Document Number: AN4262
Rev. 0, Feb 2011

Gas and Water Metering Application With MC9S08GW64

by: Nick Wang
Microcontroller Solution Group
Shanghai

Contents

1 Introduction

This application note serves mostly to introduce the Position Counter (PCNT) module of the MC9S08GW64, which is designed especially for gas and water metering applications. It also describes other modules that optimize these same applications.

As we know, gas and water meters are based on a mechanical flow meter. The sensor types include optical and magnetic. They work with a rotary wheel to convert the flow to an analog or digital signal output. How to decode these output signals efficiently and accurately is the greatest challenge in this kind of application.

Besides accurate flow sensor decoding, low power is another key requirement, because gas and water meters are battery-operated.

2 Flow sensor types and methodologies

This section discusses the different types of flow sensors and how each type functions.

2.1 Sensor interfaces

This section describes the different types of sensor interfaces used in gas and water meters.

2.1.1 Reed, Hall effect, or GMR sensors

A magnet is on the rotary disk, and a reed, Hall effect, or giant magnetoresistance (GMR) sensor is below the disk. When the magnet is very close to the sensor, the sensor will present an active output signal. For a GMR sensor, it is necessary to have two magnets, placed on the disk 180° apart.

Reed, Hall effect, or GMR sensors shows an example of how such sensors are used in an application.

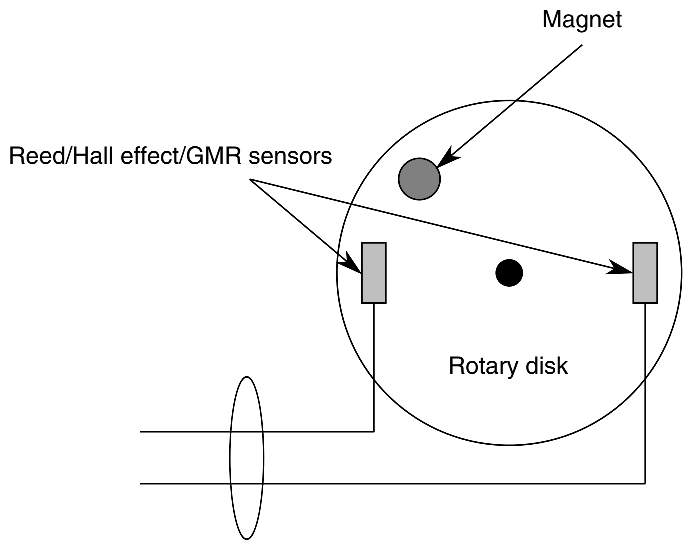


Figure 1. Reed, Hall effect, or GMR sensors

2.1.2 Optical sensors

The optical encoder wheel has transparent and opaque areas, and is placed between a light source and a photo detector. When a transparent section of the wheel is between the light source and the photo detector, there is a several milivolt signal output — when it is an opaque section of the wheel, there is no signal. Usually a light source and a photo detector array are used with an encoder wheel to detect rotation direction and flow volume.

Figure 2 shows an example of an optical sensor application.

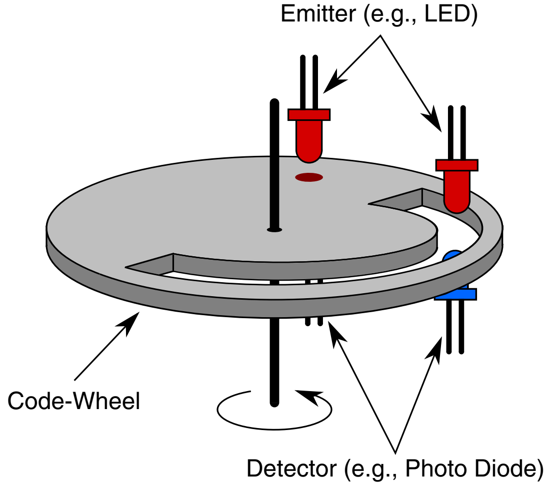


Figure 2. Optical sensor

The encoded rotary disk uses either binary or gray encoding. Figure 3 shows an example of a binary code with only three contacts. In general, where there are *n* contacts, the number of distinct positions of the shaft is 2^n.In this example, *n* is three, so there are eight positions.

