Freescale Semiconductor
Application Note

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MC9S08MP16 PGA Module Introduction and Deep Application

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1 Introduction

This application note introduces programmable gain amplified (PGA) module in MC9S08MP16. PGA module is commonly used for weak signal detection in sensor precision applications.

Freescale offers MC9S08MP16 as an 8-bit MCU with PGA module. Apart from general applications, this MCU is especially used in motor control applications, where it acts as a root detector.

This application note guides the user to achieve PGA module principle, feature, the procedure to use, and some applications.

2 PGA feature and module structure

2.1 PGA feature

The PGA is a switched capacitor which amplifies and converts differential signals to a single-ended value. This value is passed on to the analog-to-digital converter (ADC) for conversion to digital format.

The PGA module has the following features:

- Converts differential analog signals to single-ended value
- Software and hardware triggers are available.
- Large input signal range from ground to V_{DDA} is available.
- PGA outputs are driven to on-chip ADC input channels with 1x, 2x, 4x, 8x, 16x or 32x gain.
- Integrated sample/hold circuit
- Eliminates offset error associated with the sample/hold circuit to reduce 1/f noise
- Automatic offset cancellation occurs during PGA startup.
- Offset calibration eliminates any errors in the internal reference used to generate the $V_{DDA}/2$ output center point.
- Gain calibration can be used to verify the gain of the overall data path.

2.2 PGA structure

The PGA module is intended to operate in synchronization with ADC. By itself, the PGA has no useful function.

