remark
		active power of Phase A.		2'-complement	<p>obtained via dividing the read in hexadecimal form by 2^{31}.</p> <p>The value of power before and after calibration have a relationship as follows:</p> $P = P' \times (1 + S) + C$ <p>Where,</p> <p>P is the active or reactive power after calibration;</p> <p>P' is the active or reactive power before calibration;</p> <p>S is the gain calibration of the power;</p> <p>C is the offset calibration of the power.</p> <p>All the registers are used to calculate the checksum for system check.</p>
0xE971	WBPTB	To set gain calibration of the fundamental active power of Phase B.	R/W	32-bit 2'-complement	
0xE972	WBPTC	To set gain calibration of the fundamental active power of Phase C.	R/W	32-bit 2'-complement	
0xE973	WBQTA	To set gain calibration of the fundamental reactive power of Phase A.	R/W	32-bit 2'-complement	
0xE974	WBQTB	To set gain calibration of the fundamental reactive power of Phase B.	R/W	32-bit 2'-complement	
0xE975	WBQTC	To set gain calibration of the fundamental reactive power of Phase C.	R/W	32-bit 2'-complement	
0xE99C	WWBPTA	To set offset calibration of the fundamental active power of Phase A.	R/W	32-bit 2'-complement	
0xE99D	WWBPTB	To set offset calibration of the fundamental active power of Phase B.	R/W	32-bit 2'-complement	
0xE99E	WWBPTC	To set offset calibration of the fundamental active power of Phase C.	R/W	32-bit 2'-complement	
0xE99F	WWBQTA	To set offset calibration of the fundamental reactive power of Phase A.	R/W	32-bit 2'-complement	
0xE9A0	WWBQTB	To set offset calibration of the fundamental reactive power of Phase B.	R/W	32-bit 2'-complement	
0xE9A1	WWBQTC	To set offset calibration of the fundamental reactive power of Phase C.	R/W	32-bit 2'-complement	

8.3.5. Threshold Registers

Table 8-35 Energy Threshold Registers (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xEC1E	ZZEGYTHH	To set the higher 32 bits of the energy threshold.	R/W	32-bit 2'-complement	The threshold for the energy accumulation and pulse generation in high-speed mode is 16384 times of that in normal mode. These registers are accessed as 32-bit registers with 14 most significant bits padded with 0s. All the registers are used to calculate the checksum for system check.
0xEC1F	ZZEGYTHL	To set the lower 32 bits of the energy threshold.	R/W	32-bit 2'-complement	

Table 8-36 Registers of Threshold for No-load Detection (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xE8AA	CTHH	To set the top threshold for the no-load detection.	R/W	32-bit 2'-complement	This register is used to calculate the checksum for system check.
0xE8AB	CTHL	To set the bottom threshold for the no-load detection.	R/W	32-bit 2'-complement	

Table 8-37 Threshold for Current Detection (0xEC1D, ZZDCUM, R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xEC1D	ZZDCUM	To set the threshold for current detection.	R/W	24-bit 2'-complement	This register, with bit23 being the sign bit, is accessed as a 32-bit register with sign extended to 32bits. This register is used to calculate the checksum for system check with sign extended to 32 bits.

8.4. System State Registers

Table 8-38 State Register for Phase Compensation and Gain Calibration of the Total Active Power (0xC004, PECAEC)

0xC004, R, State Register for Phase Compensation and Gain Calibration of the Total Active Power, PECAEC				
Bit		Default Value	Function Description	
Bit[31:22]	Reserved	-		
Bit[21:20]	PECC	-	To indicate the section being used for gain calibrating the total active power of Phase C.	00, Section 0; 01, Section 1; 10, Section 2.
Bit[19:18]	Reserved	-		
Bit[17:16]	PECB	-	To indicate the section being used for gain calibrating the total active power of Phase B.	00, Section 0; 01, Section 1; 10, Section 2.
Bit[15:14]	Reserved	-		
Bit[13:12]	PECA	-	To indicate the section being used for gain calibrating the total active power of Phase A.	00, Section 0; 01, Section 1; 10, Section 2.
Bit11	Reserved	-		
Bit[10:8]	AECC	-	To indicate the section being used for phase compensation of Phase C.	000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.
Bit7	Reserved	-		
Bit[6:4]	AECB	-	To indicate the section being used for phase compensation of Phase C.	000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.
Bit3	Reserved	-		

0xC004, R, State Register for Phase Compensation and Gain Calibration of the Total Active Power, PECAEC				
Bit		Default Value	Function Description	
Bit[2:0]	AECA	-	To indicate the section being used for phase compensation of Phase C.	000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.
When the metering frequency is 6.5536MHz, the updating time of the register is 80ms, and the settling time 500ms.				

Table 8-39 State Register for No-Load Detection for Total Active Energy Metering of Phase A (0xEC09, ZZCPAPA)

0xEC09, R/W, State Register for No-Load Detection for the Total Active Power Metering of Phase A, ZZCPAPA					
Bit		Default Value	R/W	Function Description	
Bit[31:12]	Reserved	-		-	-
Bit11	CPBQC	0	R	To indicate the state of no-load detection for the fundamental reactive power metering of Phase C.	1, in creeping state; 0, in metering state.
Bit10	CPBQB	0	R	To indicate the state of no-load detection for the fundamental reactive power metering of Phase B.	1, in creeping state; 0, in metering state.
Bit9	CPBQA	0	R	To indicate the state of no-load detection for the fundamental reactive power metering of Phase A.	1, in creeping state; 0, in metering state.
Bit8	CPBPC	0	R	To indicate the state of no-load detection for the fundamental active power metering of Phase C.	1, in creeping state; 0, in metering state.
Bit7	CPBPB	0	R	To indicate the state of no-load detection for the fundamental active power metering of Phase B.	1, in creeping state; 0, in metering state.
Bit6	CPBPA	0	R	To indicate the state of no-load detection for the fundamental active power metering of Phase A.	1, in creeping state; 0, in metering state.

0xEC09, R/W, State Register for No-Load Detection for the Total Active Power Metering of Phase A, ZZCPAPA					
Bit		Default Value	R/W	Function Description	
Bit5	CPAQC	0	R	To indicate the state of no-load detection for the total reactive power metering of Phase C.	1, in creeping state; 0, in metering state.
Bit4	CPAQB	0	R	To indicate the state of no-load detection for the total reactive power metering of Phase B.	1, in creeping state; 0, in metering state.
Bit3	CPAQA	0	R	To indicate the state of no-load detection for the total reactive power metering of Phase A.	1, in creeping state; 0, in metering state.
Bit2	CPAPC	0	R	To indicate the state of no-load detection for the total active power metering of Phase C.	1, in creeping state; 0, in metering state.
Bit1	CPAPB	0	R	To indicate the state of no-load detection for the total active power metering of Phase B.	1, in creeping state; 0, in metering state.
Bit0	CPAPA	0	R/W	To indicate the state of no-load detection for the total active power metering of Phase A.	1, in creeping state; 0, in metering state.

Table 8-40 Other State Registers for No-Load Detection (R/W)

Address	Mnemonic	Description	R/W	Format	Remark
0xEC0A	ZZCPAPB	To indicate the state of no-load detection for the total active power metering of Phase B.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC0B	ZZCPAPC	To indicate the state of no-load detection for the total active power metering of Phase C.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC0C	ZZCPAQA	To indicate the state of no-load detection for the total reactive power metering of Phase A.	R/W	32-bit 2'-complement	Only bit0 is valid.

Address	Mnemonic	Description	R/W	Format	Remark
					1, in creeping state; 0, in metering state.
0xEC0D	ZZCPAQB	To indicate the state of no-load detection for the total reactive power metering of Phase B.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC0E	ZZCPAQC	To indicate the state of no-load detection for the total reactive power metering of Phase C.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC0F	ZZCPBPA	To indicate the state of no-load detection for the fundamental active power metering of Phase A.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC10	ZZCPBPB	To indicate the state of no-load detection for the fundamental active power metering of Phase B.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC11	ZZCPBPC	To indicate the state of no-load detection for the fundamental active power metering of Phase C.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC12	ZZCPBQA	To indicate the state of no-load detection for the fundamental reactive power metering of Phase A.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC13	ZZCPBQB	To indicate the state of no-load detection for the fundamental reactive power metering of Phase B.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.
0xEC14	ZZCPBQC	To indicate the state of no-load detection for the fundamental reactive power metering of Phase C.	R/W	32-bit 2'-complement	Only bit0 is valid. 1, in creeping state; 0, in metering state.

9. Energy Metering

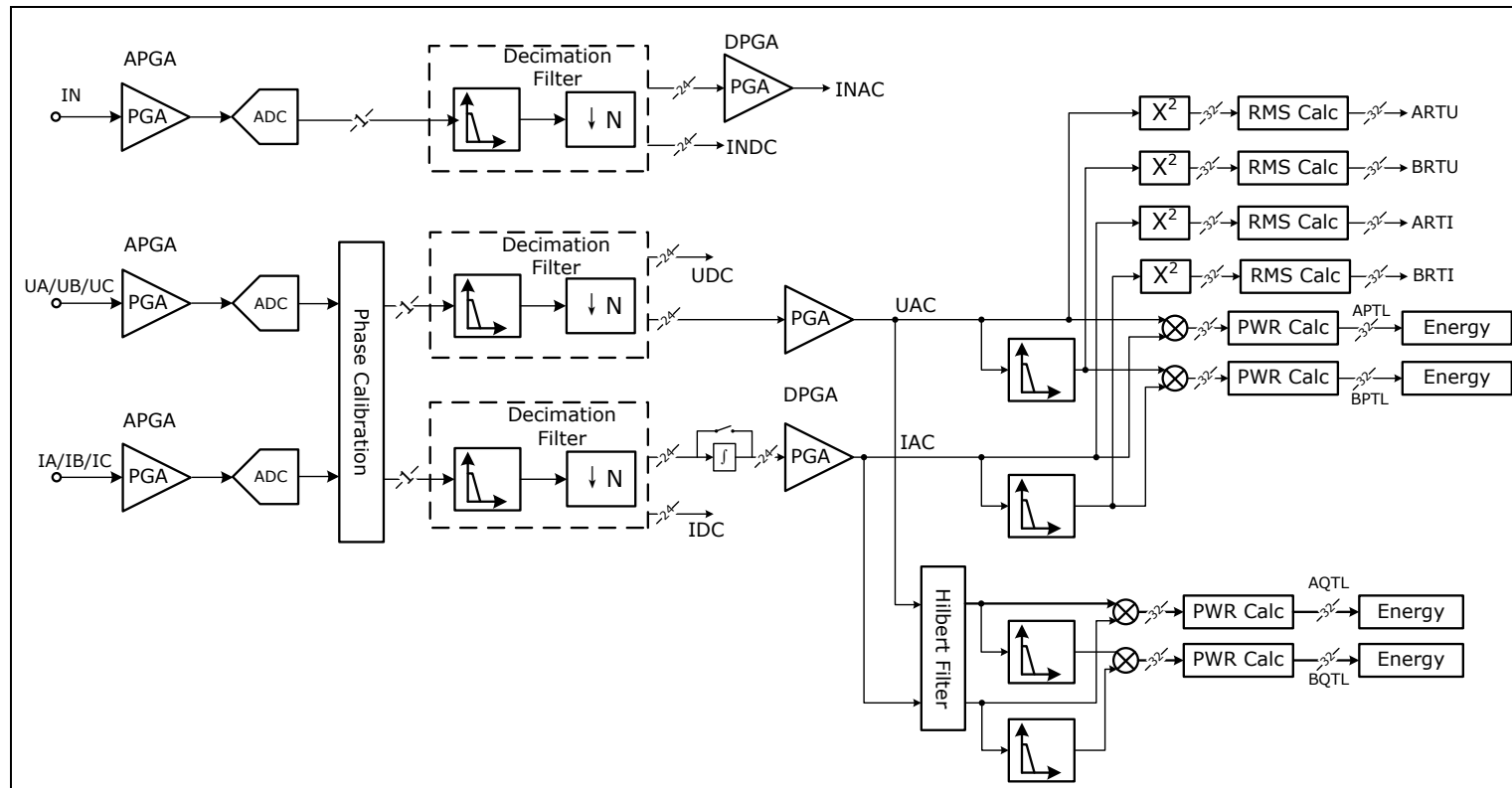


Figure 9-1 Digital Signal Processing in Energy Metering Block

In the OPM0, or normal operating mode, the metering frequency is 6553.6kHz, and the sampling frequency of the ADCs is 819.2kHz.

9.1. Data RAM

The following table describes the allocation of data RAM of the energy metering block of the V9203.

The registers of the V9203, which have respective length, are accessed by the master MCU as 32-bit registers.

Table 9-1 Description of Data RAM of Energy Metering Block

Address Range	Length	Content	Read	Write
0xC800~0xC837	32-bit	Reserved. When the energy metering block is initialized, the MTPARA0 (0xC000) is initialized to 0x10000000, and then write 0s in the RAM located at addresses of the range of 0xC800~0xC837 and 0xC880~0xC8B7 to clear the RAM.		
0xC880~0xC8B7	32-bit			
0xD000~0xD00B	32-bit	Energy accumulation registers and pulse counter in high-speed mode	The master MCU read of the register directly.	The master MCU write of the register directly.
0xE000~0xE08F	48-bit	Reserved. These addresses must not be accessed for proper operation.		
0xE800~0xE9A7	32-bit	Metering data registers and registers for calibration.	The master MCU read of the register directly.	The master MCU write of the register directly.
0xE9A8~0xEAB7	32-bit	Reserved. These addresses must not be accessed for proper operation.		
0xEC00~0xEC52	32-bit	Energy metering configuration registers, and system state registers.	The master MCU read of the register directly.	The master MCU write of the register directly.
0xF000~0xF02B	48-bit	Reserved. These addresses must not be accessed for proper operation.		
0xF02C~0xF033	48-bit	Registers for DC component.	Read a 48-bit data in 2 steps, for example, Step1, accessing the registers located at 0xF014 as a 32-bit register with 24 bits being the lower bytes of the 48-bit data, and the sign bit extended to 32 bits (bit23 being the sign bit). This data is signified as D0;	Write a 48-bit data in 2 steps, for example, Step1, accessing the registers located at 0xF014 as a 32-bit register with 24 bits being the lower bytes of the 48-bit data, and 8 most significant bits being random values. This data

Address Range	Length	Content	Read	Write
			<p>Step2, accessing the registers located at 0xF015 as a 32-bit register with 24 bits being the higher bytes of the 48-bit data, and the sign bit extended to 32 bits (bit23 being the sign bit). This data is signified as D1;</p> <p>Both D0 and D1 combine the 48-bit data.</p>	<p>is signified as D0;</p> <p>Step2, accessing the registers located at 0xF015 as a 32-bit register with 24 bits being the higher bytes of the 48-bit data, and 8 most significant bits being random values. This data is signified as D1;</p> <p>Both D0 and D1 combine the 48-bit data.</p>
0xF034~0xF1EF	48-bit	Reserved. These addresses must not be accessed for proper operation.		
0xF800~0xF87F	24-bit	Reserved. These addresses must not be accessed for proper operation.		