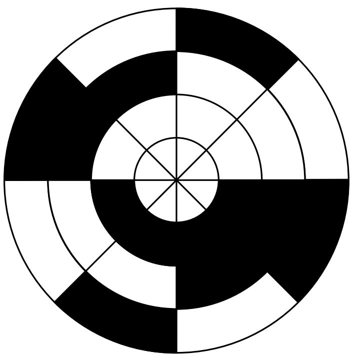


Figure 3. Binary encoded disk with three contacts

Table 1. Binary encoding with three contacts

Sector	Contact 1	Contact 2	Contact 3	Angle
1	Off	Off	Off	0–45°
2	Off	Off	On	45–90°
3	Off	On	Off	90–135°
4	Off	On	On	135–180°
5	On	Off	Off	180–225°
6	On	Off	On	225–270°
7	On	On	Off	270–315°
8	On	On	On	315–360°

Gray encoding is a system of binary counting in which adjacent codes differ in only one position. An example of gray-coding using three contacts is shown in Figure 4.

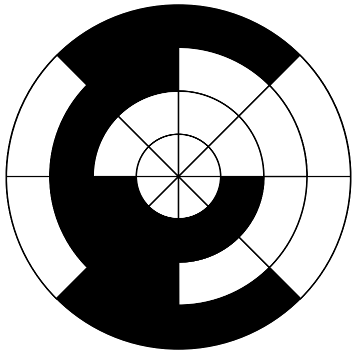


Figure 4. Gray encoded disk with three contacts

Table 2. Gray encoding with three contacts

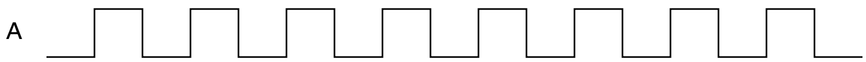
Sector	Contact 1	Contact 2	Contact 3	Angle
1	Off	Off	Off	0–45°
2	Off	Off	On	45–90°
3	Off	On	On	90–135°
4	Off	On	Off	135–180°
5	On	On	Off	180–225°
6	On	On	On	225–270°
7	On	Off	On	270–315°
8	On	Off	Off	315–360°

2.2 Waveform modes of flow sensors

There are many possible waveform modes to be considered in applications of this kind, depending on which type of sensor is used. This section describes the waveform modes of different flow sensors when used in an application.

2.2.1 Single direct counter mode

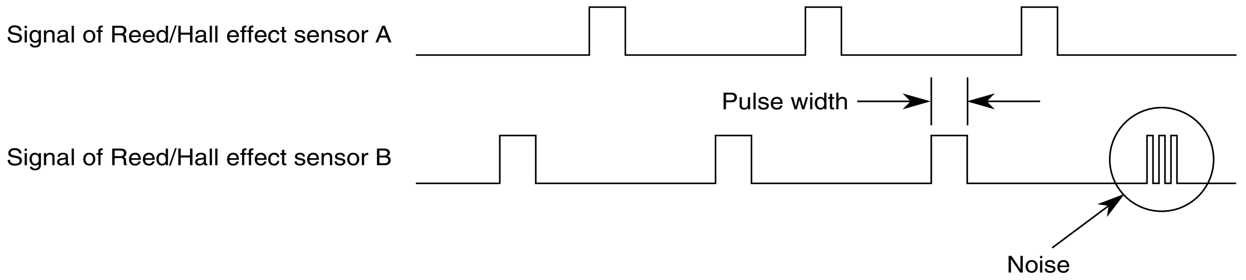
When a rotary disk has only a single sensor — for example if there is only one inductor in a single reed/Hall effect sensor below a disk which also has only one magnet on it — the waveform shown here is produced.



In this mode, it is not possible to determine the direction of the disk, so it is impossible to tell whether it is moving forward or backward.

2.2.2 180 degree dual sensor mode

The sensors most used are reed sensors, although Hall effect and GMR sensors are beginning to be popular in this mode. For reed and Hall effect sensors, two sensors are placed 180° apart and the rotary disk has only one magnet on it. For GMR sensors there must be two magnets placed 180° apart on the disk. The waveform is as below.

