ANALOG DEVICES

AN-1415
APPLICATION NOTE

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ADE9078 Low Power Mode for No Voltage Detection

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INTRODUCTION

In China, there is a requirement for polyphase meters related to no voltage detection. This requirement defines no voltage as any voltage on all phases lower than the threshold when power is on, and when the current is greater than 5% of the nominal voltage.

When a no voltage event happens, the meter records phase voltage, phase current, power factor, and active power. The meter is designed as a dual power supply. One is based on an external power line and the other is based on an external battery. When a voltage event does not occur, the ac/dc power supply stops working, and the battery-powered microcontroller sets the ADE9078 analog front end (AFE) to detect current.

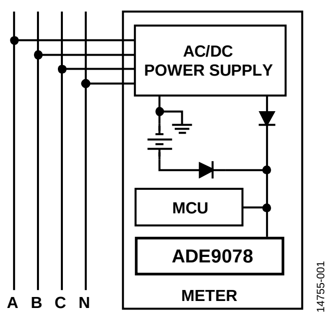

Figure 1. Block Diagram of Power Supply Circuit in the Meter

This application note focuses on how to configure the ADE9078 to detect a no voltage event.

ADE9078 POWER MODE INTRODUCTION

The power mode of the ADE9078 is explained in this section. The ADE9078 has four power modes for switching. The user saves power depending on which power mode is used.

Table 1 shows the specifications of the different power modes.

Table 1. Power Consumption for Each Power Mode

Power Mode	Power Consumption	Comments
PSM0	12 mA	Normal mode, seven ADCs enabled
PSM1	9 mA	Fast rms, watt, VAR measurement within 30 ms for tamper detection
PSM2	200 µA	Compares current to threshold, V_{DD} = 3.3 V, AVDDOUT = 0 V, DVDDOUT = 0 V
PSM3	300 nA	Idle, V_{DD} = 3.3 V, AVDDOUT = 0 V, DVDDOUT = 0 V

Power Saving Mode 0 (PSM0) mode is full function mode, which consumes the current at 12 mA. The user can set PSM0 mode to read/write all registers in the ADE9078. PSM0 is suitable for a meter powered by a power line. Normally, the ADE9078 works in PSM0 mode, which means at least one of the phases supplies power for the meter.

PSM1 and PSM2, in combination with PSM3, enable low power tamper detection, which is required in China. These operating modes enable the user to check for tampering. In scenarios involving tampering, a battery is typically used to power the ADE9078.

The tamper measurement mode, PSM1, allows the user to make key measurements quickly, such as the voltage rms (IRMS), current rms (VRMS), watts, and voltage ampere reactive (VAR) with a reduced consumption when compared to PSM0. It uses a different computation method than PSM0. These measurements are computed over 20 ms. In IRMS measurement, the accuracy achieved is lower than 0.2% at 40.5 ms after entering PSM1 mode at 600:1. For watts, the accuracy achieved is lower than 0.2% at 40.5 ms after entering PSM1 mode at 600:1.

In the PSM2 operating mode, the ADE9078 enters a low power state where only a low power comparator is active. The low dropout regulator (LDO), analog-to-digital converter (ADC), digital signal processor (DSP), and crystal oscillator are turned off. The input currents, I_A, I_B, and I_C, are compared against a user selected level set in the PSM2_CFG register. If any of the three currents exceed the threshold, IRQ0 and IRQ1 are generated. The amount of time used to detect the peak currents is determined by the user and set in the LPLINE[4:0] bits of the PSM2_CFG register. The time for the measurement period is (LPLINE[4:0] + 4)/50 sec. The ADE9078 indicates that a tamper has been detected if at least LPLINE[4:0] + 1 peaks are obtained on a current channel. The maximum allowed value in LPLINE[4:0] is 0x0A.

PSM3 is idle mode, which means all functions inside the ADE9078 are shut down and the current achieved is lower than 1 µA.

The PM0 and the PM1 pins (PMx) control PSMx mode, x refers to PSM0 through PSM3.

Table 2 shows the PMx states and related PSMx mode.

Table 2. PMx State and Related PMx Mode

PSMx Mode	PM0	PM1
PSM0	0	0
PSM1	0	1
PSM2	1	0
PSM3	1	1

Use the input/output pins of the MCU to connect the PM0 and PM1 pins to select the power mode.