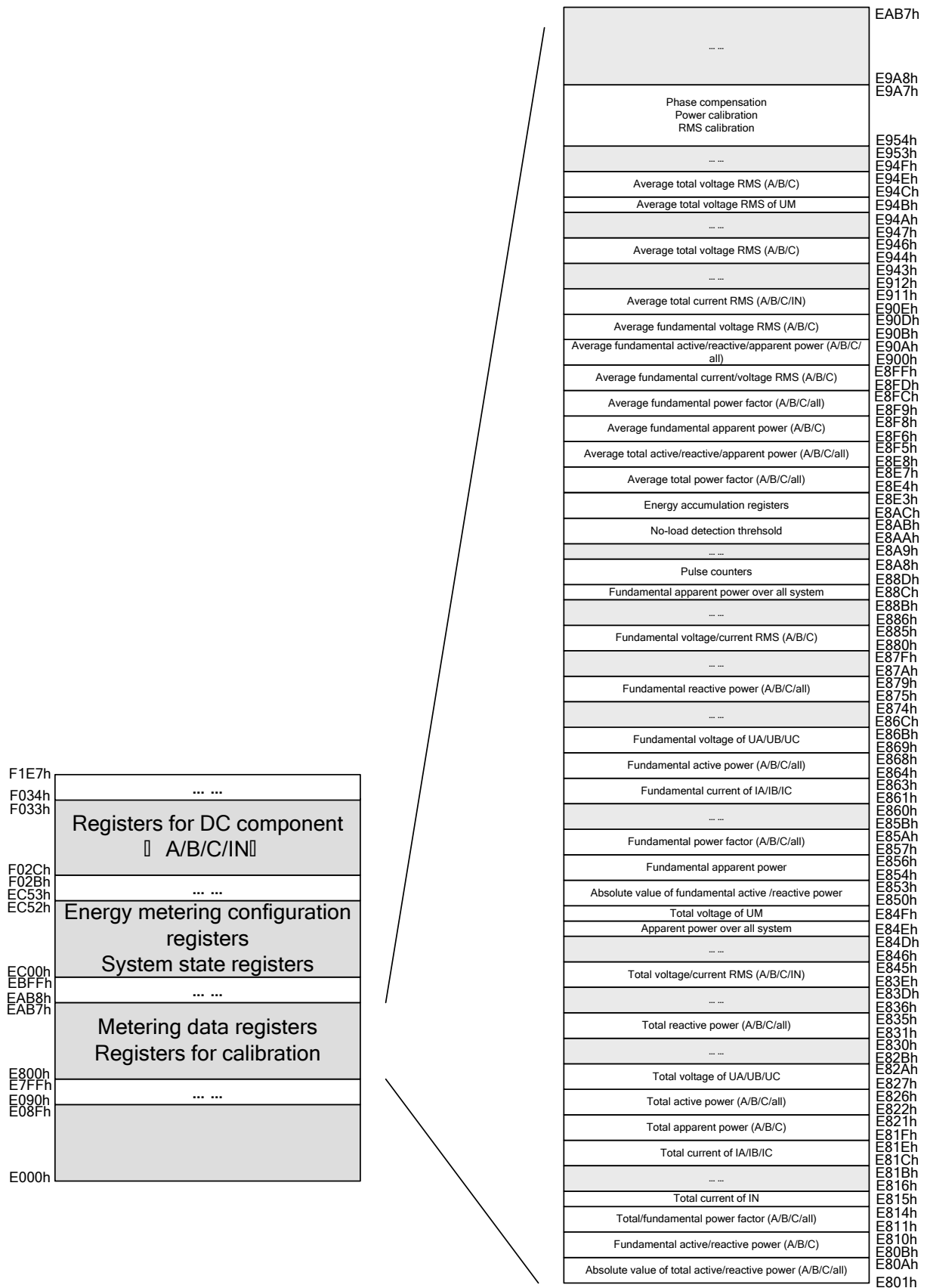


Figure 9-2 RAM Allocation

Table 9-2 Metering Parameters

	Raw waveform	DC	Total / Fundamental				Phase	Line frequency	Power factor
			Instantaneous and average RMS	Instantaneous/average algebra/absolute values of active power	Instantaneous/average algebra/absolute values of reactive power	Instantaneous and average apparent power			
Current of IA	√	√	√	√	√	√	√	√	√
Current of IB	√	√	√	√	√	√	√	√	√
Current of IC	√	√	√	√	√	√	√	√	√
Voltage of UA	√	√	√	√	√	√	X	√	√
Voltage of UB	√	√	√	√	√	√	√	√	√
Voltage of UC	√	√	√	√	√	√	√	√	√
Current of IN	√	√	X	X	X	X	X	X	X
On the overall system	X	X	X	√	√	√	X	X	√

9.2. Analog Input

The V9203 has 7 analog inputs forming current and voltage channels. The current channels consist of 4 fully differential voltage inputs: 2 inputs for each phase and 2 for neutral wire. And the voltage channels consist of 3 pseudo differential voltage inputs: UAP, UBP and UCP are positive inputs for voltage channels, and UN is negative input for all voltage channels. Each input has a maximum voltage of $\pm 200\text{mV}$, and each pair of a maximum differential voltage of $\pm 400\text{mV}$.

For current channels, a current transformer (CT) or Rogowski coil can be used for analog inputs.

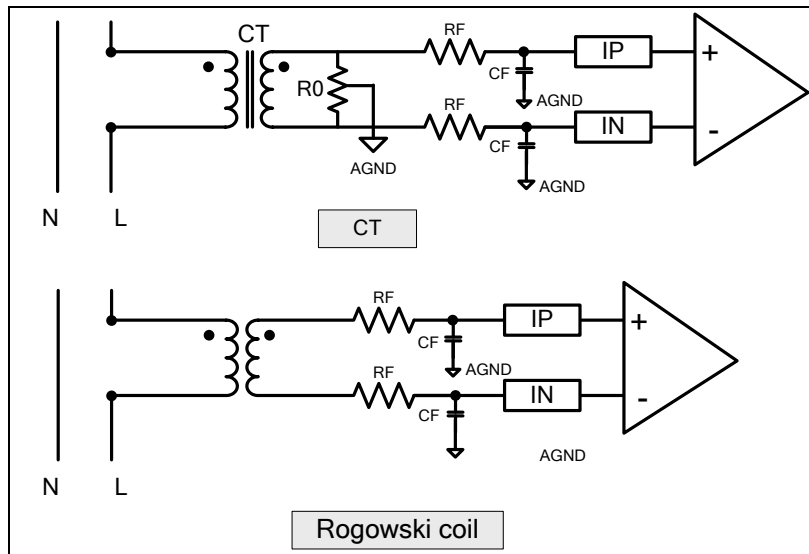


Figure 9-3 Analog Input of Current Channels

If a Rogowski coil is used for analog inputs, users must enable the digital integrator to shift the phase by 90 degrees, which introduces a gain A which is related to the line frequency, after the direct current / voltage is switched off. The integrator can be enabled via bit12 (DIDTEN) of MTPARA2 (0xC002).

When the line frequency is 50Hz, the gain A_0 for RMS calculation is 0.636043109985836, and the gain A_1 for active / reactive power calculation is 0.635598782982145.

Table 9-3 Enabling Digital Integrator

Register	Bit	Description
MTPARA2, 0xC002	Bit12, DIDTEN	0, disable; 1, enable.

For voltage channels, a potential transformer (PT) or a resistor-divider network can be used for analog inputs.

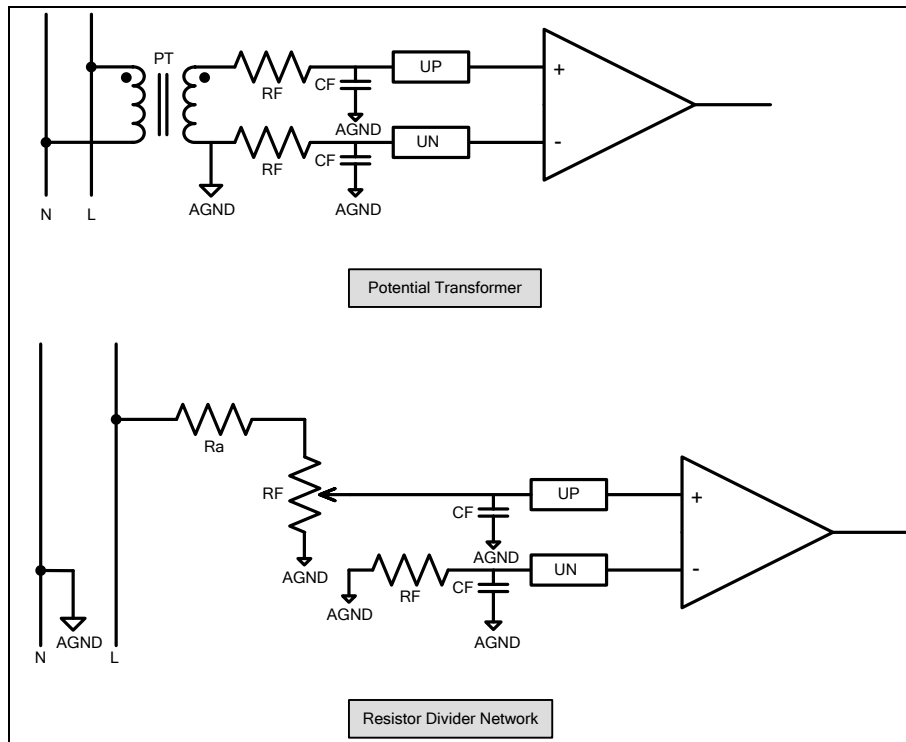


Figure 9-4 Analog Input of Voltage Channels

The full measurement scale of the ADCs is $\pm 1.1V$. To match the output signal of the transformers to the measurement scale of the ADCs, analog programmable gain amplifiers (APGA) with possible gain selection of 2, 4, 16, and 32 for current inputs, and of 1 and 2 for voltage inputs, are set. The product of the analog input and the set APGA should not be over $\pm 1.1V$.

$$\begin{aligned} U_a' &= PGA_{ua} \times A_{ua} \times \sin \omega t \\ I_a' &= PGA_{ia} \times A_{ia} \times \sin(\omega t + \psi) \end{aligned} \quad \text{Equation 9-1}$$

Where, PGA_{ua} and PGA_{ia} are the APGA for the current and voltage channel of Phase A; A_{ua} and A_{ia} are the amplitude of current and voltage inputs.

In OPM1, or power-off/no-voltage pre-detection mode, the APGA for current input is recommended to be 32.

Table 9-4 APGA Configuration

Register	Bit		Description
ANCtrl0, 0x8000	Bit18	GUC	To set analog PGA gain of UC input. 0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
	Bit17	GUB	To set analog PGA gain of UB input. 0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
	Bit16	GUA	To set analog PGA gain of UA input. 0, $\times 1$; 1, $\times 2$. $\times 2$ is recommended.
	Bit[14:12]	GIN<2:0>	To set analog PGA gain of IN input.

Register	Bit		Description
			000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used.
	Bit[10:8]	GIC<2:0>	To set analog PGA gain of IC input. 000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used.
	Bit[6:4]	GIB<2:0>	To set analog PGA gain of IB input. 000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used.
	Bit[2:0]	GIA<2:0>	To set analog PGA gain of IA input. 000, ×2; 001, ×4; 010, ×16; 011/100/101/110/111, ×32 To ensure the output from the sensor matches the full scale of ADC, the default value should not be used.

9.3. Analog-to-Digital Conversion

Second-order Σ - Δ ADCs are used in the 7 channels of the V9203, and its full measurement scale is $\pm 1.1V$. Σ - Δ ADCs can be enabled or disabled via configuring ANCtrl2 register (0x8002).

Table 9-5 Enable/Disable ADCs of Each Channel

Register	Bit		Description
ANCtrl2, 0x8002	Bit30	ADPDUCN	To enable the ADC of Channel UC.
	Bit29	ADPDUBN	To enable the ADC of Channel UB.
	Bit28	ADPDUAN	To enable the ADC of Channel UA.
	Bit27	ADPDINN	To enable the ADC of Channel IN.
	Bit26	ADPDICN	To enable the ADC of Channel IC.
	Bit25	ADPDIBN	To enable the ADC of Channel IB.
	Bit24	ADPDIAN	To enable the ADC of Channel IA.
0, disable; 1, enable. In immediately 976 μ s after reset, these bits will be set to 0b11111111 automatically, to enable all ADCs of the channels.			

The sampling frequency of ADCs, or ADC clock (ADCCLK), is derived from the 13.1072MHz crystal oscillator when the clock scaler is enabled. By default, it is 819.2kHz, one eighth of the metering clock (MTCLK), and can be configured via bit[19:18] of ANCtrl3 (0x8003).

Table 9-6 Configuring ADCCLK

Register	Bit	Description
ANCtrl3, 0x8003	Bit[19:18] ADCLKSEL<1:0>	To select the sampling frequency for the oversampling ADC (ADC frequency). Base: 204.8kHz. 00, ×4; 01, ×8; 10, ×1; 11, ×2

When logic high is input to both the pins PM0 and PM1, in which the V9203 works in OPM0 (normal operation mode), the metering frequency must be 8 times of the ADC frequency.

After the analog-to-digital conversion, the analog input is converted to be 24-bit digital signal with both bit23 and bit22 being the sign bit.

The digital signal must be input to a phase compensation circuit to correct the phase angle error introduced by the transformers.

9.4. Phase Compensation

A phase compensation circuit composed of a time delay chain of fixed length is applied to correct the phase angle error via delaying the selected signal. Either current or voltage signals can be delayed.

In 50Hz power grid, when the sampling frequency of the phase compensation circuit (f_{smpI}) is 819.2kHz, the calibration resolution is 0.022°/lsb, and the maximum phase angle error to be corrected is 2.8°. The value of f_{smpI} is determined by the configuration of bits ADCLKSEL<1:0> (bit[19:18] of ANCtrl3, 0x8003).

The value (N) to be set to the phase compensation control registers can be calculated via the following equation:

$$N = Round\left(\frac{1}{\pi} \times \frac{f_{smpI}}{100} \times \{\pm arccos[\cos\theta \times (1 + E)] - \theta\}\right) \quad \text{Equation 9-2}$$

where

N is the value, signed, to be set to the registers to correct the phase angle error. A positive N indicates that the current signal must be delayed, so "0" must be set to the sign bit; a negative N indicates that the voltage signal must be delayed, so "1" must be set to the sign bit;

θ is the phase angle between current and voltage signals, in unit of radian. A positive θ indicates a phase lead in current signal; a negative θ indicates a phase lead in voltage signal;

E is the energy metering error displayed in LCD screen of the calibration equipment;

f_{smpI} is the sampling frequency of the phase compensation circuit, Hz.

Table 9-7 f_{smpI} Determines Phase Compensation Resolution and Correction Range

N	ADCLKSEL<1:0> Configuration	f_{smpI} (Hz)	Resolution (°/lsb)	Correction Range (°)
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N	ADCLKSEL<1:0> Configuration		f_{smp} (Hz)	Resolution (°/lsb)	Correction Range (°)
[-127, +127]	bit[19:18], 0x8003	00	819200	0.022	2.8
		01	1638400	0.011	1.4
		10	204800	0.088	11.2
		11	409600	0.044	5.6

Table 9-8 Registers for phase compensation

Register	Bit		Description
MTPARA0, 0xC000, R/W	Bit[12:8]	MSKA	<p>To set the range of the hysteresis error of the fundamental current threshold for the phase compensation. 0, default.</p> <p>For example, if the value of MSKA is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of the register of the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff and the bottom threshold is 0xab00.</p>
MTPARA2, 0xC002, R/W	Bit24	AECEN	<p>To disable phase compensation in sections.</p> <p>1, disable; 0, enable (by default).</p>
Registers for Phase Compensation in Sections (R/W)	Bit[23:0]		<p>Address range: 0xE954~0xE958.</p> <p>To set the phase compensation for Phase C/B/A.</p> <p>bit23/bit15/bi7 is the sign bit of the phase compensation.</p>
Current Threshold for Phase Compensation in Sections (R/W)	32-bit		<p>Address range: 0xE97C~0xE987.</p> <p>To set current threshold for phase compensation in sections.</p>
State Register for Phase Compensation and Gain Calibration of Total Active Power (0xC004, PECAEC, R)	Bit[10:8]	AECC	<p>To indicate the section being used for phase compensation of Phase C.</p> <p>000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.</p>
	Bit[6:4]	AECB	<p>To indicate the section being used for phase compensation of Phase B.</p> <p>000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.</p>
	Bit[2:0]	AECA	<p>To indicate the section being used for phase</p>

Register	Bit	Description
		compensation of Phase A.
		000, Section 0; 001, Section 1; 010, Section 2; 011, Section 3; 100, Section 4.

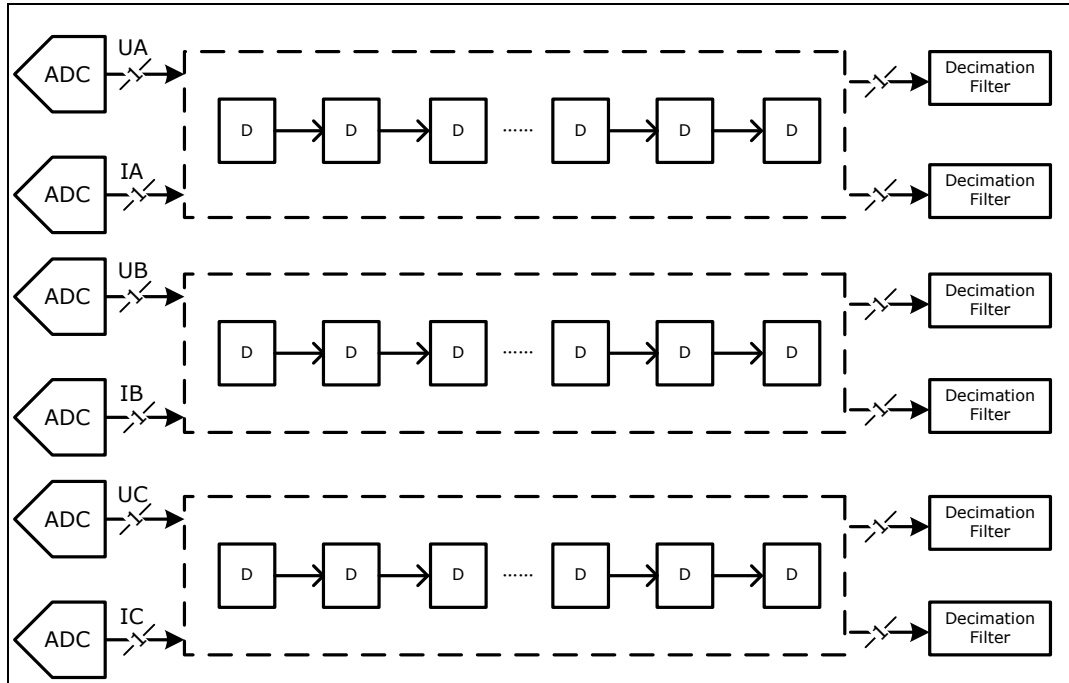


Figure 9-5 Phase Compensation

Phase compensation in 5 sections is applied to the V9203 to widen the dynamic range. By default, this function is enabled, and it can be disabled via setting bit24 in MTPARA2 (0xC002). When phase compensation in sections is enabled, the circuit compares the fundamental instantaneous current RMS after calibration (IRMS) to the pre-set current thresholds for each phase, and then decides to use the register for phase compensation in sections for correcting phase angle error. When this function is disabled, the registers of Section0 are used. The PECAEC register (0xC004) gives phase compensation states.