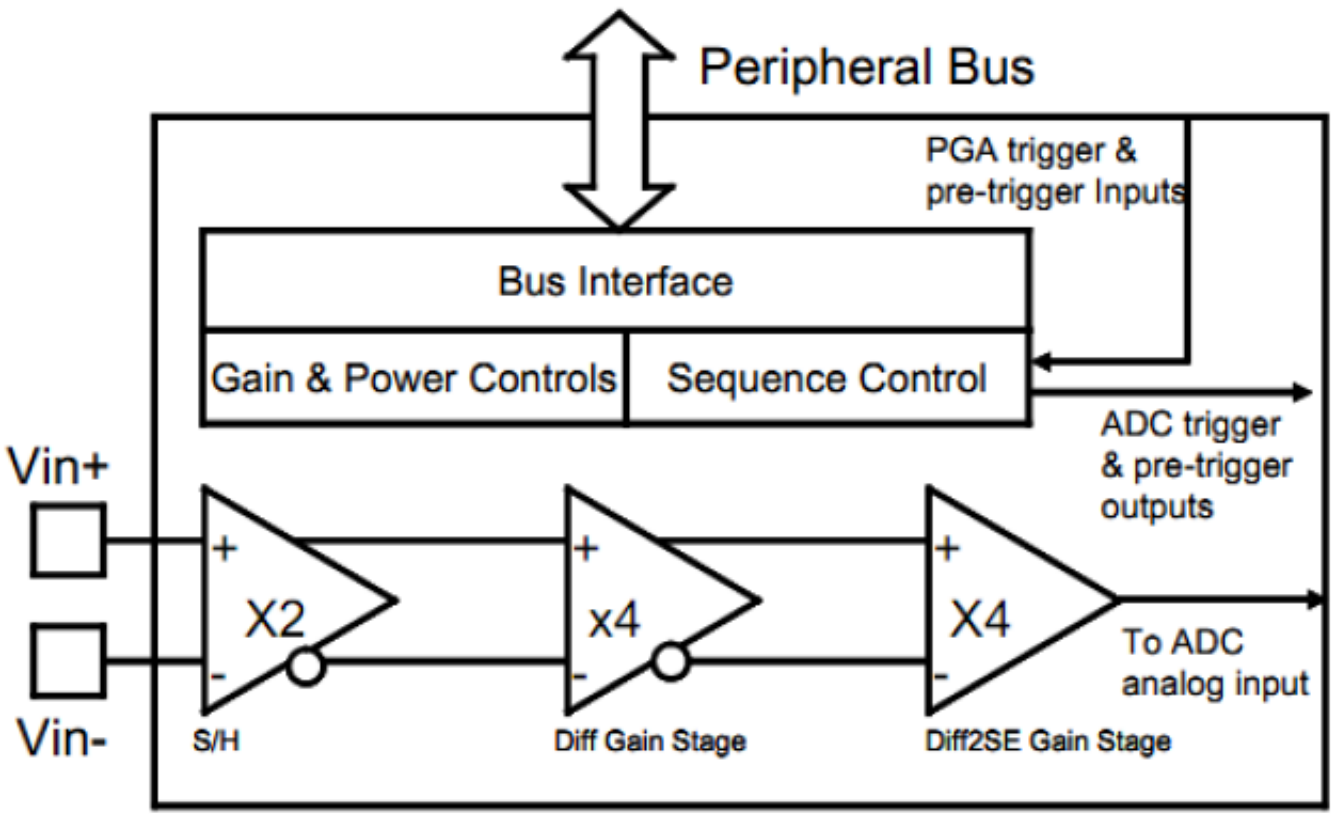


Figure 1. PGA module structure

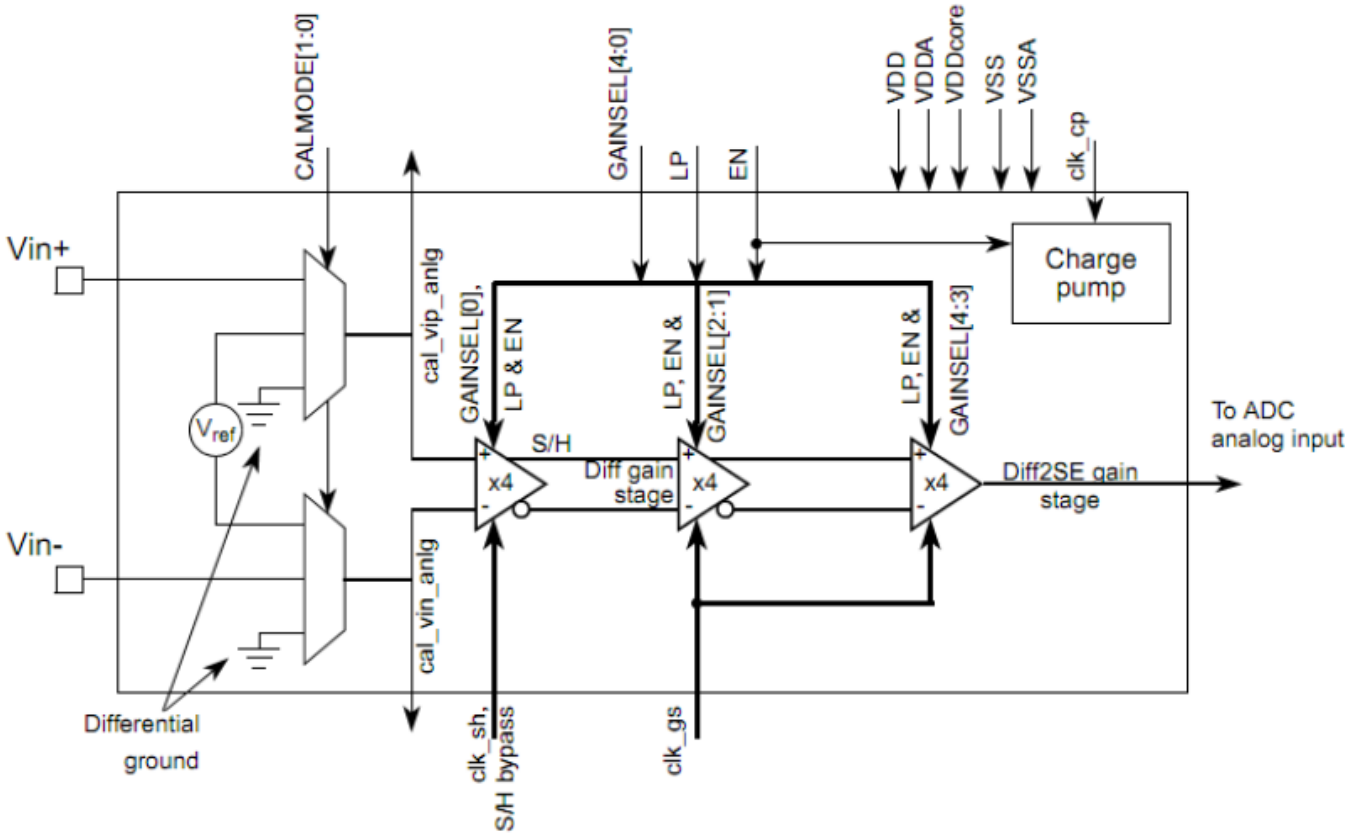


Figure 2. Analog block diagram of the PGA module

2.3 PGA calculation

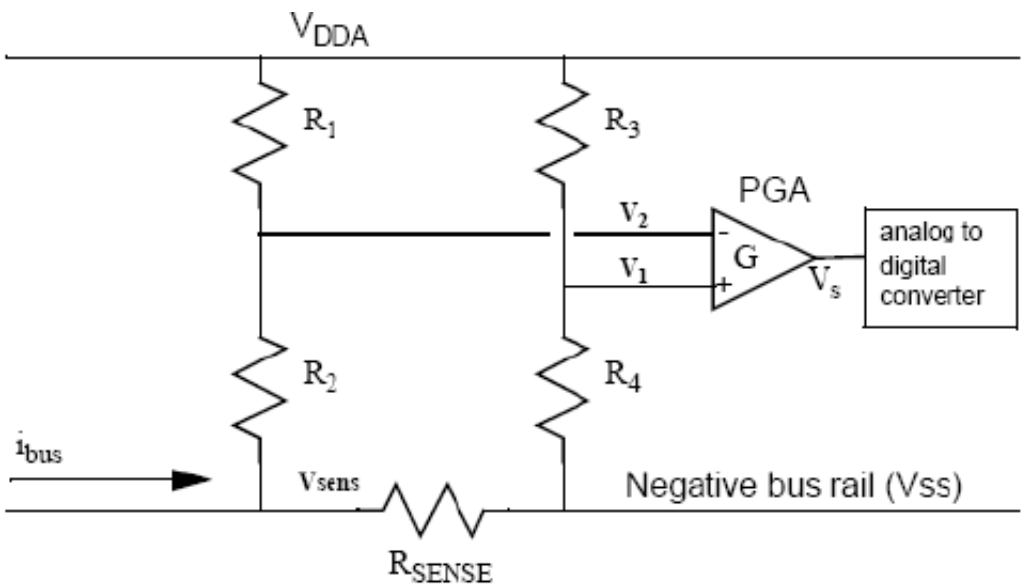


Figure 3. PGA sample diagram

The following equations can be used to calculate PGA.

Assume:

$$\Delta V = (V_1 - V_2)$$

$$V_s - (V_{DDA}/2) = \Delta V * G$$

$$R_1 = R_2 = R_3 = R_4 = R$$

The equation can be re-written as:

$$\Delta V = (V_{sens} - V_{DDA}/2)/G$$

As a first order approximation, assume $R >> R_{SENSE}$ and that the PGA input currents are zero.

Then:

$$V_{sens} = i_{bus} * R_{SENSE}$$

$$V_2 = 0.5*(V_{DDA} - V_{sens})$$

$$V_1 = 0.5V_{DDA}$$

$$\Delta V1 = V_1 - V_2 = 0.5V_{DDA} - 0.5(V_{DDA} - V_{sens})$$

3 PGA module operation

The output of the PGA module must be relative with that of the ADC module. In MC9S08MP16, ADC channel13 is used to measure PGA output voltage. MC9S08MP16 provides PGA calibration function and PGA mission mode.

3.1 PGA startup

The PGA module provides the following three types of startup flows according to different trigger modes:

- Software trigger
- Hardware trigger
- PDB trigger

3.1.1 Software Trigger mode

- The PGA module must be enabled by setting PGACNTL0[EN] to 1.
- Trigger mode must be set to software by setting PGACNTL0[TM] to 1.

NOTE

For ADC setting requirements, please see MC9S08MP16RM, available on http://www.freescale.com.

In this mode, a PGA conversion will be initiated after writing 1 to PGACNTL2[SWTRIG]. This character can be used with other functions in MC9S08MP16, such as RTC and timer.

3.1.2 Hardware Trigger mode

- The PGA module must be enabled by setting PGACNTL0[EN] to 1.
- Trigger mode must be set to hardware by setting PGACNTL0[TM] to 0

NOTE

For ADC setting requirements, please see MC9S08MP16RM, available on http://www.freescale.com

In this mode, a PGA conversion will be initiated on the positive edge of the hardware trigger.

3.1.3 PDB Trigger mode

- The PDB module provides the hardware trigger to the PGA module.
- Trigger mode must be set to hardware by setting PGACNTL0[TM] to 0.

NOTE

For ADC setting requirements, please see MC9S08MP16RM, available on http://www.freescale.com.

