Implementing MAF Sensor with GreenPAK
SLG46583V

This app note implements a MAF Sensor with SLG46583V. This app note focus on how a GreenPAK can be used to perform the same functionality as a sophisticated &expensive MAF sensor. This application note comes complete with design files which can be found in the reference section.

Contents

1.   References

For related documents and software, please visit:

GreenPAK™ Programmable Mixed-signal Products | Renesas

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Find out more in a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the GreenPAK IC.

[1]   GreenPAK Designer Software, Software Download and User Guide
[2]   Implementing MAF Sensor with GreenPAK.gp, GreenPAK Design File
[3]   GreenPAK Development Tools, GreenPAK Development Tools Webpage
[4]   GreenPAK Application Notes, GreenPAK Application Notes Webpage
[5]   SLG46583V Datasheet

2.   Terms and Definitions

MAF	Mass Air Flow sensor
PWM	Pulse Width Modulator
LDO	Low Drop Out regulator
ECU	Engine Control Unit

3.   Introduction

What is MAF. Mass Air flow sensor is a commonly used sensor for injection engines. At the engine chambers, the fuel and air has been mixed to cause the required explosion to move the piston. The fuel air mix should be at the best performance ratio. If the fuel is higher than required ratio, then the engine is less efficient and causes low utilization of fuel, leading to low performance and downgrading of the engine power. To inject fuel into engine, the ECU "Engine Control Unit" needs to know the exact amount of air entering the engine. In case of having the correct airflow, measurement will help the ECU to calculate the best amount of fuel to inject. The MAF solves this issue by giving the ECU the exact measurement of the air flow entering the engine chamber.

The MAF sensor stays at the input of the air tube, blocking a portion of it to take a sample of air flow. The MAF uses a simple technique to measure the air flow by having a small path for the airflow sample. Inside this path, there is a small heater that is controlled such that it stays at the same temperature whatever the airflow is passing through it. This is possible with the help of a simple PID controller that keeps the heater temperature constant. The controller measures the heater temperature during the feedback loop during which it rises/reduces the heater power to maintain the temperature at a certain point.

By a simple calculation, if the heater temperature is constant as the controller changes its power in accordance to the change in airflow then the current passing through the heater represents the amount of air flow passing through the heater. It is a simple technique of blowing a hot surface(heater) will causes the heat to dissipate faster; the hot surface will require more power to become hot again if the airflow is continuing blowing it.

Why this simple technique? The airflow in the engine doesn't change very fast. It doesn't require a very fast response sensor to measure the airflow, so an easy way out is to avoid using a very sophisticated sensor.

Most of the MAF sensors in the market uses an ASIC chip to implement the sensor has budget constraints in engineering and upgrading. The ASIC takes months maybe years of work to get designed with no issues. Implementing this sensor with an FPGA will be a good idea but it is impossible to fit inside the sensor tiny chassis; GreenPAK is the best of two worlds to implement the sensor in a tiny board with much less engineering work.

4.   Design Flow

In this application note we will compare a real MAF sensor in the market with the implemented one using GreenPAK. The next paragraph will show the test results of in hand real MAF sensor and how to test it, then we will show how to implement it with GreenPAK and simulate the test to get the same output with a better response as the airflow changes is very slow compared to GreenPAK which is an advantage to this implementation.

5.   Testing a MAF from the Market

We chose a MAF sensor from the market that uses an ASIC chip. In real life this sensor should be fixed into the engine airflow tube; in order to test it we must replicate the environment of a controllable airflow tube which is the placed in the path of the airflow. The next figure shows the 3D printed tube to hold the sensor in the correct way. By having a controllable airflow source, you will be able to test the MAF sensor.
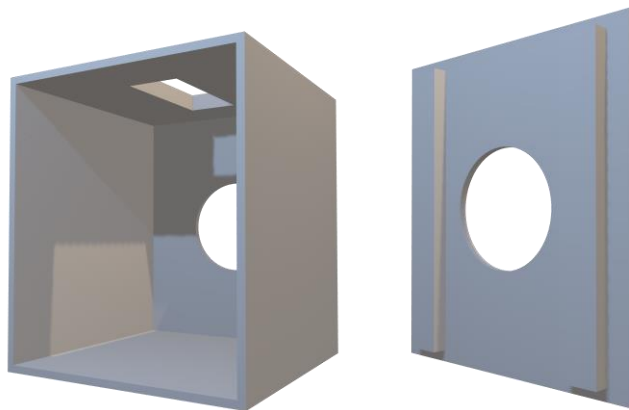
Figure 1: 3D printed Chamber