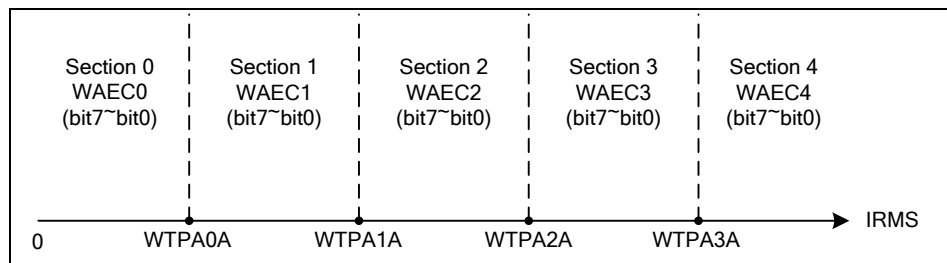


Figure 9-6 Phase Compensation in Sections (Phase A)

A hysteresis error mechanism is applied to the current threshold for phase compensation in sections. It means the threshold is not an accurate value but a value in a range which is determined by bit[12:8] (MSKA) of MTPARA0 (0xC000). The configuration of MSKA sets the range of the hysteresis error of the fundamental current threshold for the phase compensation. For example, if the value of MSKA is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of the register of

the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff, and the bottom threshold is 0xab00.

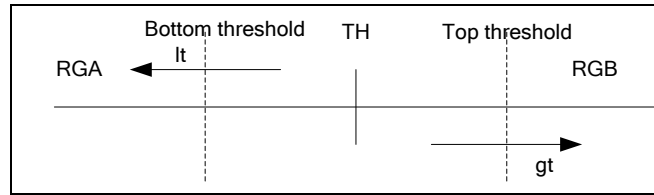


Figure 9-7 Hysteresis Error Mechanism for Phase Compensation

9.5. Digital Input

Decimation filters are used to reduce the noise of the 1-bit code stream output from the oversampling Σ/Δ ADC. The decimation filter can reduce the sampling frequency, and after being sampled in a lower frequency, the raw waveform of each signal is acquired.

Bit[6:0] of MTPARA0 (0xC000) enables or disables the code stream input into the decimation filters. When this function is enabled, the code stream is accumulated to the filter; when this function is disabled, a constant "0" is input for digital signal processing.

Table 9-9 Enable/Disable Digital Inputs

Register	Bit		Description
MTPARA0, 0xC000	Bit6	ADCIC	To enable digital signal input of Channel IC for digital signal processing. 1, enable. 0, disable.
	Bit5	ADCIB	To enable digital signal input of Channel IB for digital signal processing. 1, enable. 0, disable.
	Bit4	ADCIA	To enable digital signal input of Channel IA for digital signal processing. 1, enable. 0, disable.
	Bit3	ADCIN	To enable digital signal input of Channel IN for digital signal processing. 1, enable. 0, disable.
	Bit2	ADCUC	To enable digital signal input of Channel UC for digital signal processing. 1, enable. 0, disable.
	Bit1	ADCUB	To enable digital signal input of Channel UB for digital signal processing. 1, enable. 0, disable.
	Bit0	ADCUA	To enable digital signal input of Channel UA for digital signal processing. 1, enable. 0, disable.

Digital programmable gain amplifiers (DPGA) with possible gain selection of 1~128, via MTPARA1 (0xC001), are applied to digital signals output from the decimation filters to amplify the signals. It is recommended to set the DPGA to 8 or 16 if the voltage signal after APGA is much less than the measurement scales of the ADCs, to improve the performance.

Table 9-10 DPGA gain selection for digital signals

Register	Bit		Description
MTPARA1, 0xC001	Bit[26:24]	ATXIN	To set digital PGA gain of IN input. $\times 1 \sim \times 128 (2^{ATXIN})$
	Bit[22:20]	ATXIC	To set digital PGA gain of IC input. $\times 1 \sim \times 128 (2^{ATXIC})$
	Bit[18:16]	ATXUC	To set digital PGA gain of UC input. $\times 1 \sim \times 128 (2^{ATXUC})$
	Bit[14:12]	ATXIB	To set digital PGA gain of IB input. $\times 1 \sim \times 128 (2^{ATXIB})$
	Bit[10:8]	ATXUB	To set digital PGA gain of UB input. $\times 1 \sim \times 128 (2^{ATXUB})$
	Bit[6:4]	ATXIA	To set digital PGA gain of IA input. $\times 1 \sim \times 128 (2^{ATXIA})$
	Bit[2:0]	ATXUA	To set digital PGA gain of UA input. $\times 1 \sim \times 128 (2^{ATXUA})$

After the digital programmable gain amplifiers, the digital signals are acquired via the following equation:

$$\begin{aligned}
 U_a &= PGAd_{ua} \times PGA_{ua} \times \frac{A_{ua}}{1.185} \times \sin \omega t = DU_a \times \sin \omega t \\
 I_a &= PGAd_{ia} \times PGA_{ia} \times \frac{A_{ia}}{1.185} \times \sin(\omega t + \varphi) = DI_a \times \sin(\omega t + \varphi)
 \end{aligned}$$

Equation 9-3

Where, $PGAd_{ua}$ and $PGAd_{ia}$ are the DPGA gain, PGA_{ua} and PGA_{ia} are the APGA gain, A_{ua} and A_{ia} are the amplitude of current and voltage inputs, and 1.185 is the reference voltage.

9.6. Raw Waveform Output

Direct Memory Access (DMA) is used for transferring raw waveform of the 7 voltage and current signals to the peripheral components via the DMA_SPI interfaces. When some bits of bit[22:16] of MTPARA2 (0xC002) is set to 1s, the pins DSCK (Pin35), DSCS (Pin36) and DSDO (Pin37) are used to transfer the raw waveform of the corresponding channel. When all bits of bit[22:16] are set to 1s, the raw waveform of the 7 channels, in the sequence of UA, IA, UB, IB, UC, IC, and then IN, is transferred from the three interfaces.

Table 9-11 Registers for Raw Waveform Output

Register	Bit	Description
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Register	Bit		Description
MTPARA2, 0xC002	Bit27	DSPICK	To select the parity type for the output data from the DMA_SPI interfaces. 0, even parity; 1, odd parity.
	Bit26	DSPIMD	To select the frame format of the output data from the DMA_SPI interfaces. 0, 32-bit, one frame for a 32-bit data output; 1, 16-bit, two frames for a 32-bit data output.
	Bit[22:16]	DSPHEN	To enable the raw waveform output of the channels from the DMA_SPI interfaces. 1, enable; 0, disable. Bit22, raw waveform of IN; Bit21, raw waveform of IC; Bit20, raw waveform of UC; Bit19, raw waveform of IB; Bit18, raw waveform of UB; Bit17, raw waveform of IA; Bit16, raw waveform of UA.

When the metering frequency is 6.5536MHz, the updating frequency of the raw waveform is 6.4kHz. To ensure the transfer of waveform in time, the frequency for transferring a data frame should be at least 51.2kHz. If the data frame is a 32-bit serial data, the baud rate should be at least 1638.4kbps. So, to ensure the transfer of serial data in time and reliably, the baud rate is set to 3.2768Mbps.

The raw waveform can be transferred to the peripheral components via the DMA_SPI interfaces in two modes.

1. Mode 0: transferring 22-bit raw waveform in one 32-bit data frame. The form of the data frame transferred is as shown in the following table.

When a low logic is output on the pin DSCS (Pin36), the data is ready to be transferred. During the transfer, 32 DSCK signals are derived. And on the low-to-high DSCK transition, the transfer starts. If a high logic is output on the pin DSCS when all the 32 bits of data are transferred, the transfer is finished. The slave SPI interfaces of the peripheral components receive the 32-bit data, and sample the signal on the high-to-low DSCK transition when the DSCS is active low.

Table 9-12 Transferring Data Frame via DMA_SPI Interfaces (Mode 0)

Bit	Description
Bit[31:30]	Bit21 of the 22-bit raw waveform of each channel.
Bit[29:8]	Bit21~bit0, the 22-bit raw waveform of each channel.

Bit	Description
Bit7	0
Bit[6:4]	3-bit ADC address. 000, for Channel UA; 001, for Channel IA; 010, for Channel UB; 011, for Channel IB; 100, for Channel UC; 101, for Channel IC; 110, for Channel IN.
Bit[3:1]	000
Bit0	Parity bit. Users can select the parity via configuring bit27 (DSPICK) of MTPARA2 (0xC002).

2. Mode 1: transferring 22-bit raw waveform in two 16-bit data frames. The form of the data frame transferred is as shown in the following table.

When a low logic is output on the pin DSCS (Pin36), the data is ready to be transferred. During the transfer, 16 DSCK signals are derived. And on the low-to-high DSCK transition, the transfer starts. If a high logic is output on the pin DSCS when all the 16 bits of data are transferred, the transfer of the higher bytes (bit[21:11]) of the raw waveform of each channel is finished. A DSCK signal later, a low logic is output on the pin DSCS (Pin36) again, and the lower bytes of the raw waveform is ready to be transferred. During the transfer, 16 DSCK signals are derived. And on the low-to-high DSCK transition, the transfer starts. If a high logic is output on the pin DSCS when all the 16 bits of data are transferred, the transfer of the lower bytes (bit[10:0]) of the raw waveform of each channel is finished. The slave SPI interfaces of the peripheral components receive the 16-bit serial data, and sample the signal on the high-to-low DSCK transition when the DSCS is active low.

Table 9-13 Transferring Data Frame via DMA_SPI Interfaces (Mode 1)

Step	Bit	Description
Step 1	Bit15	1, indicates the higher bytes of the raw waveform of each channel is being transferred.
	Bit[14:4]	The 11 most significant bits (bit[21:11]) of the raw waveform of the each channel.
	Bit[3:1]	3-bit ADC address 000, for Channel UA; 001, for Channel IA; 010, for Channel UB; 011, for Channel IB; 100, for Channel UC; 101, for Channel IC; 110, for Channel IN.
	Bit0	Parity bit. Users can select the parity via configuring bit27 (DSPICK) of MTPARA2 (0xC002).
Step 2	Bit15	0, indicates the lower bytes of the raw waveform of each channel is being transferred.
	Bit[14:4]	The 11 least significant bits (bit[10:0]) of the raw waveform of the each channel.
	Bit[3:1]	3-bit ADC address 000, for Channel UA; 001, for Channel IA; 010, for Channel UB; 011, for Channel IB; 100, for Channel UC; 101, for Channel IC; 110, for Channel IN.

Step	Bit	Description
	Bit0	Parity bit. Users can select the parity via configuring bit27 (DSPICK) of MTPARA2 (0xC002).

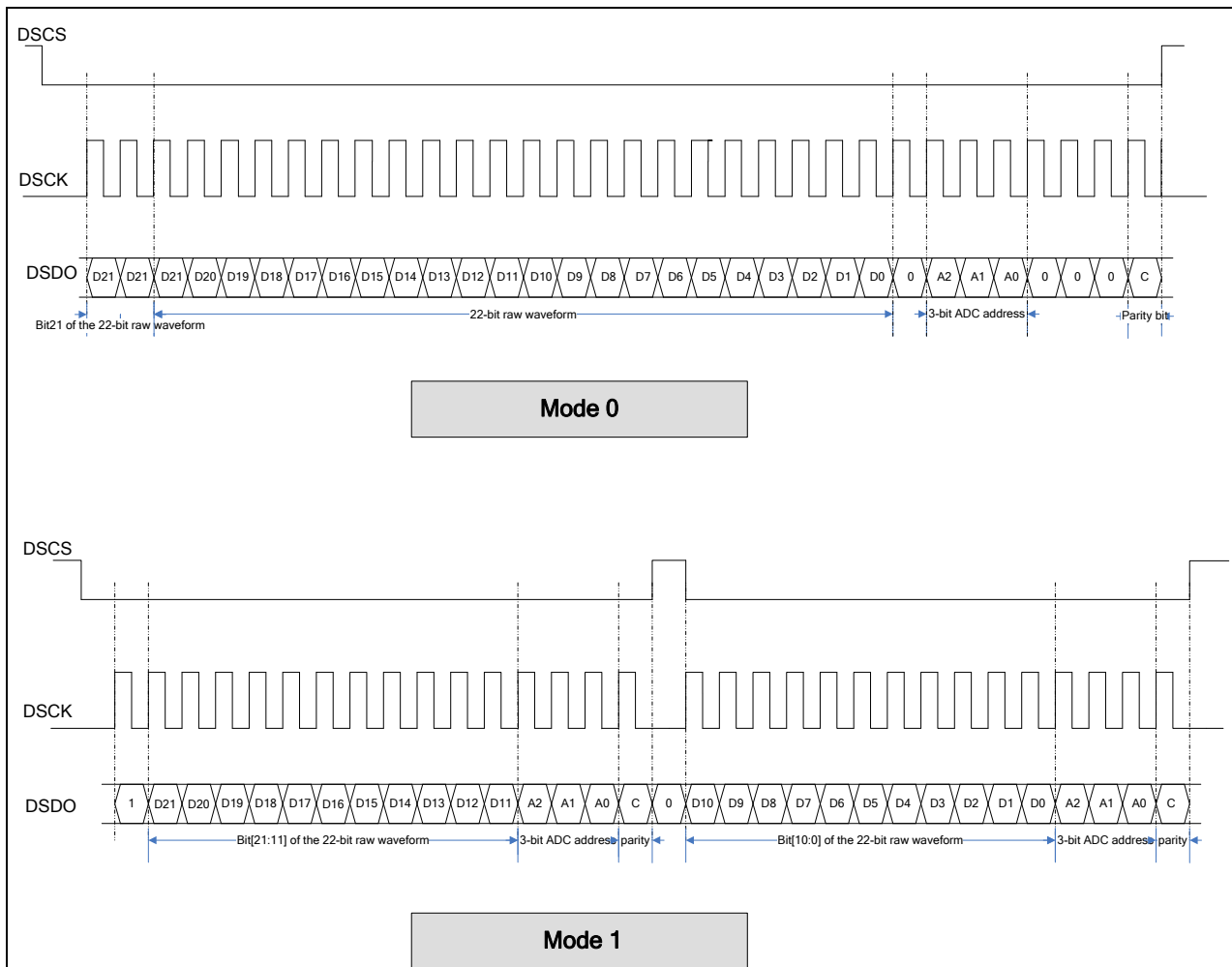


Figure 9-8 Modes for Raw Waveform Output

9.7. DC Components

By default, the output signals output from the decimation filters is input to the DC-stopping circuit to switch off the direct current/voltage to distinguish the alternating component which is for the power and RMS calculation to improve the accuracy, from the direct component which is stored in the registers for DC components (0xF02C~0xF032).

If the direct component in the raw waveforms is known, users can preset a value in the registers located at the address 0xEC16~0xEC1C for each channel. Then, the system can switch off the direct voltage or current of each phase automatically.

The registers for DC components (0xF02C~0xF032) and for presetting bias for direct current/voltage (0xEC16~0xEC1C) are accessed as 32-bit registers with bit23 being the sign bit and being extended to 32 bits.

As for the registers for DC components, when the metering frequency is 6.5536MHz, the updating time is 20ms, and the settling time is 100ms; when the metering frequency is 1.6384MHz, the updating time is 80ms, and the settling time is 400ms; when the metering frequency is 819.2kHz, the updating time is 160ms, and the settling time is 800ms.

When the V9203 is used for direct current application, users can switch on the direct current / voltage via setting bit11 (DCBYPASS) to 1 to prevent the raw waveform from being high-pass filtered, and the signal composed of direct and alternating component will be used for RMS calculation and energy metering.

9.8. RMS Calculation

The alternating component of the phase current and voltage can be used for:

1. The total current and voltage RMS calculation directly;
2. The fundamental current and voltage RMS calculation after being processed the bandpass filter which introduces a gain of 1/1.175435.