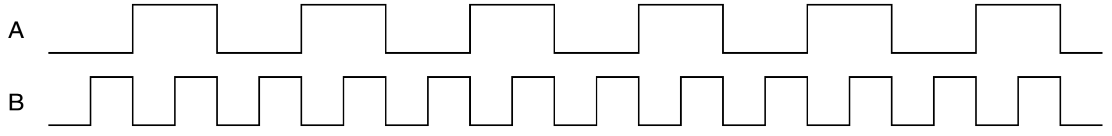


Noise is easy to prevent in this mode. A filter should be implemented in the application.

If there is a pulse first from the B sensor and then a pulse from the A sensor, the sensor state (AB) is 00-01-00-10. The "00" state occurs either side of the "01" state, so in this mode the direction cannot be determined.

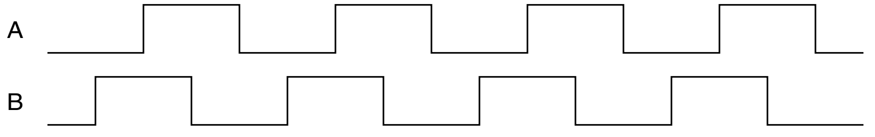
2.2.3 Two-signal binary mode

A two-signal binary mode is when a binary-encoded rotary disk has two contact sensors, such as optical sensors. In this mode, the direction can be determined. The waveform produced when the disk is moving in the forward direction is shown here.



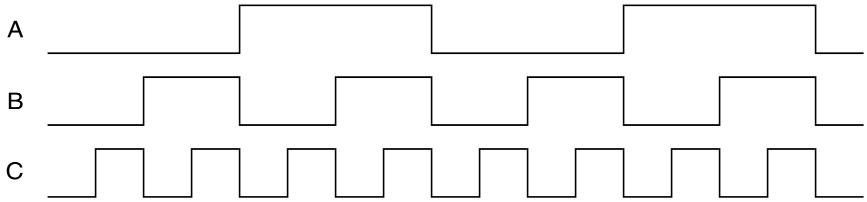
2.2.4 Two-signal gray mode

Two-signal gray mode is when a gray-encoded rotary disk has two contact sensors, such as optical sensors. In this mode, the direction can be determined. The waveform produced when the disk is moving in the forward direction is shown here.



2.2.5 Three-signal binary mode

Three-signal binary mode is when a binary-encoded rotary disk has three contact sensors, such as optical sensors. In this mode, the direction can be determined. The waveform produced when the disk is moving in the forward direction is shown here.



3 Gas and water metering application with MC9S08GW64

The MC9S08GW64 is well-suited for gas and water metering applications for a number of reasons, as explained here.

3.1 MC9S08GW64 advantages and features

The MC9S08GW64 is a family of low-power devices based on the high-performance S08 core. It is a highly integrated, high-performance family which comes packed with valuable features: 32–64K flash memory, 2–4K RAM, a flexible internal clock generator that eliminates the need for external components, low voltage operation, LCD driver, analog-to-digital converter (ADC), serial communication modules, etc.

The MC9S08GW64 incorporates the following specific features:

- Up to 4×40 or 8×36 LCD driver
- Two 16-bit SAR ADCs with one pair dedicated differential input
- Programmable analog comparator with on-chip programmable reference generator output
- Four serial communications interface (SCI) modules
- One SPI
- One IIC
- 16/32 bit programmable cyclic redundancy check (PCRC)
- Two 8-bit and one 16-bit modulo timer
- Programmable delay block (PDB), optimized for scheduling ADC conversion
- Independent real-time clock with independent power domain; tamper detection and indicator
- Flextimer module with selectable input capture, output compare, and edge-aligned PWM capability on each channel
- Position counter (PCNT) — can work in Stop3 mode

3.2 Specially designed position counter module

The sensors work with a rotary wheel to convert flow volume to analog or digital signal output. How to decode these output signals efficiently and accurately is the big challenge in an application. The specially designed position counter module (PCNT) in the MC9S08GW64 is easy to interface with different sensors, and will decode the sensors' signal efficiently with very little software configuration.

