Tire Temperature Analyzer
For High Performance Applications

Hardware Description
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Introduction

Imagine a tire temperature monitoring system that tracks temperatures at the most optimal time, when the vehicle is on the track. This IR based system has the capabilities to measure and record temperatures of multiple locations on a single tire. It can measure in the middle, inside and outside of the tire. Upon completion of a track session all that is required is a simple download for a graphical representation of tire temperature and how that correlates to the lateral G forces experienced by the vehicle. All this functionality is delivered in a small package that will be mounted above the surface of the tire. This document describes the hardware implementation of said device.

Physical Description and Sketch

The final appearance of the device will be centered around functionality and ease of attachment to the vehicle. The resulting enclosure is a simple rectangular box. A sketch of the final design can be seen in figure 1. The box contains the main MCU, linear voltage regulator, CAN transceiver, and low voltage reset. The box also has connections on either end. One end connects to the CAN bus and receives 12 volts and ground from the vehicle via a Delphi GT-150 series 4-wire automotive connector (J4). The other end supplies a regulated 5 volts, ground, and the communication bus to the three IR thermometers via three GT-150 series 4-wire automotive connectors (J1/P1, J2/P2, J3/P3). The box will be connected to the same device used to mount the IR thermometers above the tire. This mounting hardware can be seen in Figure 2 and Figure 3 and was designed by students of the VRI.

Figure 1: Mounting hardware with sample IR sensors attached.  Figure 2: Mounting hardware attached to wheel.
Figure 3: a) The Box. b) CAN and power connector. c) Sensor pig tails terminated with connectors.
Detailed Hardware description

Microcontroller

At the heart of the design is the microcontroller, FreeScale’s MC9S12DP512 16-bit microcontroller (U1). Among the resources needed on the MCU are a Controller Area Network (CAN) controller and an Inter-IC BUS (IIC) interface. The CAN controller will be used to put calculated temperature data on the bus and eventually to the logger on the vehicle. The IIC interface will be used to receive data from the sensors themselves. The microcontroller will act as a communication interface between the CAN and the digital output of the IR sensors.

The microcontroller’s power is decoupled through several capacitors (C6, C10, C11, and C12). The MCU also has external phase-locked loop (PLL) circuitry to control the system clock frequency of 24 MHz. The 16 MHz crystal (XTAL1) is used in the PLL circuit and then internally scaled up to the system clock frequency. Capacitors C4, C5, C7, C8, and C9 along with resistor R9 make up the PLL filter and decoupling network.

There is a 10 pin male header (J5) located on the circuit board to act as a background debug module (BDM) connector for programming and debugging. A standard 6 pin BDM connector can be used on pins 1 through 6, while pins 7 and 8 allow access to MODA and MODB signals, respectively. Pin 9 allows access to the ECLK signal.

CAN Transceiver

In order for successful CAN communication there must be a CAN transceiver. This is to satisfy SAEJ1939/11 standards, the CAN physical layer, a PCA82C250 CAN transceiver (U4) is used. Twisted pair bus termination as specified by SAEJ1939/11 is accomplished using a 120Ω resistor (R1). The CAN transceiver is the interface between the CAN protocol controller onboard the MCU and the physical bus. The device provides differential transmit capability to the bus and differential receive capability to the CAN controller. The RXD and TXD pins of the transceiver are connected directly to the RXCAN0 and TXCAN0 pins of the microcontroller. The CANL and CANH pins are connected to the vehicles CAN bus through the 120Ω terminating resistor. The pin RS is connected to digital ground through a 10KΩ resistor to control the slew rate. It is currently set at 20 v/µS and is connected to ground because standby mode is not required for this application. VREF is left as a NC because it is just the output voltage reference of the transceiver.

Digital Infrared Sensors (IRS)

The sensors are infrared (IR) thermometers for non contact temperature measurements. Both the IR sensitive thermopile detector chip and the signal conditioning ASIC are integrated in the same TO-39 can. They were designed to be very robust for use in automotive applications. Their temperature ranges are well within an acceptable range for this application. The ambient temperature range is -40 to 125 °C while the object temperature range only needs to be between 0 to 170 °C. These sensors are factory
calibrated with a digital SMBus output giving full access to the measured temperature in the complete temperature range with a resolution of 0.1°C. The SMBus output is compatible with the IIC interface on the MCU.

The three sensors (IRS1, IRS2, and IRS3) are connected to the main unit through three GT-150 series 4-wire automotive connectors (J1/P1, J2/P2, J3/P3) and a twisted pair shielded cable. The SCL and SDA pins of the MCU and IRSs are connected directly to each other and there is a 715Ω pull-up resistor (R3 and R4) on each of the line to limit the current to between 100µA and 350µA while maintaining the required rise times.

Power Supply

Another piece of hardware in the design is the LM2940T-5.0 (U2), a 5.0 volt linear voltage regulator. The regulator is designed for use in an automotive environment and uses the 12 volt system of the car and regulates that down to 5 volts. Both the input power and regulated output power are decoupled through capacitors (C1 and C2). The output will have to be able to source no more than around 200 mA, only a fraction of the 1 A rating.

The last piece of hardware is the low voltage reset (LVR) for the MCU. It is there to make sure the MCU is always operating above the minimum 4.5v required for proper functioning.