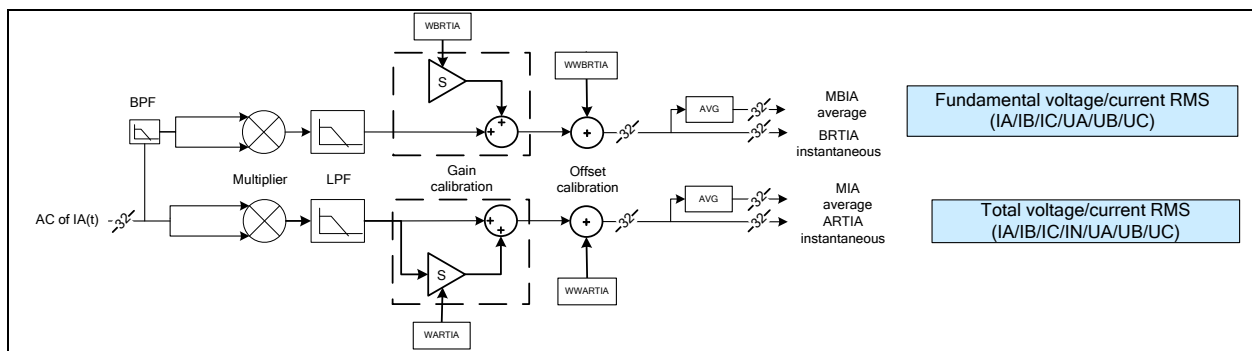


Figure 9-9 Total / Fundamental RMS Calculation

9.8.1. RMS Calculation

The value of the total current or voltage RMS is equal to that of the digital signal. Take Phase A as an example,

$$I_{arms} = DI_a = PGAdia \times PGAia \times \frac{Aia}{1.185} \quad \text{Equation 9-4}$$

And the fundamental current or voltage RMS is acquired following the equation:

$$BI_{arms} = BDIA = PGAdia \times PGAia \times \frac{Aia}{1.185} \times \frac{1}{1.175435} \quad \text{Equation 9-5}$$

Where,

PGAdia is the digital gain;

PGAia is the analog gain;

Aia is the amplitude of current and voltage inputs;

1.185 is the reference voltage.

After gain calibration and offset calibration, the RMS is stored in the registers for total/fundamental current/voltage RMS. All the registers are in the format of 32-bit 2'-complement, positive constantly.

Table 9-14 Registers Related to RMS Calculation

Register	Address	Data Format	Description
Registers for Total Current/Voltage RMS	0xE83E~0xE844	32-bit, complement, positive.	Instantaneous total current and voltage RMS of each phase and neutral wire.
	0xE90E~0xE911		Average total current RMS of each phase and neutral wire.
	0xE944~0xE946		Average total voltage RMS of each phase.
Registers for Fundamental Current/Voltage RMS	0xE880~0xE885	32-bit, complement, positive.	Instantaneous fundamental current and voltage RMS of each phase.
	0xE8FD~0xE8FF		Average fundamental current RMS of each phase.
	0xE90B~0xE90D		Average fundamental voltage RMS of each phase.

As for all the registers for total current/voltage RMS, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 20ms and settled in 150ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 80ms and settled in 600ms, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 160ms and settled in 1.2s, and the average data are updated in 5.12s and settled in 8s.

As for all the registers for fundamental current/voltage RMS, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 20ms and settled in 200ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 80ms and settled in 800ms, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 160ms and settled in 1.6s, and the average data are updated in 5.12s and settled in 8s.

9.8.2. RMS Calibration

To improve the linearity of the data when weak signals are input, the current or voltage RMS calculated via Equation 9-4 or Equation 9-5 must be gain and offset calibrated, as shown in the following equation, and then the calibrated RMS is stored in the registers.

$$RMS = RMS' \times (1 + S) + C \quad \text{Equation 9-6}$$

Where,

RMS' is the current or voltage RMS calculated via Equation 9-4 or Equation 9-5;

RMS is the current or voltage RMS after calibration;

S is the gain calibration;

C is the offset calibration.

Users can set the calibration value in the registers listed in the following table.

Table 9-15 Registers Related to RMS Calibration

Registers	Address	Data Format	Description
Registers for Calibrating the Total Voltage/Current RMS	0xE968~0xE96E	32-bit, 2'-complement	To set gain calibration for the total current / voltage RMS of each phase and Channel IN.
	0xE994~0xE99A		To set offset calibration for the total current / voltage RMS of each phase and Channel IN.
Registers for Calibrating the Fundamental Voltage/Current RMS	0xE976~0xE97B	32-bit, 2'-complement	To set gain calibration for the fundamental current / voltage RMS of each phase.
	0xE9A2~0xE9A7		To set offset calibration for the fundamental current / voltage RMS of each phase.

9.9. Power Calculation

The alternating component of the phase current and voltage can be used for:

1. The active power calculation directly;
2. The reactive power calculation after a phase shift by 90 degrees via a Hilbert filter.

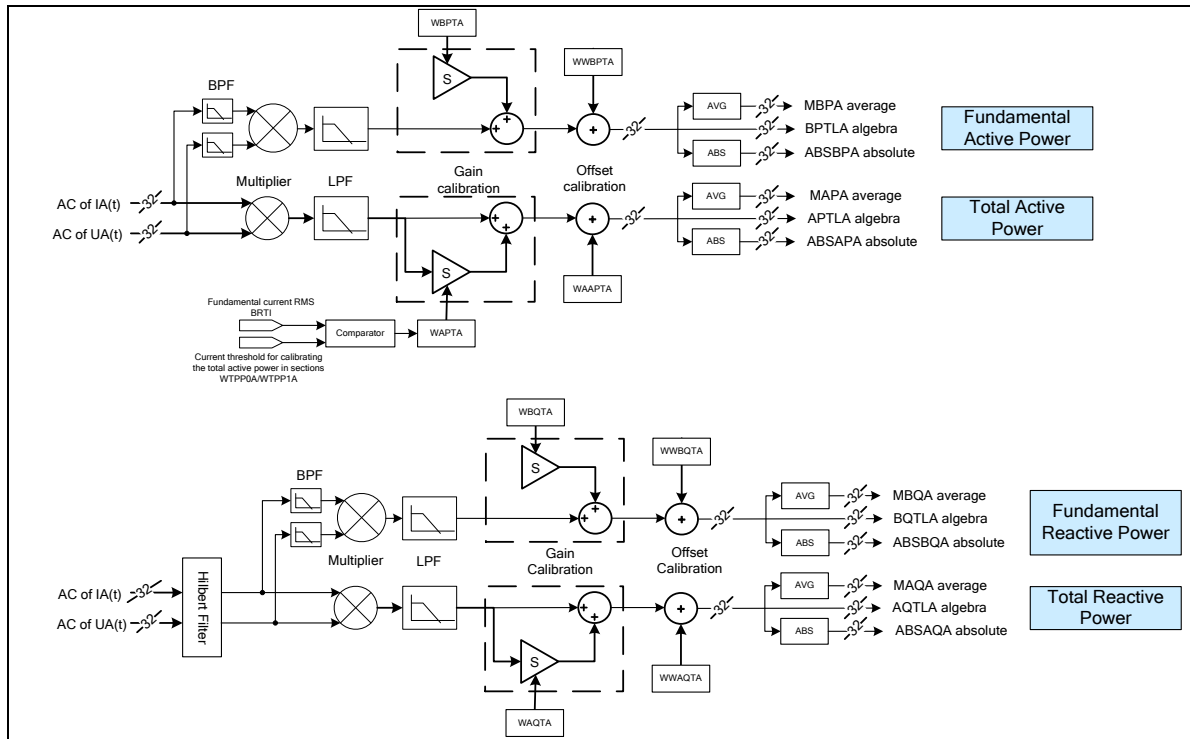


Figure 9-10 Active/Reactive Power Calculation

9.9.1. Total Active/Reactive Power Calculation

The total signal, including fundamental wave and harmonic wave, is used to calculate total active and reactive power directly. Take Phase A as an example, the active power is acquired via the following equation:

$$P_A = \frac{DU_a \times DI_a \times \cos \psi}{4} \quad \text{Equation 9-7}$$

And the reactive power is acquired following the equation:

$$Q_A = \frac{DU_a \times DI_a \times \sin \psi}{4} \quad \text{Equation 9-8}$$

Where, DU_a and DI_a are the value of the digital signal.

After gain calibration and offset calibration, the active and reactive power is stored in the total active/reactive power registers. And the active and reactive power can be averaged and processed to acquire the absolute value. All the registers are in the format of 32-bit 2'-complement.

The algebra and absolute value of the total active and reactive power of each phase is used for calculating total power on the overall system, and the absolute value of the total power is for the energy accumulation and pulse generation in normal mode.

Table 9-16 Registers for Total Active/Reactive Power

Register	Address	Data Format	Description
Total active/reactive	0xE805~0xE807	32-bit,	Absolute value of the instantaneous

Register	Address	Data Format	Description
power registers		2'-complement, positive	total active power of each phase.
	0xE808~0xE80A		Absolute value of the instantaneous total reactive power of each phase.
	0xE824~0xE826	32-bit, 2'-complement	Algebra value of the instantaneous total active power of each phase.
	0xE833~0xE835		Algebra value of the instantaneous total reactive power of each phase.
	0xE8E8~0xE8EA		Average total active power of each phase.
	0xE8F0~0xE8F2		Average total reactive power of each phase.

As for all the registers for total active/reactive power, when the metering frequency is 6.5536MHz, the instantaneous algebra and absolute data are updated in 80ms and settled in 400ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous algebra and absolute data are updated in 320ms and settled in 1.6s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous algebra and absolute data are updated in 640ms and settled in 3.2s, and the average data are updated in 5.12s and settled in 8s.

9.9.2. Fundamental Active/Reactive Power Calculation

Filtered by the bandpass filter, introducing a gain of 1/1.175435, the signal of each phase, is used to calculate the fundamental active and reactive power. Take Phase A as an example,

$$\text{Fundamental active power: } BPA = \frac{BDUa \times BD Ia \times \cos \psi}{4} = \frac{PA}{1.38165} \quad \text{Equation 9-9}$$

$$\text{Fundamental reactive power: } BQA = \frac{BDUa \times BD Ia \times \sin \psi}{4} = \frac{QA}{1.38165} \quad \text{Equation 9-10}$$

Where, BDUa and BD Ia are the fundamental voltage and current, calculated as follows,

$$\begin{aligned} BDUa &= \frac{DUa}{1.175435} \\ BD Ia &= \frac{DIa}{1.175435} \end{aligned} \quad \text{Equation 9-11}$$

After gain calibration and offset calibration, the active and reactive power is stored in the fundamental active/reactive power registers. And the active and reactive power can be averaged and processed to acquire the absolute values. All the registers are in the format of 32-bit 2'-complement.

The algebra and absolute value of the fundamental active and reactive power of each phase is used for calculating fundamental power on the overall system, and the absolute value of the fundamental power is for the energy accumulation and pulse generation in normal mode.

Table 9-17 Registers for Fundamental Active/Reactive Power

Register	Address	Data Format	Description
Registers for fundamental active and reactive power	0xE80B~0xE80D	32-bit, 2'-complement, positive.	Absolute value of the instantaneous fundamental active power of each phase.
	0xE80E~0xE810		Absolute value of the instantaneous fundamental reactive power of each phase.
	0xE866~0xE868	32-bit, 2'-complement	Algebra value of the instantaneous fundamental active power of each phase.
	0xE877~0xE879		Algebra value of the instantaneous fundamental reactive power of each phase.
	0xE900~0xE902		Average fundamental active power of each phase of each phase.
	0xE905~0xE907		Average fundamental reactive power of each phase.

As for all the registers for fundamental active/reactive power, when the metering frequency is 6.5536MHz, the instantaneous algebra and absolute data are updated in 80ms and settled in 450ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous algebra and absolute data are updated in 320ms and settled in 1.8s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous algebra and absolute data are updated in 640ms and settled in 3.6s, and the average data are updated in 5.12s and settled in 8s.

9.9.3. Power Calibration

To improve the linearity of the data when weak signals are input, the active or reactive power calculated must be gain and offset calibrated, as shown in the following equation, and then the calibrated power is stored in the registers.

$$P = P' \times (1 + S) + C \quad \text{Equation 9-12}$$

Where,

P' is the active or reactive power calculated via Equation 9-7, Equation 9-8, Equation 9-9 or Equation 9-10;

P is the active or reactive power after calibration;

S is the gain calibration;

C is the offset calibration.

9.9.3.1. Gain Calibration

Users can set the gain calibration values in the registers listed in the following table.

Table 9-18 Registers Related to Power Gain Calibration

Register	Bit		Description
MTPARA0, 0xC000, R/W	Bit[20:16]	MSKP	<p>To set the range of the hysteresis error of the fundamental current threshold for the total active power gain calibration.</p> <p>For example, if the value of MSKP is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of register of the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff, and the bottom threshold is 0xab00.</p>
MTPARA2, 0xC002, R/W	Bit25	PECEN	To disable gain calibrate the total active power in sections. 1, disable; 0, enable (by default).
PECAEC, 0xC004, R	Bit[21:20]	PECC	<p>To indicate the section being used for gain calibrating the total active power of Phase C.</p> <p>00, Section 0; 01, Section 1; 10, Section 2.</p>
	Bit[17:16]	PECB	<p>To indicate the section being used for gain calibrating the total active power of Phase B.</p> <p>00, Section 0; 01, Section 1; 10, Section 2.</p>
	Bit[13:12]	PECA	<p>To indicate the section being used for gain calibrating the total active power of Phase A.</p> <p>00, Section 0; 01, Section 1; 10, Section 2.</p>
Registers for calibrating the total active/reactive power	32-bit		<p>Address: 0xE959~0xE967.</p> <p>To set the gain calibration for the total active/reactive power of each phase.</p>
Current threshold for calibrating the total active power in sections	32-bit		<p>Address: 0xE988~0xE98D.</p> <p>To set current threshold for calibrating the total active power of each phase.</p>
Registers for calibrating the fundamental active/reactive power	32-bit		<p>Address: 0xE970~0xE975.</p> <p>To set the gain calibration for the fundamental active/reactive power of each phase.</p>

Gain Calibration of the total active power in 3 sections is applied to the V9203 to widen the dynamic

range. By default, this function is enabled, and it can be disabled via setting bit25 in MTPARA2 (0xC002). When gain calibration of the total active power in sections is enabled, the circuit compares the instantaneous fundamental current RMS after calibration (IRMS) to the pre-set current thresholds for each phase, and then decides to use the register for gain calibration in sections for correcting gain error. When this function is disabled, the registers of Section0 are used. The PECAEC register (0xC004) gives gain calibration states.

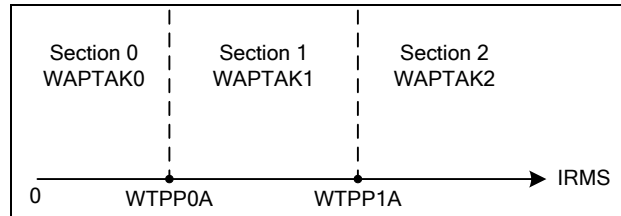


Figure 9-11 Gain Calibration of the Total Active Power in Sections (Phase A)

A hysteresis error mechanism is applied to the current threshold for gain calibration in sections. It means the threshold is not an accurate value but a value in a range which is determined by bit[20:16] (MSKP) of MTPARA0 (0xC000). The configuration of MSKP sets the range of the hysteresis error of the fundamental current threshold for the gain calibration. For example, if the value of MSKP is set to 0x8, and the fundamental current threshold is set to 0xabcd, the 8 least significant bits of register of the fundamental current threshold represents the hysteresis error range, that is the top threshold is 0xabff, and the bottom threshold is 0xab00.

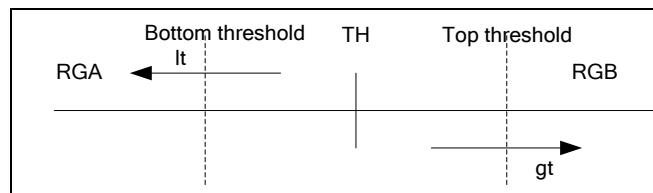


Figure 9-12 Hysteresis Error Mechanism for Gain Calibration of Total Active Power

9.9.3.2. Offset Calibration

To improve the energy metering accuracy, the offset calibration is introduced to the power calculation to eliminate the offset caused by the crosstalk.

Users can set the offset calibration values in the registers listed in the following table.

Table 9-19 Registers Related to Power Offset Calibration

Register	Address	Data Format	Description
Registers for calibrating the total active/reactive power	0xE98E~0xE993	32-bit	To set offset calibration for the total active/reactive power of each phase.
Registers for calibrating the fundamental active/reactive power	0xE99C~0xE9A1	32-bit	To set offset calibration for the fundamental active/reactive power of each phase.

9.10. Apparent Power Calculation

The apparent power can be calculated in two methods:

1. Based on the instantaneous total/fundamental current and voltage RMS:

$$S = \frac{I_{rms} \times U_{rms}}{4} \quad \text{Equation 9-13}$$

Where, S is the total/fundamental apparent power;

I_{rms} is the total/fundamental current RMS after calibration;

U_{rms} is the total/fundamental voltage RMS after calibration.

2. Based on the instantaneous total/fundamental active and reactive power:

$$S = \sqrt{P^2 + Q^2} \quad \text{Equation 9-14}$$

Where, S is the total/fundamental apparent power;

P is the total/fundamental active power after calibration;

Q is the total/fundamental reactive power after calibration.