Figure 2: Bench Setup

The following figure and table show the MAF PINs

Figure 3: MAF Pins

Table 1: MAF PINs

| 1	2	3	4	5	6
VCC (12V)	GND	Return MAF AGND	MAF Signal	Thermistor N	Thermistor P

The expected output is an analog signal on MAF-signal (PIN 4) compared to AGND (PIN 3). The analog voltage represents the air flow passing through the sensor's path. Some MAF sensors output is pulse width modulated

(PWM) instead. Other universal sensors which are compatible with all ECUs, produces a PWM signal and an optional RC circuit to convert the PWM to a DC voltage as an analog representation of the MAF.

By having the 3D printed host as shown in Figure 1, and a controllable blower attached to the input of the host we can measure the output of the MAF sensor. When the power is turned on, the sensor sends a signal to ECU by pulling its output high for 160ms. This will allow the ECU to note that the MAF has started measuring .
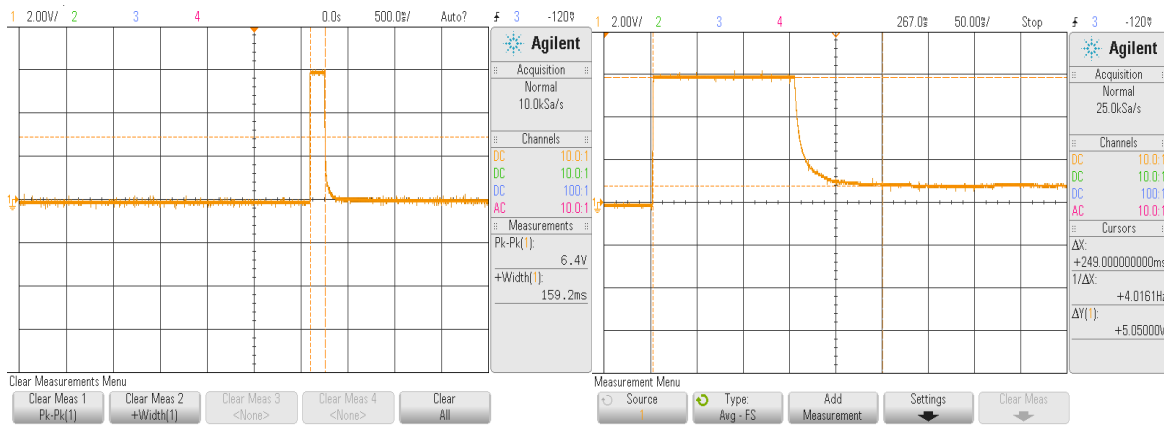
a) power ON at no airflow   b) power ON with airflow

Figure 4: Test Setup

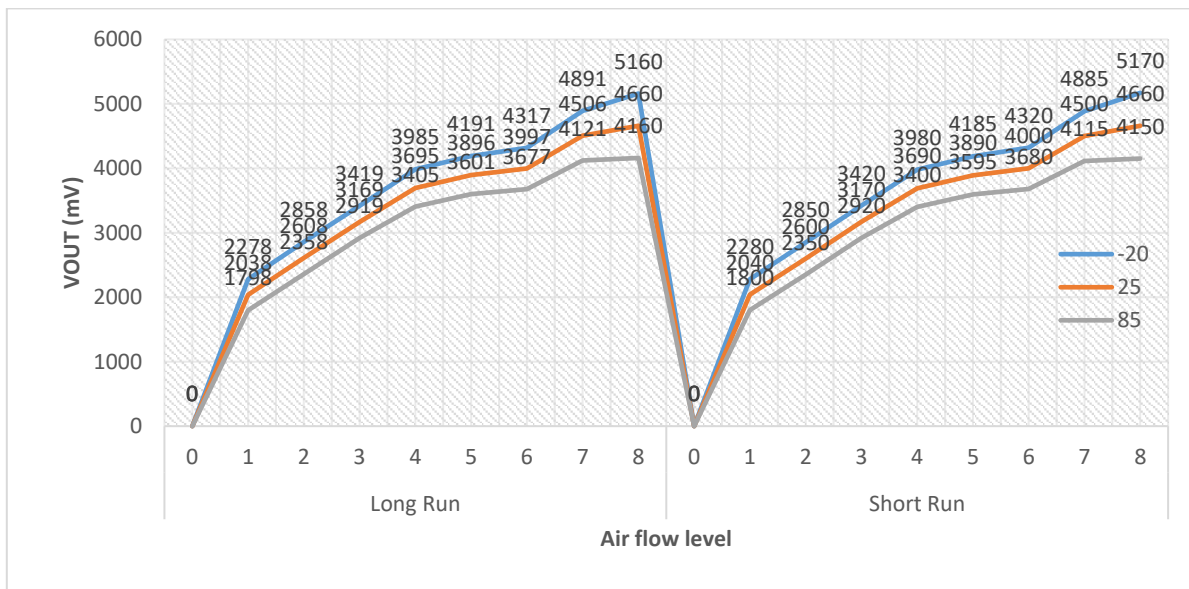The following curve shows the MAF output vs input air flow at different temperatures:

Figure 5: Output vs Airflow

6.   Implementing MAF using the GreenPAK

First the suitable GP device should be chosen. The SLG46583V is a very suitable device as it has an LDO that can power the heater to implement the constant heat. The following figure shows the block diagram of the MAF sensor and its implementation.
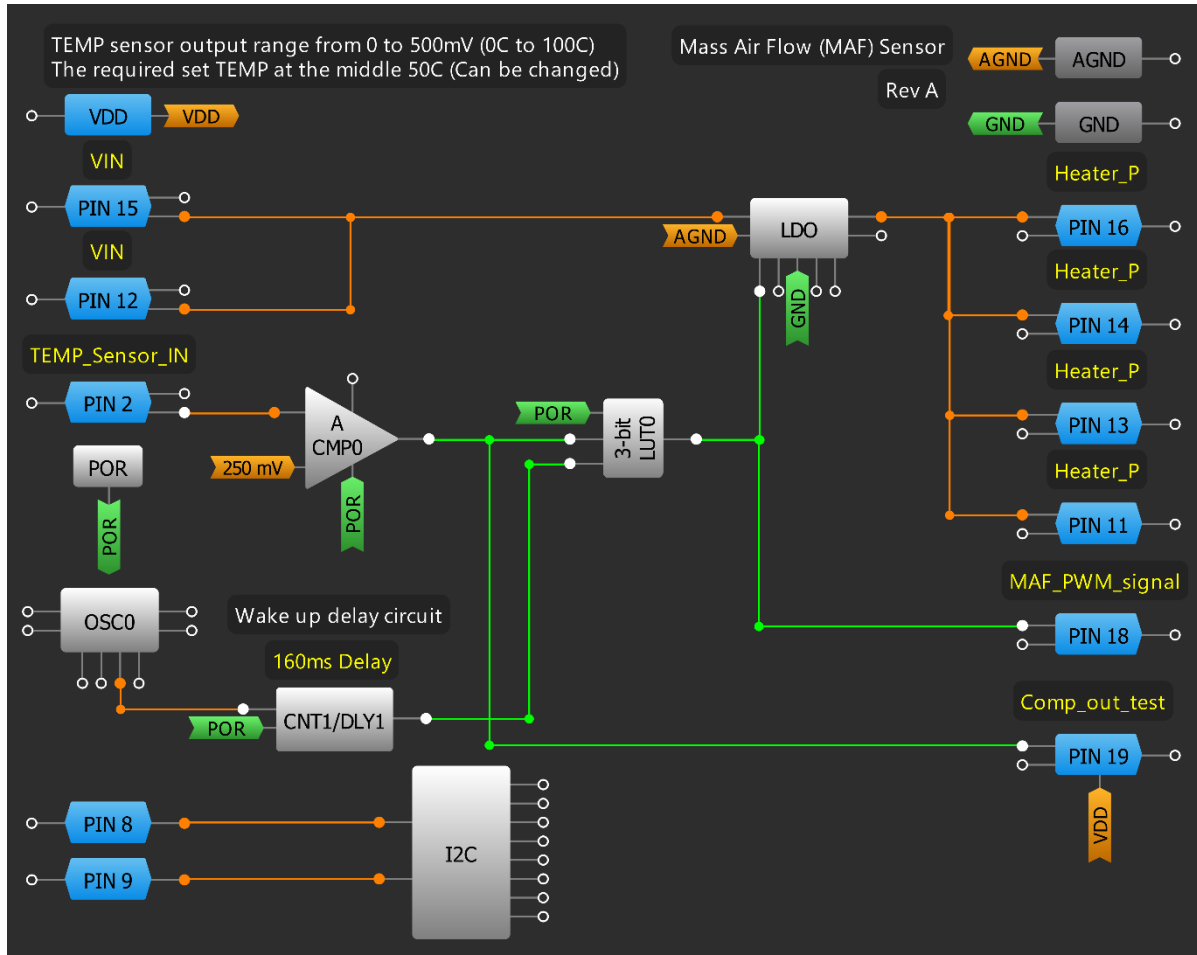

