TB044

Sensing Air Flow with the PIC16C781

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INTRODUCTION

Programmable Switch Mode Controllers (PSMC) are not just for switching power supplies. This technical brief describes how to use the PIC16C781 PSMC in combination with the Integrated Operational Amplifier, Digital-to-Analog Converter (DAC), and gated timer to construct a thermally operated air flow sensor with minimum external components.

Theory of Operation

Air flow is detected by the cooling effect of air movement across a heated resistor. The circuit schematic is shown in Figure 1. R5 and R7 are thin film platinum Resistance Temperature Detectors (RTD). These are essentially thermistors with a very linear temperature response. The flow sensor is comprised of R6 and R7. The bias on R7 is intentionally set below the bias on R5. R6 and R7 are thermally linked so that when R7 is heated by R6, the resistance of R7 increases. As R7 resistance increases, the voltage across R7 also increases until it matches the voltage across R5, at which time the Op Amp output will shut down the Programmable Switch Mode Controller (PSMC) and cease heating R6. As moving air cools R6, more power is required to heat the R6-R7 pair to maintain the same R7 resistance and voltage.

Changes in ambient temperature conditions are compensated by two voltage dividers, R2-R5 and R1-R7. R2 and R5 form a voltage divider between the Op Amp output and the Op Amp inverting input. Similarly, R1 and R7 form a voltage divider between the variable DAC reference and the non-inverting Op Amp input. Since R5 and R7 are identical RTD's, resistance variations due to self heating, as well as changes in the ambient conditions, cancel out at the Op Amp inputs.

R6 heat is controlled by a closed loop comprised of:

- R7 Voltage
- Op Amp
- Comparator
- PSMC
- R6 driver Q1

R7 is heated by R6. If moving air cools R6, the amount of heat transferred to R7 is reduced. The resistance of R7 falls with the temperature. As R7 resistance falls, the voltage drop across R7 also falls. The Op Amp output is directly proportional to the voltage across R7. When the Op Amp output goes below VR, the comparator output goes high. The PSMC responds to the high comparator output by supplying drive pulses to Q1, thereby heating up R6. The temperature rise of R6 overcomes the cooling effect of moving air, and heat is transferred to R7 closing the loop.

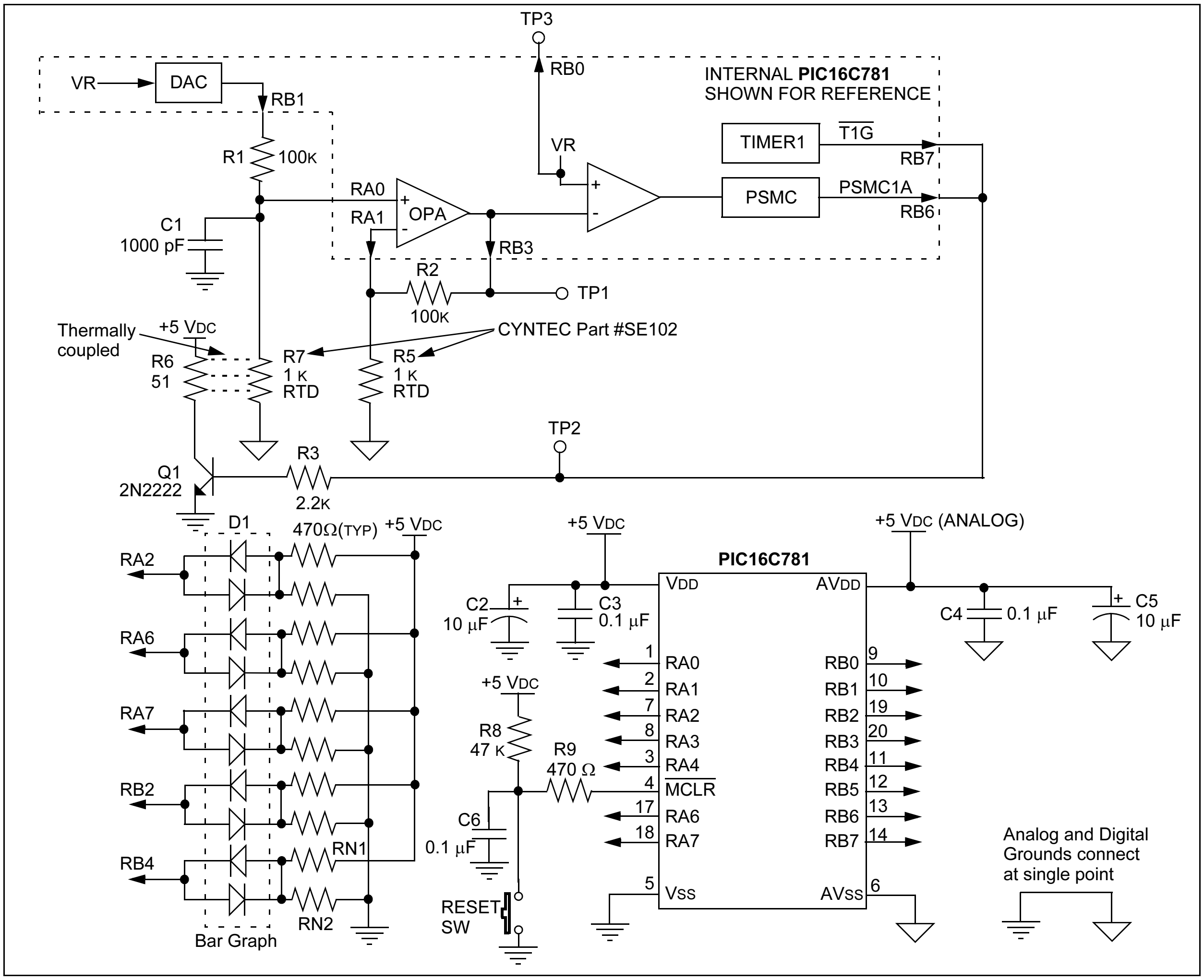
The PSMC is configured for pulse skipping. The control loop generates pulses until the temperature of R7, and the corresponding resistance, is high enough to disable the pulse drive. At equilibrium, the number of drive pulses match the heating requirement to keep the voltage at R7 equal to the voltage at R6.