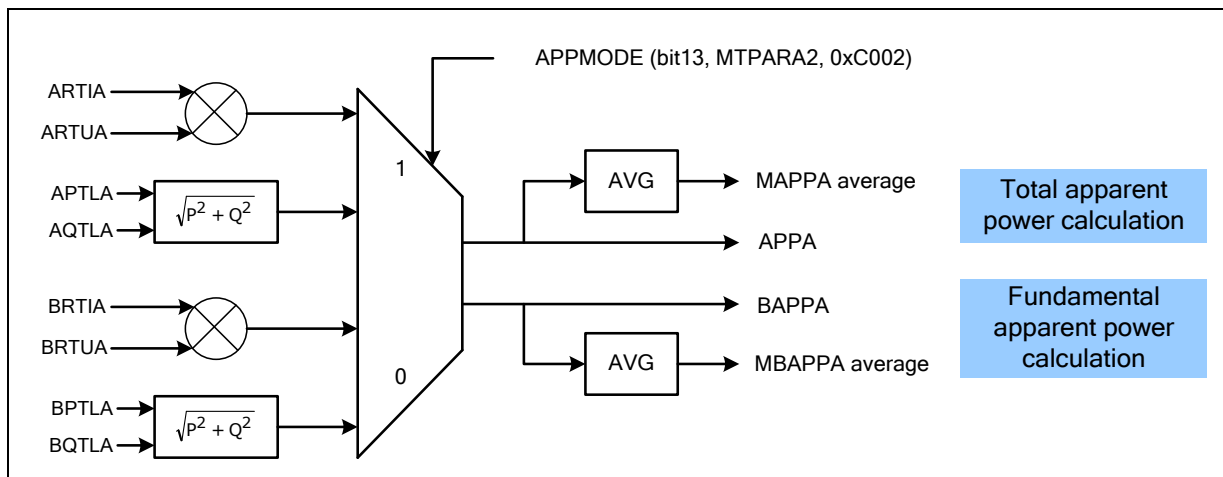


Figure 9-13 Apparent Power Calculation

The apparent power is stored in the instantaneous apparent power registers. And the apparent power can be averaged to acquire the average value. All the registers are in the format of 32-bit 2'-complement.

The instantaneous apparent power of each phase is used for calculating the apparent power on the overall system, and for the energy accumulation and pulse generation in normal mode.

Table 9-20 Registers Related to Apparent Power Calculation

Register	Bit	Description
MTPARA2, 0xC002	Bit13	To select the apparent power calculation method.
	APPMODE	0, to calculate the apparent power based on the current

Register	Bit	Description
		RMS; 1, to calculate the apparent power based on the active and reactive power.
Registers for total apparent power		Address: 0xE81F~0xE821. The instantaneous total apparent power of each phase, 32-bit, 2'-complement, positive.
		Address: 0xE8EB~0xE8ED. The average total apparent power of each phase, 32-bit, 2'-complement, positive.
Registers for fundamental apparent power		Address: 0xE854~0xE856. The instantaneous fundamental apparent power of each phase, 32-bit, 2'-complement, positive.
		Address: 0xE8F6~0xE8F8 The average fundamental apparent power of each phase, 32-bit, 2'-complement, positive.

As for all the registers for total apparent power, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 400ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.6s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.2s, and the average data are updated in 5.12s and settled in 8s.

As for all the registers for fundamental apparent power, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 450ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.8s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.6s, and the average data are updated in 5.12s and settled in 8s.

9.11. Power Factor Calculation

The power factor of each phase or on the overall system can be calculated following the equation:

$$\cos\theta = \frac{|P|}{S} \quad \text{Equation 9-15}$$

Where, $\cos\theta$, is the reading of the power factor registers, 32-bit, unsigned;

$|P|$, is the value of the registers for the absolute value of the total/fundamental instantaneous active power of each phase/on the overall system;

S_i is the value of the registers for the total/fundamental instantaneous apparent power of each phase/on the overall system.

The power factor is stored in the 32-bit unsigned registers. And the power factor can be averaged to acquire the average value.

Table 9-21 Registers Related to Power Factor Calculation

Register	Address	Format	Description
Registers for the total power factor.	0xE811~0xE813	32-bit, unsigned.	The instantaneous total power factor of each phase.
	0xE8E4~0xE8E6		The average total power factor of each phase.
	0xE814		The instantaneous total power factor on the overall system.
	0xE8E7		The average total power factor on the overall system.
Registers for the fundamental power factor.	0xE857~0xE859	32-bit, unsigned.	The instantaneous fundamental power factor of each phase.
	0xE8F9~0xE8FB		The average fundamental power factor of each phase.
	0xE85A		The instantaneous fundamental power factor on the overall system.
	0xE8FC		The average fundamental power factor on the overall system.

The actual power factor is the ratio of the reading of the above registers to 2^{31} , which should be in the range of $2 \sim 0$. When the ratio is higher than 1, the power factor is defined to be 1.

As for all the registers for total power factor, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 400ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.6s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.2s, and the average data are updated in 5.12s and settled in 8s.

As for all the registers for fundamental power factor, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 450ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.8s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.6s, and the average data are updated in 5.12s and settled in 8s.

9.12. Calculating Power On The Overall System

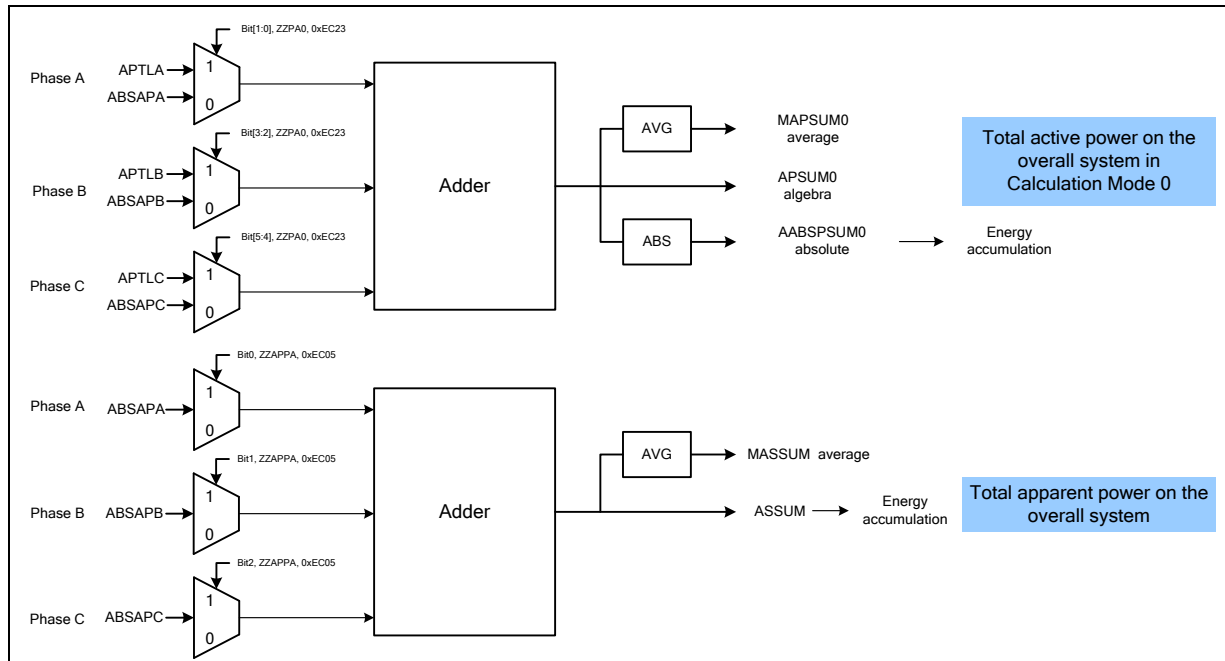


Figure 9-14 Power on the overall system Calculation

In the V9203, there are two methods to calculate the active/reactive power on the overall system, but only one method to calculate the apparent power on the overall system.

9.12.1.Active/Reactive Power on the Overall System

Select one of the three values, algebra value, absolute value, and the value "0", for each phase, and sum them up, to acquire the total/fundamental active/reactive power on the overall system. When the selection is done via configuring the registers ZZPA0 (0xEC23) or ZZQA0 (0xEC47), the sum is the total/fundamental active/reactive power on the overall system in Calculation Mode 0. And, when the selection is done via configuring the registers ZZPA1 (0xEC24) or ZZQA1 (0xEC48), the sum is the instantaneous total/fundamental active/reactive power on the overall system in Calculation Mode 1. Then, the sum is averaged or processed to acquire the absolute value. The absolute value is for energy accumulation.

Table 9-22 Registers Related to Active/Reactive Power On the overall system Calculation

Register	Description
Register for total/fundamental active power on the overall system Calculation Mode 0 (0xEC23, ZZPA0).	0x15 is recommended.
Register for total/fundamental active power on the overall system Calculation Mode 1 (0xEC24, ZZPA1).	0x2A is recommended.

Register	Description
Register for total/fundamental reactive power on the overall system Calculation Mode 0 (0xEC47, ZZQA0).	0x15 is recommended.
Register for total/fundamental reactive power on the overall system Calculation Mode 1 (0xEC48, ZZQA1).	0x2A is recommended.
Registers for total active/reactive power on the overall system.	Address: 0xE801~0xE804. The absolute value of the instantaneous total active/reactive power on the overall system, 32-bit, 2'-complement, positive.
	Address: 0xE822~0xE823. The algebra value of the instantaneous total active power on the overall system, 32-bit, 2'-complement.
	Address: 0xE831~0xE832. The algebra value of the instantaneous total reactive power on the overall system, 32-bit, 2'-complement.
	Address: 0xE8EE~0xE8EF. The average total active power on the overall system, 32-bit, 2'-complement.
	Address: 0xE8F3~0xE8F4. The average total reactive power on the overall system, 32-bit, 2'-complement.
Registers for fundamental active/reactive power on the overall system.	Address: 0xE850~0xE853. The absolute value of the instantaneous fundamental active/reactive power on the overall system, 32-bit, 2'-complement, positive.
	Address: 0xE864~0xE865. The algebra value of the instantaneous fundamental active power on the overall system, 32-bit, 2'-complement.
	Address: 0xE875~0xE876. The algebra value of the instantaneous fundamental reactive power on the overall system, 32-bit, 2'-complement.

Register	Description
	Address: 0xE903~0xE904. The average fundamental active power on the overall system, 32-bit, 2'-complement.
	Address: 0xE908~0xE909. The average fundamental reactive power on the overall system, 32-bit, 2'-complement.

As for all the registers for total active/reactive power on the overall system, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 400ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.6s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.2s, and the average data are updated in 5.12s and settled in 8s.

As for all the registers for fundamental active/reactive power on the overall system, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 450ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.8s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.6s, and the average data are updated in 5.12s and settled in 8s.

9.12.2.Apparent Power on the Overall System

Select one of the two values, the apparent power and the value "0", for each phase, and sum them up, to acquire the instantaneous total/fundamental apparent power on the overall system, which is for apparent energy accumulation. The selection is done via configuring the register ZZAPPA (0xEC05). Then, the sum is averaged to acquire the average value.

Table 9-23 Registers Related to Apparent Power On the overall system Calculation

Register	Description
Register for total/fundamental apparent power on the overall system calculation (0xEC05, ZZAPPA).	0x07 is recommended.
Registers for the total apparent power on the overall system.	Address: 0xE84E. The instantaneous total apparent power on the overall system, 32-bit, 2'-complement, positive.
	Address: 0xE8F5. The average total apparent power on the overall system, 32-bit, 2'-complement, positive.

Register	Description
Registers for the fundamental apparent power on the overall system.	Address: 0xE88C. The instantaneous fundamental apparent power on the overall system, 32-bit, 2'-complement, positive.
	Address: 0xE90A. The average fundamental apparent power on the overall system, 32-bit, 2'-complement, positive.

As for all the registers for total apparent power on the overall system, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 400ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.6s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.2s, and the average data are updated in 5.12s and settled in 8s.

As for all the registers for fundamental apparent power on the overall system, when the metering frequency is 6.5536MHz, the instantaneous data are updated in 80ms and settled in 450ms, and the average data are updated in 640ms, and settled in 1s; when the metering frequency is 1.6384MHz, the instantaneous data are updated in 320ms and settled in 1.8s, and the average data are updated in 2.56s and settled in 4s; when the metering frequency is 819.2kHz, the instantaneous data are updated in 640ms and settled in 3.6s, and the average data are updated in 5.12s and settled in 8s.

9.13. Energy Accumulation and Pulse Generation

The V9203 supports accumulating the absolute value of the active/ reactive/ apparent power on the overall system to the energy accumulator at normal speed, and accumulating the selected power on the overall system to the energy accumulator at high speed.

9.13.1. Normal Mode

Set the bit EGYEN (bit15, 0xC002, MTPARA2) to 1 enable accumulating the absolute value of the active/reactive/apparent power on the overall system to the energy accumulators in normal mode, at normal speed, 12.5Hz. When the value of the register outnumbers that preset in the energy threshold register, an energy pulse is generated, a value equal to the energy threshold is minus from the energy register, and the energy pulse counter increments by 1.

In this mode, no CF pulse can be output.

The energy threshold is calculated in the following equation:

$$PGAT = P \times T \times 6.25$$

Equation 9-16

Where, P, is the value of register for the total or fundamental active power on the overall system when rate

voltage/current is applied.

T_r is the time constant, acquired via the equation:

$$T = \frac{3600 \times 1000}{\text{PulseConstant} \times U_n \times I_n \times \text{PhaseNumber}} \quad \text{Equation 9-17}$$

9.13.2.High-Speed Mode

To improve the resolution of the CF pulse output, the circuits for energy accumulation at high speed is provided in the V9203. In this mode, the accumulation rate is 204800Hz.

Set one or some of bit[7:4] of MTPARA2 (0xC002) to enable the energy accumulation at high speed.

When this function is enabled, the power on the overall system is selected according to the configuration of the register ZZPCF0A (0xEC34), and is transferred to the corresponding power register, such as ZZPCF0 (0xEC33), for energy accumulation in high-speed mode, which is updated in 80ms. The power is accumulated to the energy accumulation registers in high-speed mode, such as EGY0L (0xD000) and EGY0H (0xD001), at a rate of 204800Hz. When the value of the register outnumbers that preset in the energy threshold register, an energy pulse is generated, a value equal to the energy threshold is minus from the energy register, and the energy pulse counter increments by 1. When the CF pulse output is enabled, one CF pulse is output when the pulses counter increments by 2.

The threshold for the energy accumulation and pulse generation in high-speed mode is 16384 times of that in normal mode, so, the 14 most significant bits must be padded with 0s.

Set the bits CFON (bit[3:0], 0xC002, MTPARA2) to enable or disable the CF pulse output. When the metering frequency is 6.5536MHz and the ADC sampling frequency is 819.2kHz, the maximum CF pulse output frequency is 102.4Hz with a pulse width of 80ms. When the pulse period is shorter than 160ms, the duty cycle is 50%.

When a weak signal is input, the V9203 can increase the meter constant to reduce the energy threshold to accelerate the pulse generation rate to improve the calibration rate. Users can accelerate the rate via configuring the bits CFFAST (bit[10:8], 0xC002, MTPARA2).

Table 9-24 Pins for CF Pulse Output

Pin #	Mnemonic	Description
26	CF0	CF pulse output. Via configuring the registers ZZPA0 (0xEC23) and ZZPA1 (0xEC24), this pin can be used to output total or fundamental active energy CF pulse of each phase or on the overall system.
27	CF1	CF pulse output. Via configuring the registers ZZQA0 (0xEC47) and ZZQA1 (0xEC48), this pin can be used to output total or fundamental reactive energy CF pulse of each phase or on the overall system.

Pin #	Mnemonic	Description
28	CF2	CF pulse output. Via configuring the registers ZZPA0 (0xEC23) and ZZPA1 (0xEC24), this pin can be used to output total or fundamental active energy CF pulse of each phase or on the overall system.
29	CF3	CF pulse output. Via configuring the registers ZZQA0 (0xEC47), ZZQA1 (0xEC48), and ZZAPPA (0xEC05), this pin can be used to output total reactive energy, or total/fundamental apparent energy CF pulse of each phase or on the overall system.