The features of the PCNT are:

- Supports interfacing to one-, two-, or three-pin rotary sensor
- Supports 180 degree gray and binary decoding modes (two signal gray mode is also called quadrature mode)
- Ability to filter sensor signals with programmable filter width
- Ability to detect and generate interrupts on an invalid sequence
- Generates interrupts on counter overflow
- Generates required signaling to activate sensors
- Generates asynchronous interrupt to wake MCU from low power modes
- Ability to function independently in stop mode
- Modulus registers to interrupt CPU on specific count or full count

- Ability to function as limited capability PWM (in other words, edge- or center-aligned PWM)
- Internal counter can function as an atomic counter and generates an interrupt on counter overflow

Figure 5 is a block diagram showing the PCNT and relevant elements of the chip. The PRACMPs function together to process the incoming signal. Each PRACMP converts an analog signal of several millivolts into normal 0 or 1 logic that can be recognized by the PCNT. For a digital signal, bypass the PRACMP section.

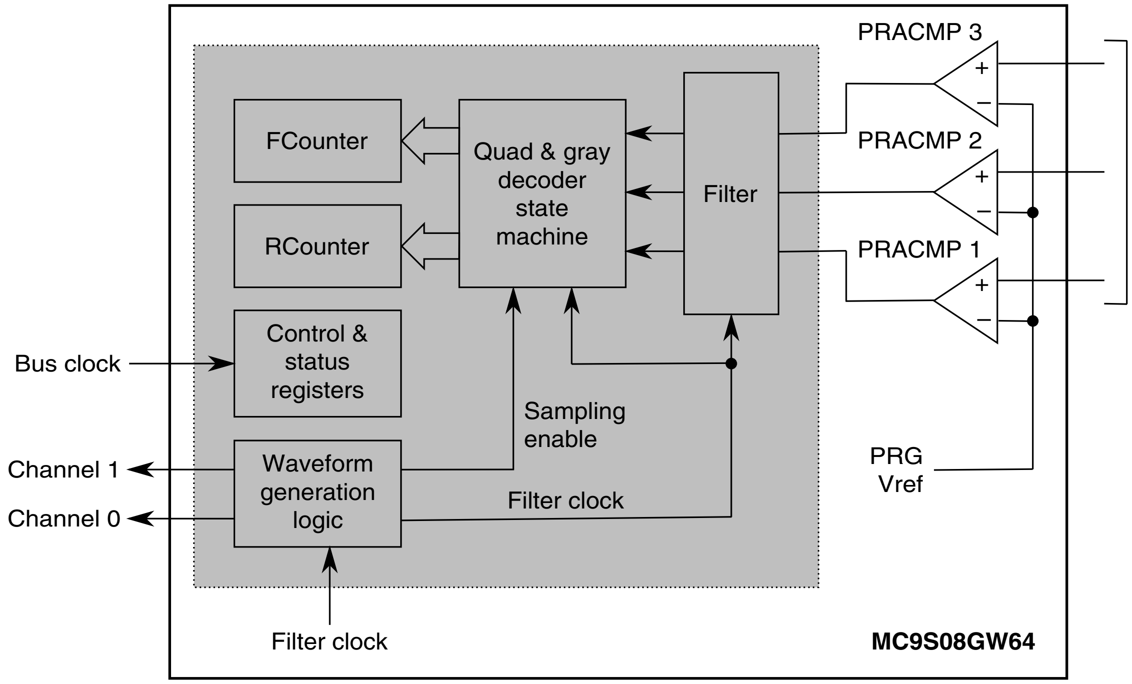
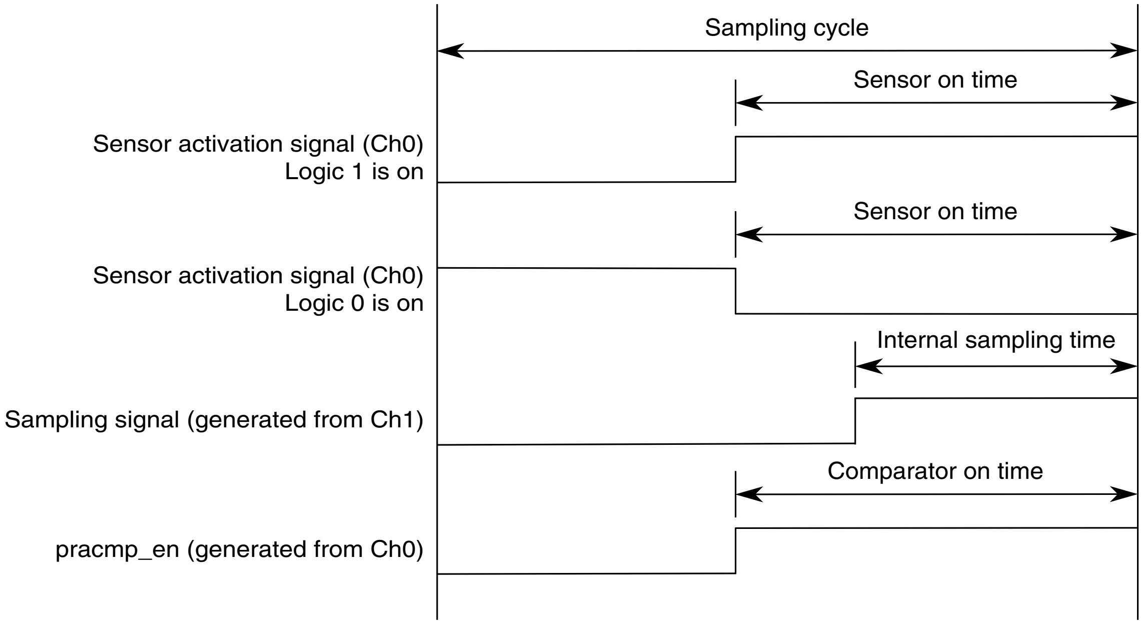