In this mode, PDB provides flexible trigger timing for PGA start conversion. PDB shares the same timer with other function and can generate different timing based on just one timer.

3.2 PGA calibration

The PGA module supports various types of calibration, including internal offset calibration, external offset calibration, and gain calibration.

3.3 PGA mission modes

Mission mode encompasses a number of options. These include:

- Number of gain stage clocks per conversion: PGACNTL2[NUM_CLK_GS]
- Low/Full Power: PGACNTL0[LP]
- Choice of Hardware or Software Trigger: PGACNTL0[TM]
- Any gain setting: PGACNTL0[GAINSEL]

4 PGA simple application

The PGA can be widely used in analog transmission and sensor signal collection in industrial fields, such as temperature, pressure, and flow meter. PGA can amplify the small signals into the ADC measuring range. This application notes gives out a thermocouple as an example.

4.1 Typical circuit

Generally, some customers use thermocouple to measure or compare temperature. In compare condition, if the voltage difference is small, PGA can be used to amplify the difference and provide larger enough voltage for ADC detection.

PGA simple application

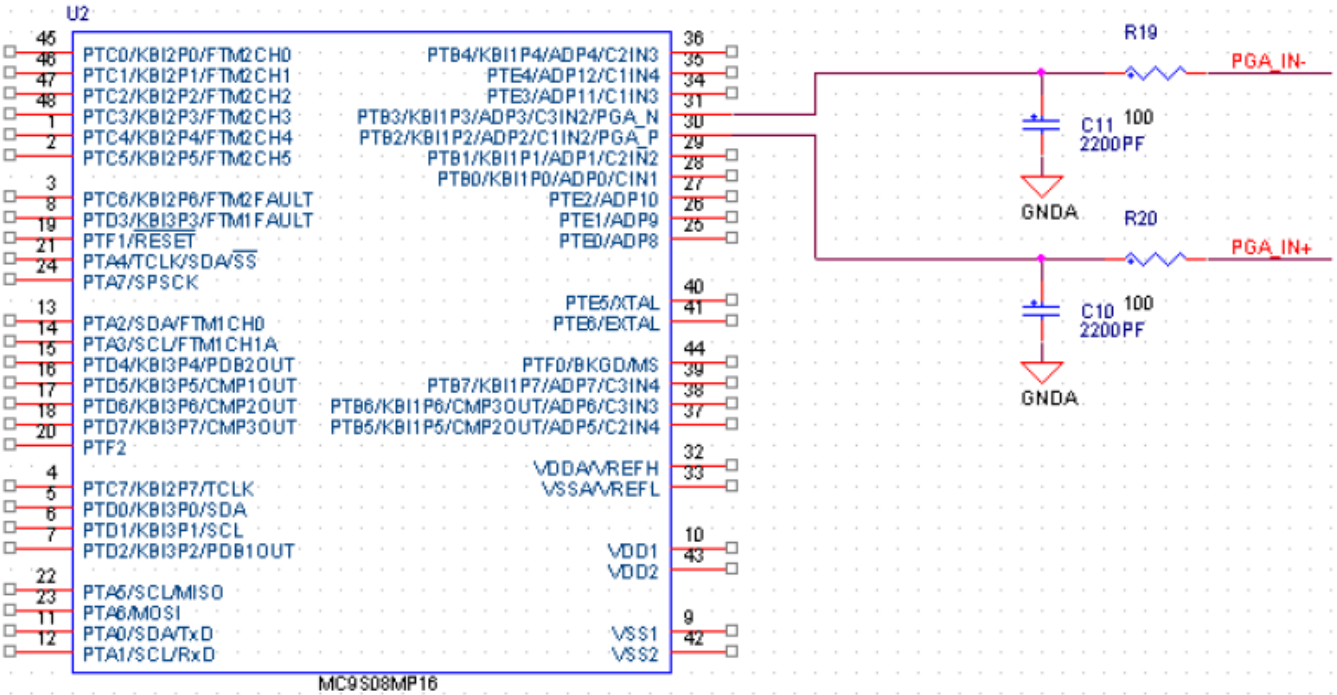
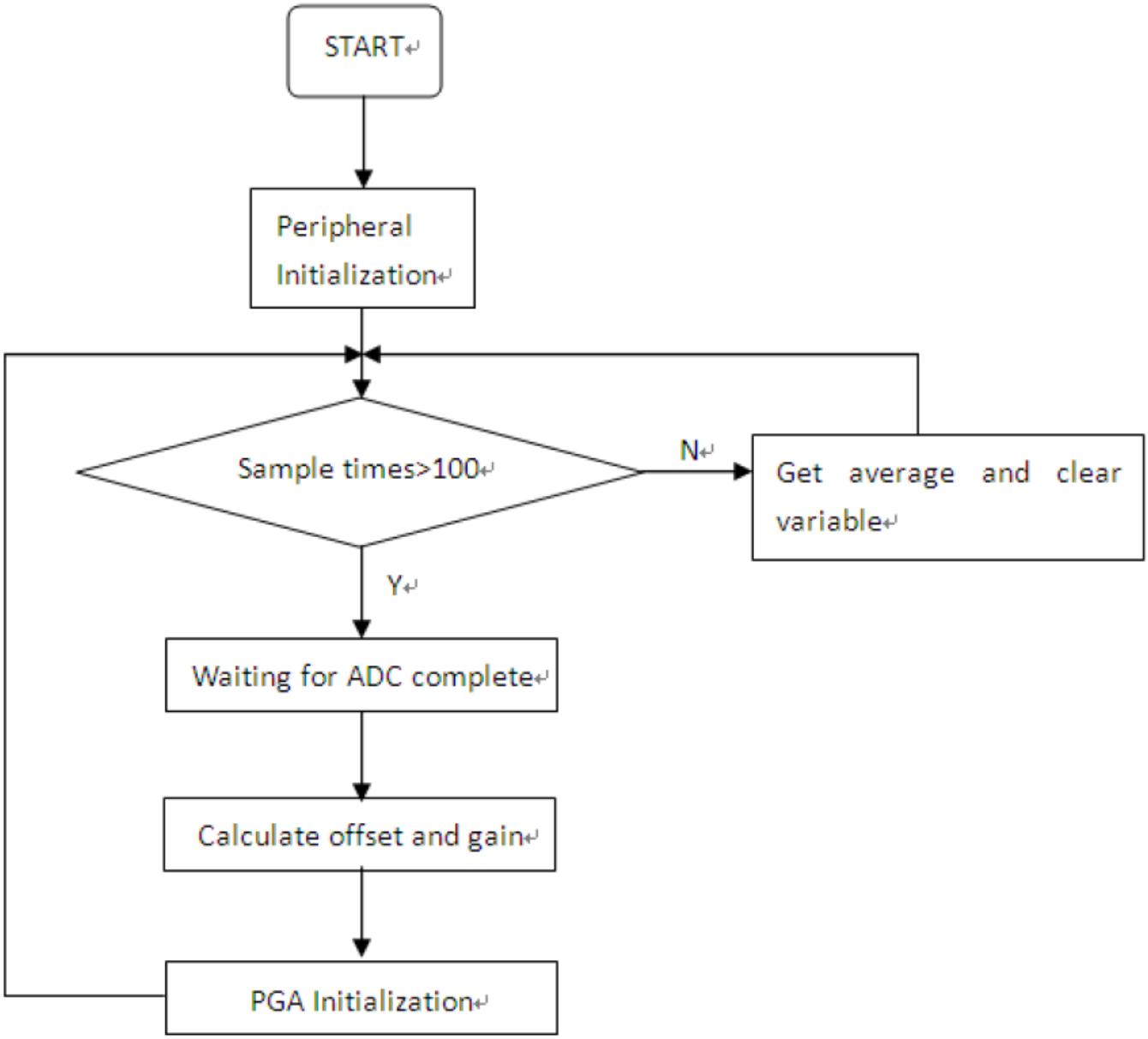


Figure 4. Typical circuit of PGA module

4.2 Sample project flowchart

This sample project uses hardware trigger for the PGA module. The hardware trigger source is PDB output. The PDB clock resource is an FTM timer. This program will get an average of 100 samples of PGA. The following figure is the flowchart of sample project.



5 Conclusion

The PGA module can amplify small signals proportionally to match the ADC sampling range. PGA can also provide several gain levels such as 1, 2, 4, 8, 16, 32. For MC9S08MP16, the integrated PGA module can save circuit and avoid the outside noise effect.

6 References

The following documents are available on http://www.freescale.com

- MC9S08MP16RM : MC9S08MP16RM, MC9S08MP16 Reference Manual
- MC9S08MP16DS : MC9S08MP16 Series Data Sheet

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