Table 9-25 Registers Related to Energy Accumulation and CF Pulse Output in High-Speed Mode

Register	Bit		Description
Register for CF pulse source selection (0xEC34, ZZPCF0A)	Bit[15:12]	CF3PS	To set the source for the CF pulse output on the pin CF3. By default, these bits are set to 0b0000, representing a non-zero value is set to be the source for the pulse output on the pin CF3.
	Bit[11:8]	CF2PS	To set the source for the CF pulse output on the pin CF2. By default, these bits are set to 0b0000, representing a non-zero value is set to be the source for the pulse output on the pin CF2.
	Bit[7:4]	CF1PS	To set the source for the CF pulse output on the pin CF1. By default, these bits are set to 0b0000, representing a non-zero value is set to be the source for the pulse output on the pin CF1.
	Bit[3:0]	CF0PS	To set the source for the CF pulse output on the pin CF0. By default, these bits are set to 0b0000, representing a non-zero value is set to be the source for the pulse output on the pin CF0.
MTPARA2, 0xC002	Bit[10:8]	CFFAST	To accelerate the pulse generation speed. 000~011, ×1 (by default); 100, ×4; 101, ×16; 110, ×64; 111, ×128.
	Bit[7:4]	CFCALC	To enable accumulating the total/fundamental active/reactive/apparent energy in high-speed

Register	Bit		Description
			<p>mode.</p> <p>1, enable; 0, disable.</p> <p>Bit7, total/fundamental apparent energy on the overall system, or total reactive energy on the overall system (CF3);</p> <p>Bit6, total/fundamental active energy on the overall system (CF2);</p> <p>Bit5, total/fundamental reactive energy on the overall system (CF1);</p> <p>Bit4, total/fundamental active energy on the overall system (CF0).</p>
	Bit[3:0]	CFON	<p>To enable CF pulse output.</p> <p>1, enable; 0, disable.</p> <p>Bit3, pulse output on the pin CF3;</p> <p>Bit2, pulse output on the pin CF2;</p> <p>Bit1, pulse output on the pin CF1;</p> <p>Bit0, pulse output on the pin CF0.</p>

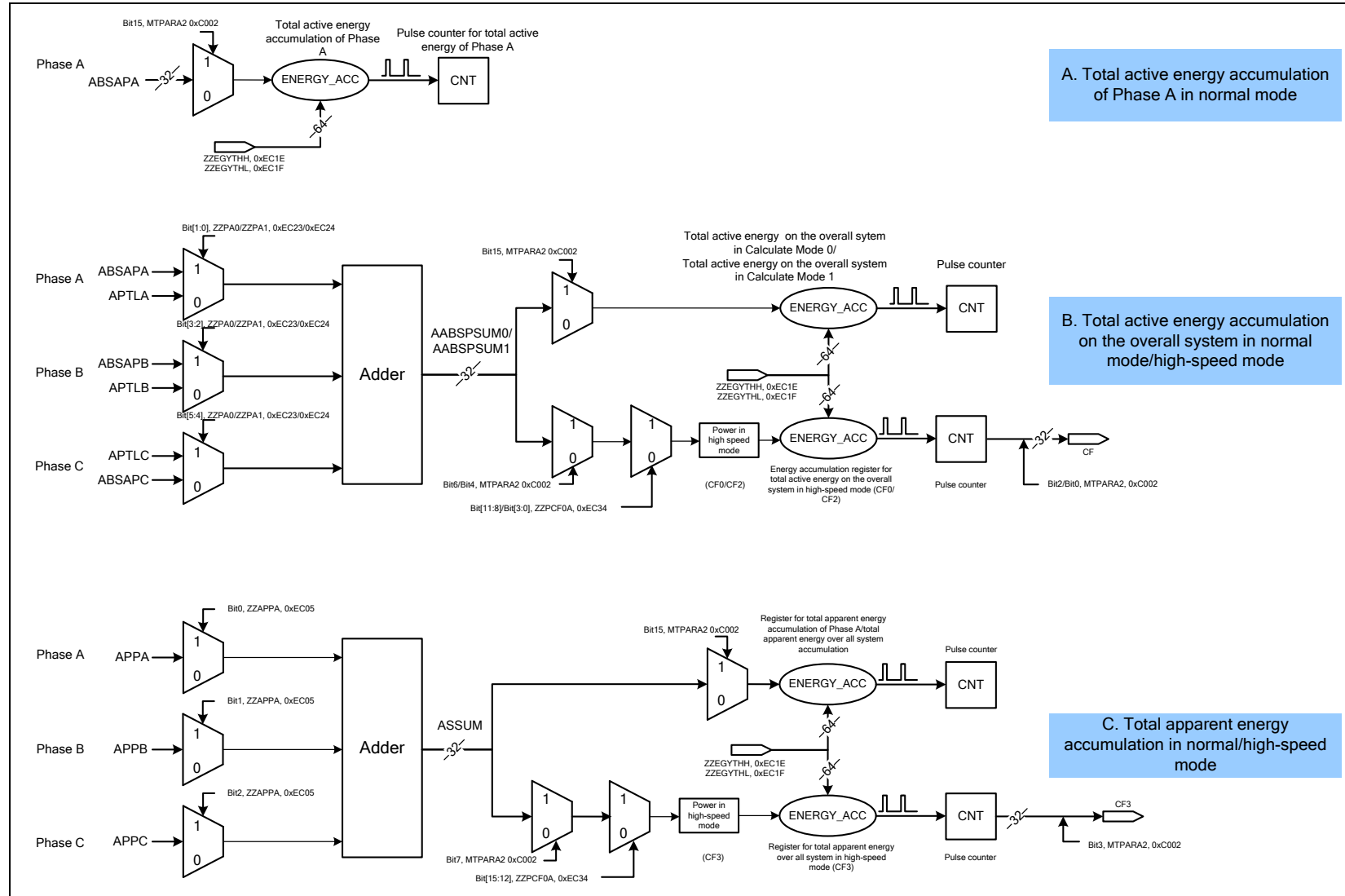


Figure 9-15 Energy Accumulation (Phase A)

9.14. No-Load Detection

The V9203 operated the no-load detection continuously, and it supports two optional modes for no-load detection:

1. One based on the instantaneous fundamental current RMS of each phase;
2. One based on the absolute value of the instantaneous total/fundamental active/reactive power.

Select the mode for no-load detection via the register ZZCPSEL (0xEC15). Preset a detection threshold in registers CTHH (0xE8AA) and CTHL (0xE8AB), and then compare the RMS or the power to the threshold to detect the no-load condition of the system or part circuits.

The registers ZZCPAPA (0xEC09) and other state registers for no-load detection in the address range of 0xEC0A~0xEC14 shows the no-load conditions for total/fundamental active/reactive energy metering of each phase.

9.15. Line Frequency Measurement

The V9203 supports line frequency measurement.

In the line frequency measurement circuit, the fundamental current or voltage signal of each phase is sampled at a frequency of 102.4kHz for zero-crossing detection, and the number of the samples among continuous 33 negative-to-positive zero-crossing points is equal to the line frequency. So the line frequency of each phase is calculated as follows:

$$f = \frac{3276800}{FRQ} \quad \text{Equation 9-18}$$

Where, f is the line frequency to be measured; FRQ is the content of the registers for line frequency of each phase, in the address range of 0xC008~0xC00A, in the form of decimal.

The positive registers for line frequency are accessed as 32-bit registers with the 15 most significant bits padded with 0s. The measurement resolution is 0.0008Hz.

When the metering frequency is 6.5536MHz, these registers are updated once every 640ms, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 1s.

When the metering frequency is 1.6384MHz, these registers are updated once every 2.56s, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 4s.

When the metering frequency is 819.2kHz, these registers are updated once every 5.12s, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 8s.

9.16. Phase Angle Measurement

In the V9203, the difference between the phase angle of the signal to be measured and that of the voltage of Phase A, which is defined as 0, is equal to the phase angle of the signal to be measured.

The phase angle measurement circuit samples the fundamental current or voltage signal of each phase at a frequency of 102.4kHz for zero-crossing detection, and the number of the samples between the N^{th} negative-to-positive zero-crossing point of the signal to be measured and the $(N-1)^{\text{th}}$ negative-to-positive zero-crossing point of the voltage of Phase A is equal to the phase angle of the signal to be measured. So the phase angle of signal to be measured is calculated as follows:

$$PH = \frac{360 \times (PHS + 1)}{2048} \quad \text{Equation 9-19}$$

Where, PH is the difference between the phase angle of the signal to be measured and that of the voltage of Phase A which is defined as 0; PHS is the content of the registers for phase, in the address range of 0xC00B~0xC00F, in the form of decimal.

The positive registers for phase angle are accessed as 32-bit registers with the 20 most significant bits padded with 0s. The measurement resolution is 0.175 degrees.

When the metering frequency is 6.5536MHz, these registers are updated once every 20ms, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 1s.

When the metering frequency is 1.6384MHz, these registers are updated once every 80ms, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 4s.

When the metering frequency is 819.2kHz, these registers are updated once every 160ms, and the settling time is associated with the signal strength. The weaker the signal is, the longer the settling time is, usually more than 8s.

9.17. Neutral Current Mismatch

As for a three-phase energy meter, the current RMS of the neutral wire should be equal to the RMS of the algebra sum of the phase currents:

$$I_N(t) = I_A(t) + I_B(t) + I_C(t) \quad \text{Equation 9-20}$$

If there is mismatch between the two values, a neutral current mismatch occurs.

In the 3-phase, 4-wire system, the measured current RMS of the neutral wire is stored in the register ARTIN (0xE841). But when the neutral wire is not used, the V9203 calculated the RMS of the algebra sum of the phase currents automatically, and stores the sum in the register MUM (0xE94B) for neutral current mismatch detection.

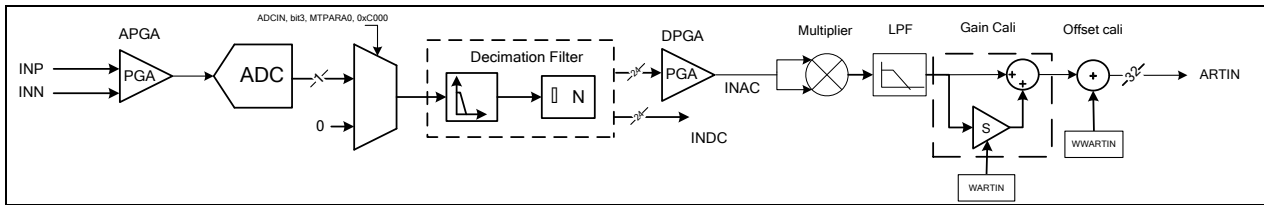


Figure 9-16 Digital Signal Processing in Neutral Wire

9.18. Zero-Crossing Detection

The V9203 supports to output the sign of the fundamental voltage and current of each phase on the pins ZX0 ~ ZX2: UA/IA on ZX0 (Pin 34), UB/IB on ZX1 (Pin 33), and UC/IC on ZX2 (Pin 32). When a high logic (1) is output on the pin, it indicates the sign is negative; when a low logic (0) is output on the pin, it indicates the sign is positive; when a high-to-low transition is output on the pin, it indicates a zero-crossing from negative to positive is occurring.

Set some bits of bit[6:1] to 1s to enable the zero-crossing interrupt. When a zero-crossing from negative to positive is detected, a zero-crossing interrupt is triggered, the flag bit is set bit, and a high logic is output on the pin IRQ0 /IRQ1 to generate an interrupt to the master MCU.

The interrupt flags can be cleared via SPI communication.

9.19. Power-off/No-Voltage Detection

In OPM1, or power-off/no-voltage pre-detection mode, use the same circuits for analog input of current, set the same analog programmable gain amplifier (APGA, 32 is recommended), and select the same digital programmable gain amplifier (DPGA), for the three current channel ADCs. Enable the output of the raw waveform of the current from the DMA_SPI interfaces. And then, users can make the current detection.

The current detection circuit in the V9203 supports full wave rectification to the raw waveform of the current output from the DMA_SPI interfaces at a sampling frequency of 6.4kHz.

If 5 continuous samples of the current waveform are higher than the pre-set threshold for current detection in ZZDCUM register (0xEC1D), a current signal is caught, and a current detection interrupt is triggered if it was enabled via setting some bits of bit[13:11] to 1s in IRQEN0 (0xA000) or IRQEN1 (0xA001). When the samples of the current wave are lower than the threshold, the interrupt bit is cleared automatically.

This interrupt can be used to fast detect the current signal in OPM1 (power-off/no-voltage pre-detection mode) and OPM2 (RMS mode).

Preset the detection threshold in the register ZZDCUM (0xEC1D) as follows:

1. Setting the gain and offset calibration for the current RMS to 0;
2. Applying rate current (I_n) to any current channel, and read the RMS (I_{rms} , a 32-bit integer, the amplitude of the I_n);

- Writing of the threshold register if the preset threshold is 0.1% of I_n :

$$TH = -\frac{I_{rms}}{1000 \times 512}, \text{ or right shifting the value } TH = -\frac{I_{rms}}{1000} \text{ by 9 bits.}$$

9.20. Initializing the V9203

When the V9203 is powered on, the clock scaler and ADCs are enabled, and the metering clock is switched to 6553.6kHz, automatically.

It is recommended to initialize the chip as follows:

- Input high logic on the pins both PM0 and PM1, and then input low logic on the pin DEEPSLEEP for more than 4ms. The system enters OPM0, or the normal operating mode;
- Write 0x10000000 to the register MTPARA0 (0xC000);
- Write 0s to the registers in the address range of 0xC800~0xC837 and 0xC880~0xC8B7 to clear the RAM;
- Write 0xAA000000 to the register MTPARA0 (0xC000), 20ms later, the RAM in the address range of 0xE000~0xE08F/0xE800~0xEAB7/0xF800~0xF87F/0xF000~0xF1EF is cleared;
- Write 0x000000FF to the register MTPARA0 (0xC000) to enable digital input of the 7 channels;
- Configure the registers MTPARA1 (0xC001) and MTPARA2 (0xC002) according to the application requirements;
- Configure the analog control registers and the registers for calibration;
- Calculate the checksum, and write it to the register MTPARA3 (0xC003);
- 1s later, write 0 to bit0 of IRQFLAG (0xA002), and read the output logic on the pin IRQ0: A logic low indicates the configuration is right and the system works normally; otherwise, re-initialize the V9203 as the above steps.

9.21. 3-Phase, 3-Wire Service

The V9203 supports both 3-phase, 4-wire service, and 3-phase, 3-wire service.

In the 3-phase, 3-wire service, Phase B is not used, so users should configure the registers as follows:

- Set the bit MTMODE (bit14, MTPARA2, 0xC002) to 1;
- Set the registers for the gain calibration of Phase B to 0x80000000, and set the registers for the power offset calibration of Phase B to 0. Then the power of Phase B does not contribute any to the energy metering;
- In the registers for power on the overall system calculation, ZZPA0 (0xEC23), ZZPA1 (0xEC24), ZZQA0 (0xEC47), ZZQA1 (0xEC48) and ZZAPPA (0xEC05), the active/reactive/apparent power of Phase B should be cleared for calculating the power on the overall system.

9.22. Calibration

9.22.1. Calibration Flow

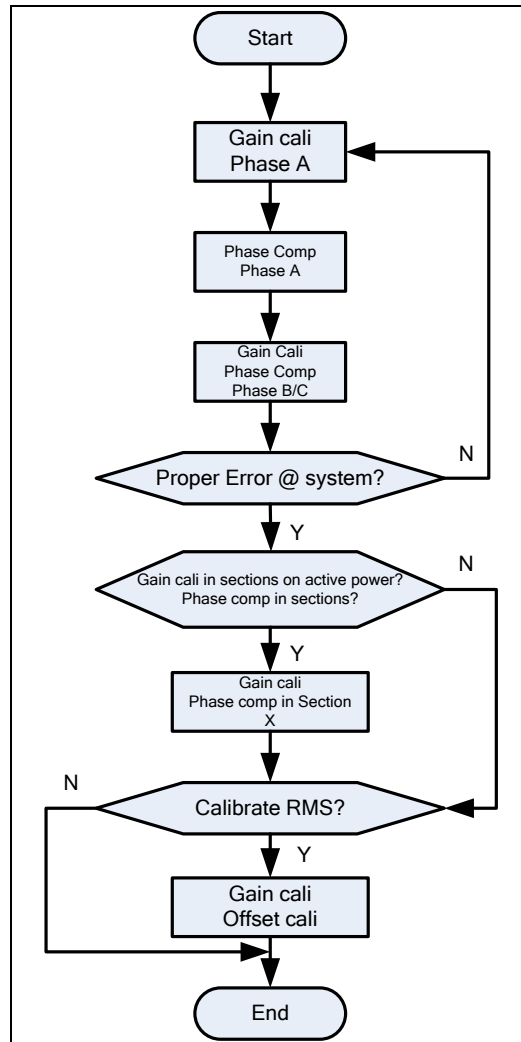


Figure 9-17 Calibration Flow

9.22.2. Equations for Calibration

All the equations in this section are suitable for both total and fundamental signal processing.

1. Equation for current/voltage RMS registers.

$$\text{Value} = V \times G \times K \quad \text{Equation 9-21}$$

Where, V is the RMS of the input signal (mV); G is the gain; and K is a constant, 2.5×10^6 .

2. Equation for power registers.

$$\text{Value} = V_i \times G_i \times V_v \times G_v \times K \times \cos\theta \times p \quad \text{Equation 9-22}$$

Where, V_i and V_v are the input current and voltage; G_i and G_v are the gains for current and voltage respectively; $\cos\theta$ is the power factor; p is the number of phase; K is a coefficient, 750 for 4-wire service, and 650 for 3-wire service.

3. Equation for ratio factor of RMS and power.

The value acquired by Equation 9-21 or Equation 9-22 is the theoretical value of the register of the RMS or power. It must be divided by a ratio factor to get the actual value.

$$I_{\text{value}} = \frac{\text{Value}}{D} \quad \text{Equation 9-23}$$

Where, Value is the content of the register acquired by Equation 9-21 or Equation 9-22; D is the ratio factor; and I_{value} is the actual value.