HARDWARE SOLUTION

As shown in Figure 2, there are two power supply sources in the meter: the ac/dc converter and the ac/dc power supply. They are switched by two diodes. The MCU senses the voltage output from the ac/dc power supply. If there is no voltage output, all phases (A, B, and C) power off. In this case, the MCU starts the no voltage detection function. When one of the three phases powers on, the ac/dc power supply outputs voltage, supplying power. Otherwise, the ac/dc shuts down, and the input/output pin triggers a low voltage to inform the MCU that a no voltage situation has occurred and that the battery is supplying power. In this situation, the MCU and the ADE9078 enter low power consumption mode.

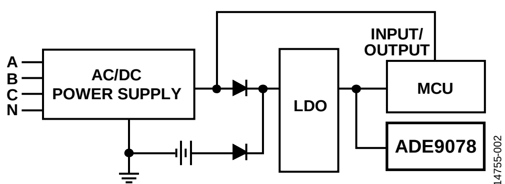

Figure 2. Block Diagram of Power Supply Switching Circuit

Figure 3 shows the connection requirement for the no voltage detection function between the MCU and the ADE9078. If a no voltage situation happens, the MCU places the ADE9078 in low power mode through the PM0 pin and PM1 pin.

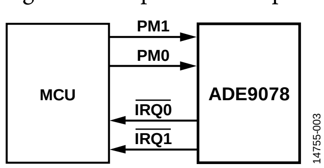

Figure 3. Connection Between MCU and ADE9078 for No Voltage Detection

SOFTWARE PROCEDURE

Figure 4 shows the procedure for no voltage detection.

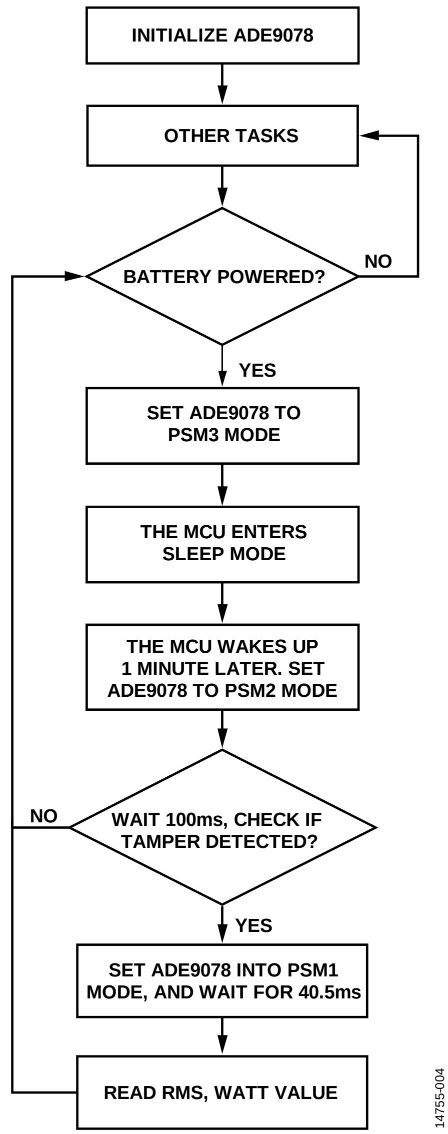

Figure 4. Software Procedure for No Voltage Detection

The PSM2_CFG register is set during initialization of the ADE9078. PSM2_CFG is the configuration register for PSM2 mode. For example, if the nominal current is 10 A, the current transformer ratio is 2500:1, and the burden resistor is 12.5 Ω, then the dynamic ratio of peak value at 5% of the nominal current is:

$$\frac{1}{\frac{10}{2500} \times 12.4 \times \sqrt{2} \times 5\%} = 400:1$$

The PKDET_LVL bits (Register 0x4B8, Bits [8:5]) configure the low power comparator peak current detection level.

Table 3 shows the setting meaning.

Table 3. PSM2 Current Peak Detect Thresholds

PKDET_LVL (Decimal)	Threshold Level
0	100:1
1	200:1
2	300:1
3	400:1
4	500:1
5	600:1
6	700:1
7	800:1
8	900:1
9	1000:1
10	1100:1
11	1200:1
12	1300:1
13	1400:1
14	1500:1
15	1600:1

PSM2_CFG[8:5] is set to 3, which means the threshold level is 400:1.