Figure 6: GreenPAK Implementation

Figure 6 shows the implementation of an MAF sensor using GreenPAK SLG46583V. The inputs are VIN (PIN 12 & PIN 15) and TEMP_Sensor_IN (PIN 2). VIN is the power input for the LDO which will supply the heater coil. TEMP_Sensor_IN is connected to the temperature sensor that measures the coil continuously. The outputs are Heater_P (PIN 11, 13, 14 and 16) which supplies the heater coil; MAF_PWM_signal (PIN 18) which is the signal goes to the MCU as a sensor output; Comp_out_test (PIN 19) which is the output for testing needs. At startup the sensor output should be high for 160ms to communicate with the MCU that the sensor is ready to measure, DLY1 makes this happens after powering up. The comparator CMP0 gives a high signal once the measured temperature represented in voltage crosses a certain value.

3-bit LUT0 has the following settings shown in Figure 7. 3-bit LUT0 make sure that the output is high if the delay output is absent. Once the delay ends, the CMP0 output leads the output.

Figure 7: 3-bit LUT0 Implementation

After the wake-up process, the sensor will continue to keep the heater coil temperature constant whatever the air flow occurs, and this sends the PWM signal out to MCU as a representation of the airflow by duty cycle.

To replicate the MAF sensor in the market, the user must fine tune the value of CMP0 ref and test the design on the same environment to match the two sensors' outputs. In case of designing a sensor for a new design from scratch, you are free to choose the value that suites your design.

To validate the design a heater and a temperature sensor is required; we have used the same heater and temperature sensor that we find in the MAF sensor by bypassing them to the GreenPAK as shown in Figure 8. The MAF reads the temperature data and generates the required PWM that controls the heater. The outputs are LDO_voltage_out and MAF_PWM_signal. As shown in **Error! Reference source not found.** the heater is enabled until reaching the desired temperature then starts to reduce the PWM duty cycle to reach the steady state.
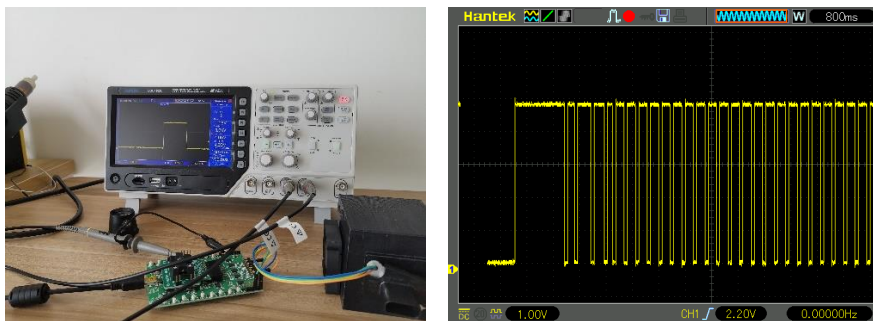