Take the total current RMS of Phase A for example,

Firstly, the content of the register is acquired as follows:

$$\begin{aligned} \text{Value} &= V \times G \times K \\ &= 20 \times 4 \times 2.5 \times 10^6 = 200000000 = 0x\text{BEBC200} \end{aligned}$$

Secondly, the ratio factor is acquired if the actual current is 1.5000A

$$\begin{aligned} 15000 &= \frac{200000000}{D} \\ D &= \frac{200000000}{15000} = 13333 \end{aligned}$$

Then, D is used as the ratio factor. Users can get the actual current RMS by dividing the content of the register by the ratio factor. By default, current RMS is accurate to the 4th decimal place.

4. Equation for line frequency registers.

$$f = \frac{3276800}{\text{FRQ}} \quad \text{Equation 9-24}$$

Where, f is the line frequency to be measured; FRQ is the content of the registers for line frequency of each phase, in the address range of 0xC008~0xC00A, in the form of decimal.

5. Equation for power factor registers.

$$\cos\theta = \frac{\text{Value}}{2^{31}} \quad \text{Equation 9-25}$$

Where, Value is content of the power factor registers; $\cos\theta$ is the actual power factor.

6. Equation for energy accumulation threshold.

$$\text{PGAT} = P \times T \times 6.25 \quad \text{Equation 9-26}$$

Where, P is the value of registers for the total or fundamental active power on the overall system when rate voltage/current is applied;

T is the time constant, acquired via the equation:

$$T = \frac{3600 \times 1000}{\text{PulseConstant} \times U_n \times I_n \times \text{PhaseNumber}} \quad \text{Equation 9-27}$$

7. Equation for no-load detection threshold.

$$\text{NPGAT} = K \times P \quad \text{Equation 9-28}$$

Where, P is the content of the power register when rate current / voltage is applied when the absolute value of the total/fundamental active/reactive power is used for no-load detection, or the content of the RMS register when the fundamental current RMS is used for no-load detection;

K is the percentage of the starting current, for example, K should not be lower than 4‰ for an energy meter of Class 1. In practice, the K could be a half of the normal value, for example, 2‰ is used for the meter of Class 1.

It must be ensured that the bottom threshold must be less than the top threshold for the no-load detection.

8. Equation for the calibration registers.

$$S = 2^{31} \left(\frac{1}{1+e} - 1 \right) + S_1 \left(\frac{1}{1+e} \right) \quad \text{Equation 9-29}$$

Where, S is the content of the registers for the gain calibration of the total/fundamental active/reactive and current/voltage RMS, in the form of 2'-complement; S_1 is the original gain calibration; e is the error.

9. Equation for registers for phase compensation.

Please note that phase compensation must be executed after power calibration.

At a lower power factor (PF), the phase angle error can cause greater energy metering error. So generally, the phase angle error is calibrated at PF=0.5L to ensure the metering accuracy. When PF=0.5L, the phase angle between current and voltage is $-\frac{\pi}{3}$. According to Equation 9-2, a relationship between E and N depicted by the following equation is reached.

$$N = \text{Round} \left(\frac{1}{\pi} \times \frac{f_{\text{smp}}}{100} \times \left\{ -\arccos[0.5 \times (1 + E)] + \frac{\pi}{3} \right\} \right) \quad \text{Equation 9-30 where,}$$

N is the value, signed, to be set to the phase compensation control registers to correct the phase angle error. A positive N indicates that current signal must be delayed, so "0" must be set to the sign bit; a negative N indicates that the voltage signal must be delayed, so "1" must be set to the sign bit;

E is the energy metering error displayed in LCD screen of the calibration equipment;

f_{smp} is the sampling frequency of the phase compensation circuit, Hz.

Equation 9-30 can be used to calculate the value N over the full range. But in practice, users can use another method to simplify the calculation.

The minimum correction range is $\pm 1.4^\circ$, and when x is in a small range, the curve for function $y = \cos x$ is approximate to a line. So when PF is equal to 0.5L and x is over the range of $\left[-\frac{\pi}{3} - \frac{1.4 \times \pi}{180}, -\frac{\pi}{3} + \frac{1.4 \times \pi}{180} \right]$, users can use a simple equation as follows to calculate the value N.

$$N = Round\left(\frac{3011}{2} \times E \times \frac{f_{smp1}}{819200}\right) \quad \text{Equation 9-31}$$

However, please note that Equation 9-31 is only an approximate equation. Beyond a certain range of E, Equation 9-30 and Equation 9-31 may lead to different results. If they are not equal to each other, users must use Equation 9-30 to correct the phase angle error.

10. Equation for registers for current threshold for phase compensation or gain calibration of total active power in sections.

$$\text{Value} = \text{ValueI} \times K \quad \text{Equation 9-32}$$

ValueI is the content of the current RMS register calculated by Equation 9-21 when rate current is applied; K is the section points in the form of the percentage of the rate current, for example, 15%.

10. Interrupt

The interrupt system manages the interrupt sources and outputs two interrupt pulses (IRQ0 and IRQ1).

Two interrupt enable registers, IRQEN0 (0xA000) and IRQEN1 (0xA001), can enable or disable the interrupts and its output on the pin IRQ0 and IRQ1 respectively, and the interrupt flag register IRQFLAG (0xA002) sets flag bit for each interrupt that is occurring.

10.1. Interrupt Registers

Table 10-1 IRQ0 Interrupt Enable Register (0xA000, IRQEN0)

0xA000, R/W, IRQ0 Interrupt Enable Register, IRQEN0				
Bit		Default Value	Function Description	
bit[31:17]	Reserved	0		
bit16	PD	0	To enable power-down interrupt, high-level triggered.	1, enable; 0, disable.
bit15	SPI	0	To enable SPI communication error interrupt, rising edge triggered.	1, enable; 0, disable.
bit14	PSE	0	To enable phase sequence error interrupt, rising edge triggered.	1, enable; 0, disable.
bit13	EXIIC	0	To enable current detection interrupt of Channel IC, level triggered.	1, enable; 0, disable.
bit12	EXIIB	0	To enable current detection interrupt of Channel IB, level triggered.	1, enable; 0, disable.
bit11	EXIIA	0	To enable current detection interrupt of Channel IA, level triggered.	1, enable; 0, disable.
bit10	CF3	0	To enable the pulse output interrupt on the pin CF3, rising edge triggered.	1, enable; 0, disable.
bit9	CF2	0	To enable the pulse output interrupt on the pin CF2, rising edge triggered.	1, enable; 0, disable.

0xA000, R/W, IRQ0 Interrupt Enable Register, IRQEN0

Bit		Default Value	Function Description	
bit8	CF1	0	To enable the pulse output interrupt on the pin CF1, rising edge triggered.	1, enable; 0, disable.
bit7	CF0	0	To enable the pulse output interrupt on the pin CF0, rising edge triggered.	1, enable; 0, disable.
bit6	ZXIC	0	To enable the interrupt by negative to positive zero-crossing of Channel IC, edge triggered.	1, enable; 0, disable.
bit5	ZXIB	0	To enable the interrupt by negative to positive zero-crossing of Channel IB, edge triggered.	1, enable; 0, disable.
bit4	ZXIA	0	To enable the interrupt by negative to positive zero-crossing of Channel IA, edge triggered.	1, enable; 0, disable.
bit3	ZXUC	0	To enable the interrupt by negative to positive zero-crossing of Channel UC, edge triggered.	1, enable; 0, disable.
bit2	ZXUB	0	To enable the interrupt by negative to positive zero-crossing of Channel UB, edge triggered.	1, enable; 0, disable.
bit1	ZXUA	0	To enable the interrupt by negative to positive zero-crossing of Channel UA, edge triggered.	1, enable; 0, disable.
bit0	CHK	0	To enable system configuration error interrupt, high-level triggered.	This interrupt is forced to be enabled even though this bit is set to 0.

The configuration of this register can be read out of the register ZZIRQ0 (0xEC20) which is accessed as a 32-bit register with the 15 most significant bits padded with 0s and is used to calculate the checksum for system check.

Table 10-2 IRQ1 Interrupt Enable Register (0xA001, IRQEN1)

0xA001, R/W, IRQ1 Interrupt Enable Register, IRQEN1				
Bit		Default Value	Function Description	
bit[31:17]	Reserved	0		
bit16	PD	0	To enable power-down interrupt, high-level triggered.	1, enable; 0, disable.
bit15	SPI	0	To enable SPI communication error interrupt, rising edge triggered.	1, enable; 0, disable.
bit14	PSE	0	To enable phase sequence error interrupt, rising edge triggered.	1, enable; 0, disable.
bit13	EXIIC	0	To enable current detection interrupt of Channel IC, level triggered.	1, enable; 0, disable.
bit12	EXIIB	0	To enable current detection interrupt of Channel IB, level triggered.	1, enable; 0, disable.
bit11	EXIIA	0	To enable current detection interrupt of Channel IA, level triggered.	1, enable; 0, disable.
bit10	CF3	0	To enable the pulse output interrupt on the pin CF3, rising edge triggered.	1, enable; 0, disable.
bit9	CF2	0	To enable the pulse output interrupt on the pin CF2, rising edge triggered.	1, enable; 0, disable.
bit8	CF1	0	To enable the pulse output interrupt on the pin CF1, rising edge triggered.	1, enable; 0, disable.
bit7	CF0	0	To enable the pulse output interrupt on the pin CF0, rising edge triggered.	1, enable; 0, disable.
bit6	ZXIC	0	To enable the interrupt by negative to positive zero-crossing of Channel IC, edge triggered.	1, enable; 0, disable.
bit5	ZXIB	0	To enable the interrupt by negative to positive zero-crossing of Channel IB, edge triggered.	1, enable; 0, disable.
bit4	ZXIA	0	To enable the interrupt by negative to positive zero-crossing of Channel IA, edge triggered.	1, enable; 0, disable.
bit3	ZXUC	0	To enable the interrupt by negative to positive zero-crossing of Channel UC,	1, enable; 0, disable.

0xA001, R/W, IRQ1 Interrupt Enable Register, IRQEN1				
Bit		Default Value	Function Description	
			edge triggered.	
bit2	ZXUB	0	To enable the interrupt by negative to positive zero-crossing of Channel UB, edge triggered.	1, enable; 0, disable.
bit1	ZXUA	0	To enable the interrupt by negative to positive zero-crossing of Channel UA, edge triggered.	1, enable; 0, disable.
bit0	CHK	0	To enable system configuration error interrupt, high-level triggered.	1, enable; 0, disable.
The configuration of this register can be read out of the register ZZIRQ1 (0xEC21) which is accessed as a 32-bit register with the 15 most significant bits padded with 0s and is used to calculate the checksum for system check.				

Table 10-3 Interrupt Flag Register (0xA002, IRQFLAG)

0xA002, R/W, Interrupt Flag Register, IRQFLAG				
bit		Default Value	Function Description	
bit[31:17]	Reserved	0		
bit16	PD	0	To indicate a power-down interrupt occurs.	1, the interrupt occurs.
bit15	SPI	0	To indicate an SPI communication error interrupt occurs.	1, the interrupt occurs.
bit14	PSE	0	To indicate a phase sequence error interrupt occurs.	1, the interrupt occurs.
bit13	EXIIC	0	To indicate a current detection interrupt of Channel IC occurs.	1, the interrupt occurs.
bit12	EXIIB	0	To indicate a current detection interrupt of Channel IB occurs.	1, the interrupt occurs.
bit11	EXIIA	0	To indicate a current detection interrupt of Channel IA occurs.	1, the interrupt occurs.
bit10	CF3	0	To indicate a pulse output interrupt on pin CF3 occurs.	1, the interrupt occurs.

0xA002, R/W, Interrupt Flag Register, IRQFLAG

bit		Default Value	Function Description	
bit9	CF2	0	To indicate a pulse output interrupt on pin CF2 occurs.	1, the interrupt occurs.
bit8	CF1	0	To indicate a pulse output interrupt on pin CF1 occurs.	1, the interrupt occurs.
bit7	CF0	0	To indicate a pulse output interrupt on pin CF0 occurs.	1, the interrupt occurs.
bit6	ZXIC	0	To indicate an interrupt by negative to positive zero-crossing of Channel IC occurs.	1, the interrupt occurs.
bit5	ZXIB	0	To indicate an interrupt by negative to positive zero-crossing of Channel IB occurs.	1, the interrupt occurs.
bit4	ZXIA	0	To indicate an interrupt by negative to positive zero-crossing of Channel IA occurs.	1, the interrupt occurs.
bit3	ZXUC	0	To indicate an interrupt by negative to positive zero-crossing of Channel UC occurs.	1, the interrupt occurs.
bit2	ZXUB	0	To indicate an interrupt by negative to positive zero-crossing of Channel UB occurs.	1, the interrupt occurs.
bit1	ZXUA	0	To indicate an interrupt by negative to positive zero-crossing of Channel UA occurs.	1, the interrupt occurs.
bit0	CHK	0	To indicate a system configuration error interrupt occurs.	1, the interrupt occurs.

10.2. System Configuration Error Interrupt

In the V9203, the configuration of the ZZPARA3 (0xEC2A) and the other 109 registers listed in the following table must be summed up for system configuration checksum calculation, and the checksum must be 0xFFFFFFFF. The checksum is calculated once every 640ms. If the checksum is 0xFFFFFFFF, it means the configuration is right; otherwise, a system configuration error occurs.

When a system configuration error occurs, the system configuration interrupt generated, and a high logic is output on the pin IRQ0 whatever bit0 of IRQEN0 register (0xA000) is set. But, if bit0 of IRQEN1 register (0xA001) is cleared, this interrupt output is disabled on the pin IRQ1.

Table 10-4 Registers for System Configuration Checksum Calculation

No.	Address	Register		R/W	Bits for Checksum Calculation	Default Value
1	0xE8AA	CTHH	To set the top threshold for the no-load detection.	R/W	32-bit	0
2	0xE8AB	CTHL	To set the bottom threshold for the no-load detection.	R/W	32-bit	0
3	0xE954	WAEC0	To set phase compensation in Section 0.	R/W	32-bit	0
4	0xE955	WAEC1	To set phase compensation in Section 1.	R/W	32-bit	0
5	0xE956	WAEC2	To set phase compensation in Section 2.	R/W	32-bit	0
6	0xE957	WAEC3	To set phase compensation in Section 3.	R/W	32-bit	0
7	0xE958	WAEC4	To set phase compensation in Section 4.	R/W	32-bit	0
8	0xE95A	WAPTAK0	To set gain calibration in Section 0 of the total active power of Phase A.	R/W	32-bit	0
9	0xE95B	WAPTAK1	To set gain calibration in Section 1 of the total active power of Phase A.	R/W	32-bit	0
10	0xE95C	WAPTAK2	To set gain calibration in Section 2 of the total active power of Phase A.	R/W	32-bit	0
11	0xE95E	WAPTBK0	To set gain calibration in Section 0 of the total active power of Phase B.	R/W	32-bit	0
12	0xE95F	WAPTBK1	To set gain calibration in Section 1 of the total active power of Phase B.	R/W	32-bit	0
13	0xE960	WAPTBK2	To set gain calibration in Section 2 of the total active power of Phase B.	R/W	32-bit	0
14	0xE962	WAPTCK0	To set gain calibration in Section 0 of the	R/W	32-bit	0

No.	Address	Register		R/W	Bits Checksum Calculation for	Default Value
			total active power of Phase C.			
15	0xE963	WAPTCK1	To set gain calibration in Section 1 of the total active power of Phase C.	R/W	32-bit	0
16	0xE964	WAPTCK2	To set gain calibration in Section 2 of the total active power of Phase C.	R/W	32-bit	0
17	0xE965	WAQTA	To set gain calibration of the total reactive power of Phase A.	R/W	32-bit	0
18	0xE966	WAQTB	To set gain calibration of the total reactive power of Phase B.	R/W	32-bit	0
19	0xE967	WAQTC	To set gain calibration of the total reactive power of Phase C.	R/W	32-bit	0
20	0xE968	WARTIA	To set gain calibration of the total current RMS of Phase A.	R/W	32-bit	0
21	0xE969	WARTIB	To set gain calibration of the total current RMS of Phase B.	R/W	32-bit	0
22	0xE96A	WARTIC	To set gain calibration of the total current RMS of Phase C.	R/W	32-bit	0
23	0xE96B	WARTIN	To set gain calibration of the total current RMS of Channel IN.	R/W	32-bit	0
24	0xE96C	WARTUA	To set gain calibration of the total voltage RMS of Phase A.	R/W	32-bit	0
25	0xE96D	WARTUB	To set gain calibration of the total voltage RMS of Phase B.	R/W	32-bit	0
26	0xE96E	WARTUC	To set gain calibration of the total voltage RMS of Phase C.	R/W	32-bit	0
27	0xE96F		It is recommended to write of 0s.	R/W	32-bit	0
28	0xE970	WBPTA	To set gain calibration of the fundamental active power of Phase A.	R/W	32-bit	0
29	0xE971	WBPTB	To set gain calibration of the fundamental active power of Phase B.	R/W	32-bit	0
30	0xE972	WBPTC	To set gain calibration of the fundamental active power of Phase C.	R/W	32-bit	0
31	0xE973	WBQTA	To set gain calibration of the fundamental reactive power of Phase A.	R/W	32-bit	0