Figure 5. PCNT block diagram

The PCNT can recognize all the sensors' output waveform modes, as mentioned earlier. In some modes, the signals of sensors include noise which are short pulses. The noise may result in erroneous input, causing the wrong count to increase or decrease. The PCNT includes a filter subset block to filter the noise from the sensor's output, and the width of the filtered short pulse is configurable.

As we know, a rotary disk may move forward or backward as the gas or water flow is disturbed, due to inherent instability in the flow. This results in abnormal states in the expectation of movement of the disk in a forward or backward direction, a state transformation. PCNT includes a state machine to store the expected transform states to increase count, to help make sure flow volume is counted correctly.

PCNT with the PWM output function is very useful in an optical sensor interface application. In an optical sensor interface, an emitter such as an LED is not always on because it consumes a large amount of current, which is unacceptable in a battery-powered system. A sampling method that means the LED period is on is used in this application. PWM output channel 0 generates the wave with a duty cycle designed to activate the LED in one sampling cycle externally. At the same time a comparator signal (which is the same as channel 0 but without polarity) is output internally to enable the PRACMP internally, because the PRACMP needs to convert the analog signal to digital. Because the light sensor needs some time to stabilize, PWM output channel 1 generates the sampling signal internally after waiting a specific interval of time, and it lasts for some duration. Depending on the LED “ON” connection in the schematic, logic “0” or “1” activates LED ON.



In some modes there is noise which may appear on the input channel. If the noise reaches the state machine it will result in a wrong count. PCNT includes a digital filter sub-block to filter the noise. The filter value can be set in a register. The FILTER VALUE is the number of filter clocks to be counted in detecting changes in the input signal (either 0 to 1 or 1 to 0). If the signal is found at the same level while counting up to FILTER VALUE, that value is allowed to go to the state machine. Otherwise, it will not be reflected at the filter output. Take caution in making the filter duration equal to 0 or 1 because any glitch on the PCNT input pins can cause a state change or set the invalid mode flag.

4 Summary

The Position Counter (PCNT) module of the MC9S08GW64 is a powerful tool that can interface with all kinds of sensors in use today. In particular, it can run in Stop3 mode with CPU stop, which reduces power consumption significantly.

Besides its PCNT module, the MC9S08GW64 is integrated with LCD, ADC, SCI, IIC, SPI, PCRC, and PRACMP low-power modules. All of them put together make the MC9S08GW64 a one-chip solution for gas and water metering applications.