Figure 8: Bench Setup & PWM Signal Output

By repeating the test of the MAF output vs input air flow at different temperatures as shown in Figure 5; The output will be similar to the targeted sensor with an offset based on the CMP0 ref. As described before the CMP0 ref will affect the final output steady voltage which will be translated to the targeted heater steady temperature. To replicate the exact sensor values, the CMP0 ref need to be adjusted.
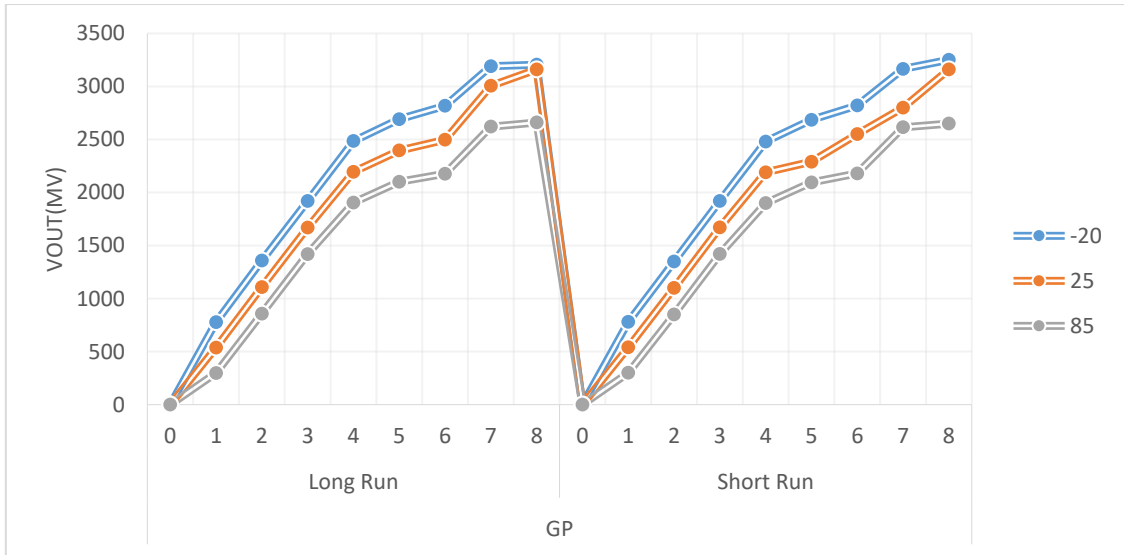
Figure 9: Output vs Airflow for GP Implementation

For comparison, you can see in Figure 10 the difference between the sensor (from market) data and the new sensor using GreenPAK.
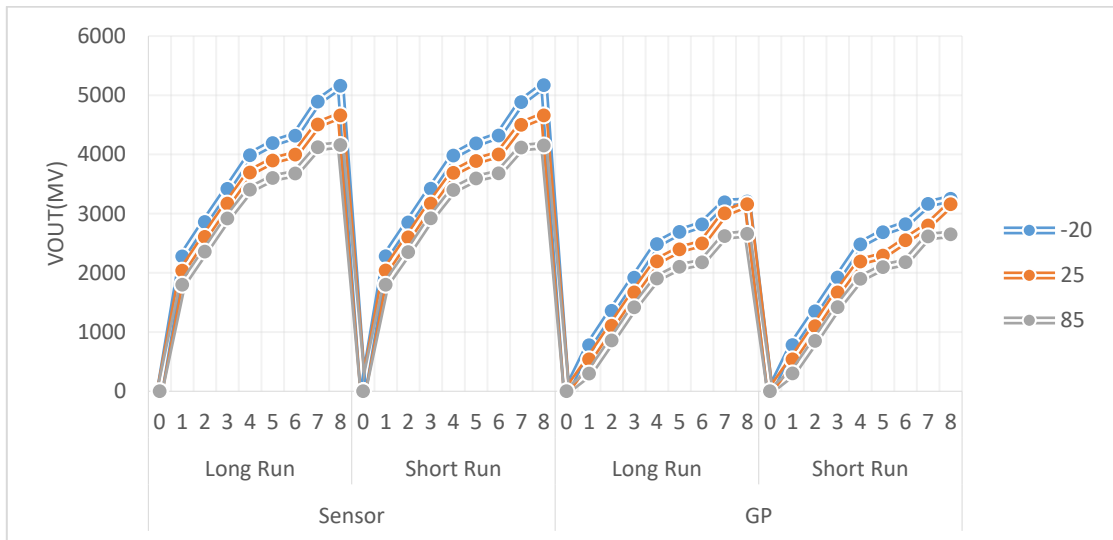

Figure 10: (Market) Sensor Vs GP Implementation

7. Conclusion

Designing a MAF sensor was very painful; every company must follow the ASIC design flow which consumes time, engineering efforts and of course a lot of money. Replacing it with FPGA is impossible, the FPGA is meant for complex designs and cannot fit into this tiny sensor. GreenPAK gathered the best of two worlds of having a tiny body and can implement a full system as shown in this application note. Updating and upgrading the sensor now became a piece of cake, just you must adjust the design and program the SLG46583V.

8. Revision History

Revision	Date	Description
1.00	Oct 5, 2022	Initial release.

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