No.	Address	Register		R/W	Bits Checksum Calculation for	Default Value
32	0xE974	WBQTB	To set gain calibration of the fundamental reactive power of Phase B.	R/W	32-bit	0
33	0xE975	WBQTC	To set gain calibration of the fundamental reactive power of Phase C.	R/W	32-bit	0
34	0xE976	WBRTIA	To set gain calibration of the fundamental current RMS of Phase A.	R/W	32-bit	0
35	0xE977	WBRTIB	To set gain calibration of the fundamental current RMS of Phase B.	R/W	32-bit	0
36	0xE978	WBRTIC	To set gain calibration of the fundamental current RMS of Phase C.	R/W	32-bit	0
37	0xE979	WBRTUA	To set gain calibration of the fundamental voltage RMS of Phase A.	R/W	32-bit	0
38	0xE97A	WBRTUB	To set gain calibration of the fundamental voltage RMS of Phase B.	R/W	32-bit	0
39	0xE97B	WBRTUC	To set gain calibration of the fundamental voltage RMS of Phase C.	R/W	32-bit	0
40	0xE97C	WTPA0A	To set Current Threshold 0 for phase compensation in sections of Phase A.	R/W	32-bit	0
41	0xE97D	WTPA0B	To set Current Threshold 0 for phase compensation in sections of Phase B.	R/W	32-bit	0
42	0xE97E	WTPA0C	To set Current Threshold 0 for phase compensation in sections of Phase C.	R/W	32-bit	0
43	0xE97F	WTPA1A	To set Current Threshold 1 for phase compensation in sections of Phase A.	R/W	32-bit	0
44	0xE980	WTPA1B	To set Current Threshold 1 for phase compensation in sections of Phase B.	R/W	32-bit	0
45	0xE981	WTPA1C	To set Current Threshold 1 for phase compensation in sections of Phase C.	R/W	32-bit	0
46	0xE982	WTPA2A	To set Current Threshold 2 for phase compensation in sections of Phase A.	R/W	32-bit	0
47	0xE983	WTPA2B	To set Current Threshold 2 for phase compensation in sections of Phase B.	R/W	32-bit	0
48	0xE984	WTPA2C	To set Current Threshold 2 for phase compensation in sections of Phase C.	R/W	32-bit	0

No.	Address	Register		R/W	Bits Checksum Calculation for	Default Value
49	0xE985	WTPA3A	To set Current Threshold 3 for phase compensation in sections of Phase A.	R/W	32-bit	0
50	0xE986	WTPA3B	To set Current Threshold 3 for phase compensation in sections of Phase B.	R/W	32-bit	0
51	0xE987	WTPA3C	To set Current Threshold 3 for phase compensation in sections of Phase C.	R/W	32-bit	0
52	0xE988	WTPP0A	To set Current Threshold 0 for calibrating the total active power of Phase A.	R/W	32-bit	0
53	0xE989	WTPP0B	To set Current Threshold 0 for calibrating the total active power of Phase B.	R/W	32-bit	0
54	0xE98A	WTPP0C	To set Current Threshold 0 for calibrating the total active power of Phase C.	R/W	32-bit	0
55	0xE98B	WTPP1A	To set Current Threshold 1 for calibrating the total active power of Phase A.	R/W	32-bit	0
56	0xE98C	WTPP1B	To set Current Threshold 1 for calibrating the total active power of Phase B.	R/W	32-bit	0
57	0xE98D	WTPP1C	To set Current Threshold 1 for calibrating the total active power of Phase C.	R/W	32-bit	0
58	0xE98E	WWAPTA	To set offset calibration of the total active power of Phase A.	R/W	32-bit	0
59	0xE98F	WWAPT B	To set offset calibration of the total active power of Phase B.	R/W	32-bit	0
60	0xE990	WWAPTC	To set offset calibration of the total active power of Phase C.	R/W	32-bit	0
61	0xE991	WWAQTA	To set offset calibration of the total reactive power of Phase A.	R/W	32-bit	0
62	0xE992	WWAQTB	To set offset calibration of the total reactive power of Phase B.	R/W	32-bit	0
63	0xE993	WWAQTC	To set offset calibration of the total reactive power of Phase C.	R/W	32-bit	0
64	0xE994	WWARTIA	To set offset calibration of the total current RMS of Phase A.	R/W	32-bit	0
65	0xE995	WWARTIB	To set offset calibration of the total current RMS of Phase B.	R/W	32-bit	0

No.	Address	Register		R/W	Bits Checksum Calculation for	Default Value
66	0xE996	WWARTIC	To set offset calibration of the total current RMS of Phase C.	R/W	32-bit	0
67	0xE997	WWARTIN	To set offset calibration of the total current RMS of Channel IN.	R/W	32-bit	0
68	0xE998	WWARTUA	To set offset calibration of the total voltage RMS of Phase A.	R/W	32-bit	0
69	0xE999	WWARTUB	To set offset calibration of the total voltage RMS of Phase B.	R/W	32-bit	0
70	0xE99A	WWARTUC	To set offset calibration of the total voltage RMS of Phase C.	R/W	32-bit	0
71	0xE99B		Reserved. It is recommended to write of 0s.	R/W	32-bit	0
72	0xE99C	WWBPTA	To set offset calibration of the fundamental active power of Phase A.	R/W	32-bit	0
73	0xE99D	WWBPTB	To set offset calibration of the fundamental active power of Phase B.	R/W	32-bit	0
74	0xE99E	WWBPTC	To set offset calibration of the fundamental active power of Phase C.	R/W	32-bit	0
75	0xE99F	WWBQTA	To set offset calibration of the fundamental reactive power of Phase A.	R/W	32-bit	0
76	0xE9A0	WWBQTB	To set offset calibration of the fundamental reactive power of Phase B.	R/W	32-bit	0
77	0xE9A1	WWBQTC	To set offset calibration of the fundamental reactive power of Phase C.	R/W	32-bit	0
78	0xE9A2	WWBRTIA	To set offset calibration of the fundamental current RMS of Phase A.	R/W	32-bit	0
79	0xE9A3	WWBRTIB	To set offset calibration of the fundamental current RMS of Phase B.	R/W	32-bit	0
80	0xE9A4	WWBRTIC	To set offset calibration of the fundamental current RMS of Phase C.	R/W	32-bit	0
81	0xE9A5	WWBRTUA	To set offset calibration of the fundamental voltage RMS of Phase A.	R/W	32-bit	0
82	0xE9A6	WWBRTUB	To set offset calibration of the fundamental voltage RMS of Phase B.	R/W	32-bit	0

No.	Address	Register		R/W	Bits for Checksum Calculation	Default Value
83	0xE9A7	WWBRTUC	To set offset calibration of the fundamental voltage RMS of Phase C.	R/W	32-bit	0
84	0xEC01	ZZANA0	Analog Control Register 0, is read out as the configuration of ANCtrl0 (0x8000).	R	32-bit	0
85	0xEC02	ZZANA1	Analog Control Register 1, is read out as the configuration of ANCtrl1 (0x8001).	R	32-bit	0
86	0xEC03	ZZANA2	Analog Control Register 2, is read out as the configuration of ANCtrl2 (0x8002).	R	32-bit	0
87	0xEC04	ZZANA3	Analog Control Register 3, is read out as the configuration of ANCtrl3 (0x8003).	R	32-bit	0
88	0xEC05	ZZAPPA	To select the mode for total/fundamental apparent power on the overall system calculation.	R/W	As a 32-bit register with 29 most significant bits padded with 0s.	0
89	0xEC15	ZZCPSEL	To select the mode for no-load detection.	R/W	As a 32-bit register with 31 most significant bits padded with 0s.	0
90	0xEC16	ZZDCIA	To preset the bias current for the current of Phase A.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
91	0xEC17	ZZDCIB	To preset the bias current for the current of Phase B.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
92	0xEC18	ZZDCIC	To preset the bias current for the current	R/W	As a 32-bit	0

No.	Address	Register		R/W	Bits for Checksum Calculation	Default Value
			of Phase C.		register with bit23 being the sign bit and with sign extended to 32 bits.	
93	0xEC19	ZZDCIN	To preset the bias current for the current of Channel IN.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
94	0xEC1A	ZZDCUA	To preset the bias current for the voltage of Phase A.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
95	0xEC1B	ZZDCUB	To preset the bias current for the voltage of Phase B.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
96	0xEC1C	ZZDCUC	To preset the bias current for the voltage of Phase C.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32 bits.	0
97	0xEC1D	ZZDCUM	To set the threshold for current detection.	R/W	As a 32-bit register with bit23 being the sign bit and with sign extended to 32	0

No.	Address	Register		R/W	Bits for Checksum Calculation	Default Value
					bits.	
98	0xEC1E	ZZEGYTHH	To set the higher 32 bits of the energy threshold.	R/W	As a 32-bit register with 14 most significant bits padded with 0s.	0
99	0xEC1F	ZZEGYTHL	To set the lower 32 bits of the energy threshold.	R/W	32-bit	0
100	0xEC20	ZZIRQ0	IRQ0 interrupt enable register is read out as the configuration of IRQEN0 (0xA000).	R	As a 32-bit register with the 15 most significant bits padded with 0s.	0
101	0xEC21	ZZIRQ1	IRQ1 interrupt enable register is read out as the configuration of IRQEN1 (0xA001).	R	As a 32-bit register with the 15 most significant bits padded with 0s.	0
102	0xEC23	ZZPA0	To select the power source for the total/fundamental active power on the overall system in Calculation Mode 0.	R/W	As a 32-bit register with the 26 most significant bits padded with 0s.	0
103	0xEC24	ZZPA1	To select the power source for the total/fundamental active power on the overall system in Calculation Mode 1.	R/W	As a 32-bit register with the 26 most significant bits padded with 0s.	0
104	0xEC27	ZZPARA0	Metering control register 0 is read out as the configuration of MTPARA0 (0xC000).	R	32-bit	0
105	0xEC28	ZZPARA1	Metering control register 1 is read out as the configuration of MTPARA1 (0xC001).	R	32-bit	0
106	0xEC29	ZZPARA2	Metering control register 2 is read out as	R	32-bit	0

No.	Address	Register		R/W	Bits for Checksum Calculation	Default Value
			the configuration of MTPARA2 (0xC002).			
107	0xEC2A	ZZPARA3	Metering control register 3 is read out as the configuration of MTPARA3 (0xC003).	R	32-bit	0
108	0xEC34	ZZPCF0A	To select the source for CF pulse.	R/W	As a 32-bit register with the 26 most significant bits padded with 0s.	0
109	0xEC47	ZZQA0	To select the power source for the total/fundamental reactive power on the overall system in Calculation Mode 0.	R/W	As a 32-bit register with the 26 most significant bits padded with 0s.	0
110	0xEC48	ZZQA1	To select the power source for the total/fundamental reactive power on the overall system in Calculation Mode 1.	R/W	As a 32-bit register with the 26 most significant bits padded with 0s.	0

10.3. Zero-Crossing Interrupts

The V9203 supports to output the sign bit of the fundamental voltage and current of each phase on the pins ZX0 ~ ZX2: UA/IA on ZX0 (Pin 34), UB/IB on ZX1 (Pin 33), and UC/IC on ZX2 (Pin 32). When a high logic (1) is output on the pins, it indicates the sign is negative; when a low logic (0) is output on the pins, it indicates the sign is positive; when a high-to-low transition is output on the pins, it indicates a zero-crossing from negative to positive is occurring.

When some bits of bit[6:1] are set to 1s, the zero-crossing interrupt is enabled when a zero-crossing from negative to positive is occurring, the flag bits are set to 1s, and high logics are output on the pin IRQ0 /IRQ1 to generate an interrupt to the master MCU.

The interrupt flags can be cleared via SPI communication.

10.4. CF Pulse Output Interrupt

When the CF pulse is output on the pins CF0~CF3, the low-to-high pulse transition can trigger an

interrupt on the pin IRQ0 or/and IRQ1 if it is enabled.

The interrupt flag can be cleared via SPI communication.

10.5. Current Detection Interrupt

The current detection circuit in the V9203 supports full wave rectification to the raw waveform of the current output from the DMA_SPI interfaces. And the sampling frequency is 6.4kHz.

If 5 continuous samples of the current wave are higher than the pre-set threshold for current detection in ZZDCUM register (0xEC1D), a current signal is caught, and a current detection interrupt is generated if it was enabled via setting some bits of bit[13:11] to 1s in IRQEN0 (0xA000) or IRQEN1 (0xA001). When the samples of the current wave are lower than the threshold, the interrupt is cleared automatically.

This interrupt can be used to fast detect the current signal in OPM1 (power-off/no-voltage pre-detection mode) and OPM2 (RMS mode).

10.6. Phase Sequence Error Interrupt

The V9203 supports phase sequence detection based on the sequence of the zero-crossing of phase voltage from negative to positive. If the sequence is not from Phase A, to Phase B, and then to Phase C, it indicates a phase sequence error interrupt is occurring. If bit15 of IRQEN0 (0xA000) or IRQEN1 (0xA001) is set to 1, the flag bit is set to "1" when the interrupt is occurring, and an interrupt pulse is output on the pin IRQ0 or IRQ1.

The interrupt flag can be cleared via SPI communication.

This interrupt must be disabled in the 3-phase, 3-wire application.

10.7. SPI Communication Interrupt

When an error occurs on the communication between the V9203 and the master MCU via the SPI interfaces, the SPI communication interrupt is triggered.

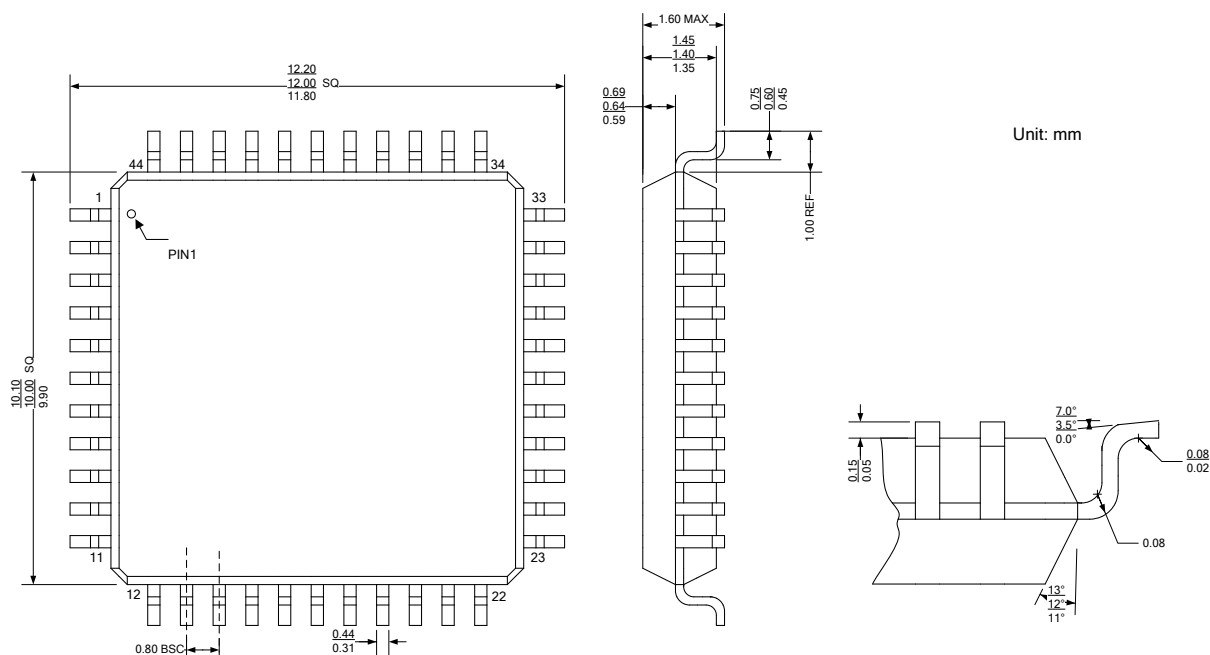
The interrupt flag can be cleared via SPI communication.

10.8. Power-Down Interrupt

When the input on the pin VDCIN is less than 1V, the power supply monitor circuit outputs logic 1 signaling the master MCU that the V9203 has been powered down.

When bit16 of IRQEN0 (0xA000) or IRQEN1 (0xA001) is set to 1, bit16 of IRQFLAG (0xA002) is set bit when the power-down interrupt is triggered, an interrupt is generated to the master MCU, and a high logic is output on the pin IRQ0 (Pin30) or IRQ1 (Pin31).

11. Outline Dimensions



Revision History

Date	Version	Description
2014-06-23	V2.0	Modified the function description of bit[15:11] of ANCtrl2 (0x8002). Modified the description of phase compensation.
2013-05-10	V1.0	Initial release.