Appendix A Sample code

This example initial code shows how to enable the PRACMP to work with the PCNT. In this case, the sensor is optical, signal input is analog, and gray encoding is used. In this case, the PRACMP should be enabled and the PCNT should generate the PWM output to drive the light source for sampling. Below is the detailed code for initialization.

```
SCGC4_MUXCTRL = 1; //enable MUX module clock
   //pin config for PRACMP
     PTAPF2 = 0x44; // PTA2 -> CMPP0<--->PCNT0, PTA3 -> CMPP1<--->PCNT1
     PTAPF3 = 0x04; // PTA4 -> CMPP2<--->PCNT2

     //Configure PRACMP for PCNT
     SIMIPS1_PCNTSS =1; // PRACMP output selected

     //Enable PRACMP0,1,2 clock
     SCGC5_PRACMP0 = 1;
     SCGC5_PRACMP1 = 1;
     SCGC5_PRACMP2 = 1;

     PRACMP0C1_PRGINS=1; //selecting external Vdd.
```

```
      PRACMP0C1 = (PRACMP0C1 & 0xC0) | 15; //setting reference level(Vin/2)
      PRACMP0C1_PRGEN=1; //enabling PRACMP0 PRG system

      PRACMP1C1_PRGINS=1; //selecting external Vdd.
      PRACMP1C1 = (PRACMP1C1 & 0xC0) | 15; //setting reference level(Vin/2)
      PRACMP1C1_PRGEN=1; //enabling PRACMP0 PRG system

      PRACMP2C1_PRGINS=1; //selecting external Vdd.
      PRACMP2C1 = (PRACMP2C1 & 0xC0) | 15; //setting reference level(Vin/2)
      PRACMP2C1_PRGEN=1; //enabling PRACMP0 PRG system


      PRACMP0C0_ACPSEL=0; //mapping CMPP0 to +ve input;
      PRACMP0C0_ACNSEL=7; //mapping PRG output to -ve input;
      PRACMP1C0_ACPSEL=1; //mapping CMPP1 to +ve input;
      PRACMP1C0_ACNSEL=7; //mapping PRG output to -ve input;
      PRACMP2C0_ACPSEL=2; //mapping CMPP0 to +ve input;
      PRACMP2C0_ACNSEL=7; //mapping PRG output to -ve input;
PRACMP0CS_ACEN=1; //enabling ACMP0
      PRACMP1CS_ACEN=1; //enabling ACMP1
      PRACMP2CS_ACEN=1; //enabling ACMP2
// pCNT clock enable
  SCGC5_PCNT =1;
// PCNTCH0 and PCNTCH1 on PTA0 and PTA1 as default
// pCNT config
        // mode
        PCNT_CTRL_MODE = 1; // gray code mode
        PCNT_CTRL_CHANNEL_SEL = 7;//3'b111
        PCNT_CTRL_FILTER_VALUE = 1; // filter = 1
// no  modulo
        PCNT_FCMOD = 0;
        PCNT_RCMOD = 0;
//pin config for sensor o/p
PTAPF1 = 0x22; // PTA0 -> PCNTCH0, PCNTCH1
// filter clock = 32.768k (OSC1)
      SIMIPS3_PCNTFCS = 0;
      // PWM configuration
        PCNT_CTRL_CPWMS = 0; // Edge aligned PWM
        // set o/p on compare up
        PCNT_CTRL_POL = 0;
        // Sampling period
        PCNT_PWM_MOD = 1638;
        // Sensor Enable
        PCNT_PWM_CH1_VAL = 1633;
        // Sampling enable
        PCNT_PWM_CH2_VAL = 1637;
/* Clear Status register */
        PCNT_STATUS = 0x7;

       // enable PCNT
       PCNT_CTRL_PCNT_EN = 1;
```

How to Reach Us:

Home Page:
www.freescale.com

Web Support:
http://www.freescale.com/support

USA/Europe or Locations Not Listed:
Freescale Semiconductor
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.freescale.com/support

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.freescale.com/support

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064
Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor China Ltd.
Exchange Building 23F
No. 118 Jianguo Road
Chaoyang District
Beijing 100022
China
+86 10 5879 8000
support.asia@freescale.com

For Literature Requests Only:
Freescale Semiconductor Literature Distribution Center
1-800-441-2447 or +1-303-675-2140
Fax: +1-303-675-2150
LDCForFreescaleSemiconductor@hibbertgroup.com

Document Number: AN4262
Rev. 0, Feb 2011