The DAC output is used to adjust the equilibrium point in still air by varying the bias on R7. At high bias levels, less heat is required by R6 to reach the equilibrium resistance level. Low required heating in still air means that there is plenty of headroom in the potential drive output, but this also means less variation due to cooling and thus low sensitivity. At low bias levels, more heat is required by R7. Greater heat means the effect of cooling is greater and, in turn, higher sensitivity. There is a limit to the drive available to R6 so that if the bias level is low enough the equilibrium resistance and voltage cannot be obtained. In other words, at low bias levels there is better sensitivity but less head room in potential heating drive. It was determined empirically that a good bias point is obtained when the Op Amp output is 100 mV below VR when R6 heating is inhibited.

The power being delivered to R6 is proportional to the cooling effect of moving air. This power is measured by counting the average time that the R6 driver is enabled. The PIC16C781 has an integral Timer1 count enable input (Timer1 Gate). By connecting the PSMC output to the Timer1 Gate input, Timer1 will count only when the PSMC output is low. Average PSMC drive time is determined by clearing Timer1 then using Timer0 to wait a fixed period and reading Timer1 at the end of that period. Since the gate is low true, higher counts indicate that less power is being delivered to R6.

A 10-segment LED bar graph is used to display relative air flow. The circuit shows how to drive ten segments with five outputs. Each microcontroller output is tied to two segments. When the output is high, one LED is driven. When the output is low, the other LED is driven. When the output is high-impedance, neither LED is driven.

FIGURE 1: CIRCUIT SCHEMATIC FOR SENSING AIR FLOW WITH PIC16C781



Zeroing and Calibration

The integral DAC makes automatic zeroing of the R7 bias current possible. While this process is in progress, the sensor should be in still air (no air flow). One LED flashes as a calibration-in-progress indicator. When the LED stops flashing, air flow may be resumed and measurements can begin. The first task after power-on initialization is to calibrate the Op Amp offset using the built-in Op Amp calibration utility of the PIC16C781. After Op Amp calibration, the DAC is initially set for about 3.0 volts output. The RTD temperatures are allowed to settle for 6 seconds, then the average PSMC drive time is measured using Timer1 and the Timer1 gate input. If the measured value is within plus or minus one display resolution of the expected zero value, then the zeroing routine is exited and measurement and display commences. If the measured value is outside of the expected window, the DAC is adjusted up or down to compensate for the offset and, after the six second settling time, another measurement is taken. This process repeats until the desired R7 bias level has been obtained.

SUMMARY

This technical brief demonstrates how temperature changes resulting in milliohm differences can be measured quickly and accurately using only the built-in peripherals of the PIC16C781. This is the first of the mixed-signal PICmicro® microcontrollers with integral DAC, operational amplifier, comparators, PSMC and gated timer inputs which, when used in harmony, make such measurements possible.

Source code for this application is available for free. Download it from the Microchip web site.

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