For LPLINE[4:0], set it to 1, so that the measurement period in PSM2 mode is (1 + 4)/50 = 100 ms.

Set the PSM2_CFG register (Register 0x4B8) to 0x31 when initializing the ADE9078.

POWER CONSUMPTION CALCULATION

When tampering is detected, the ADE9078 consumes the maximum current. The MCU sets the ADE9078 to PSM1 mode to read the rms value and watt value for event recording purposes. For each loop, the power consumption of the ADE9078 is the following:

- PSM3 mode: 60 sec × 2 μA = 120 μA
- PSM2 mode: 100 ms × 200 μA = 20 μA
- PSM1 mode: 40.5 ms × 9 mA = 364.5 μA

The total consumption of one loop is: 120 + 20 + 364.5 = 504.5 μA. If tampering lasts seven days, the consumption is

$$\frac{7 \times 24 \times 60 \times 60}{(60 + 0.1 + 0.0405)} \times 0.5054 \text{ mA} \equiv 1.412 \text{ mAh}$$

When no tampering is detected, the ADE9078 consumes the minimum current. ADE9078 does not enter PSM1 mode, because there is no need to record the rms value. After each loop, the power consumption of ADE9078 is the following:

- PSM3 mode: 60 sec × 2 μA = 120 μA
- PSM2 mode: 100 ms × 200 μA = 20 μA

The total consumption of one loop is 120 + 20 = 140 μA. If the situation lasts seven days, the consumption is

$$\frac{7 \times 24 \times 60 \times 60}{(60 + 0.1)} \times 0.14 \text{ mA} = 0.391 \text{ mAh}$$

The capacity of the battery is 1.2 Ah; therefore, it is very easy to meet the current consumption requirements of ADE9078, even though tampering may occur.

TEST RESULTS

AVDDOUT and DVDDOUT are shut down in both PSM2 and PSM3 mode. When entering PSM1 from either PSM2 or PSM3 mode, the AVDDOUT and DVDDOUT powered on as shown in Figure 5, which was measured on a ADE9078 reference meter.

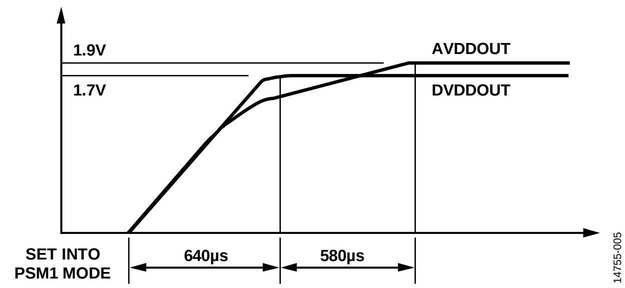

Figure 5. Power-On Sequence When Entering Into PSM1 Mode

After the PM1 pin is set to low, the PM0 pin is set to high, and both pins achieve stable voltage, AVDDOUT and DVDDOUT start to rise up from 0 V and the ADE9078 enters PSM1 mode.

Another test measured the time consumption of tamper detection in PSM2 mode. LPLINE[4:0] was set to 1. Ideally, if tampering occurs, the $\overline{\text{IRQ1}}$ pin is triggered 100 ms after entering PSM2 mode. Figure 6 shows the test results from the ADE9078 reference meter.

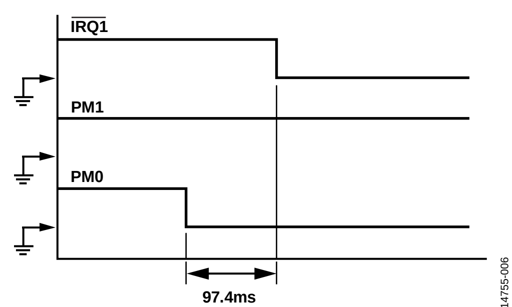

Figure 6. Time Consumption for Triggering $\overline{\text{IRQ1}}$

From entering PSM2 mode to triggering the $\overline{\text{IRQ1}}$ pin, it takes 97.4 ms. When tampering is detected, $\overline{\text{IRQ1}}$ sets to low.

CONCLUSION

The ADE9078 is a new design metrology AFE with high dynamic range and high accuracy. With four power modes, the power consumption is as low as 1 μA. The consumption on the ADE9078 is only 1.412 mAh. It is much lower than the capacity of a battery, which is 1.2 Ah. The ADE9078 can be used for no voltage detection, even during conditions lasting seven days.