ECM ENGINE CONTROL AND MONITORING

Tech Note No. 03081 Fast Response Exhaust Gas Measurement with FastTemp

Introduction

ECM's FastTemp™ is a fast-response temperature measurement device suitable for continuous use in the exhaust of combustion engines. Using rugged, standard K-Type, shielded and grounded thermocouple elements, FastTemp provides insight into thermal transients otherwise possible only with fragile miniature exposed bead wire thermocouples. FastTemp provides a galvanically isolated 5mV/°C output signal that can be directly interfaced with any data acquisition system.

Equipment Setup

Experiments were performed on a 3 cylinder production spark-ignition naturally aspirated gasoline engine. A 1/16" grounded and shielded thermocouple was installed in the exhaust collector in a position central to all three cylinders, but not with fully symmetric access to each of the exhaust ports. Immediately downstream of the collector, an ECM AFRecorder Model 1200 UEGO sensor was installed to measure the Air-Fuel Ratio of the exhaust gas.

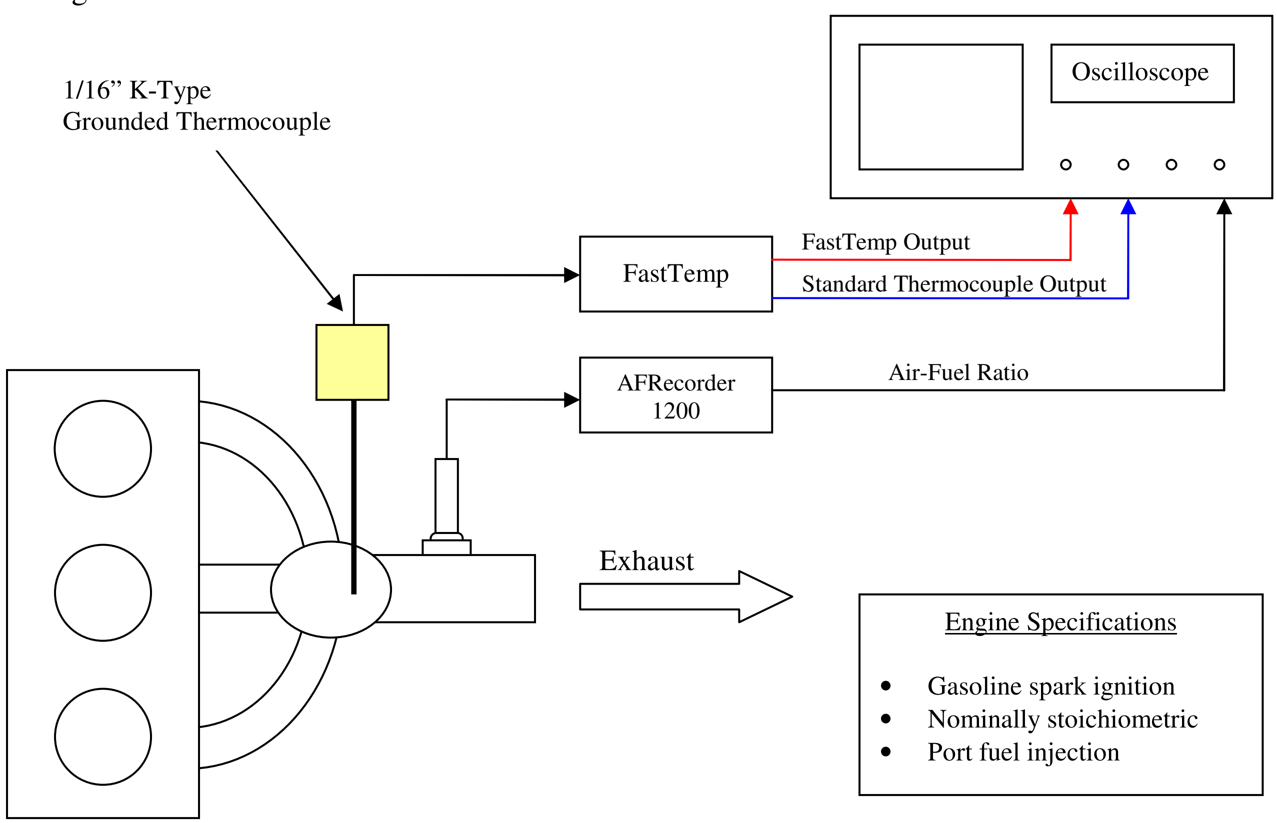

Figure 1: Equipment Schematic Layout

Equipment Setup –cont’d

Analog voltages from FastTemp and the AFRecorder are measured with a 4-channel Tektronix TDS3034B oscilloscope. Two measurements are recorded from FastTemp: the fast response temperature output and a standard amplified thermocouple output. For each of these signals, the output transfer function was 5mV/°C. The AFRecorder was programmed to provide a 0-5V linear output over the range of 8-18:1 AFR. For AFR’s outside of this range (for example when reading ambient air), the AFRecorder continues to read full scale output (18:1 AFR).

Results

For a comparison of the response characteristics of the FastTemp output and a standard thermocouple response, a no-load step in engine speed was performed. Shown in Figure 2 is a test where engine speed is stepped from idle to approximately 3000 rpm and back to idle in a no-load condition. At approximately 1.8 seconds into the test, the throttle is opened, causing engine speed to increase to 3000 rpm. At this point the AFR undergoes a lean condition as the ECU is unable to maintain stoichiometric AFR under the sudden transient. This causes a sudden drop in exhaust gas temperature to 250°C before the ECU is able to compensate.

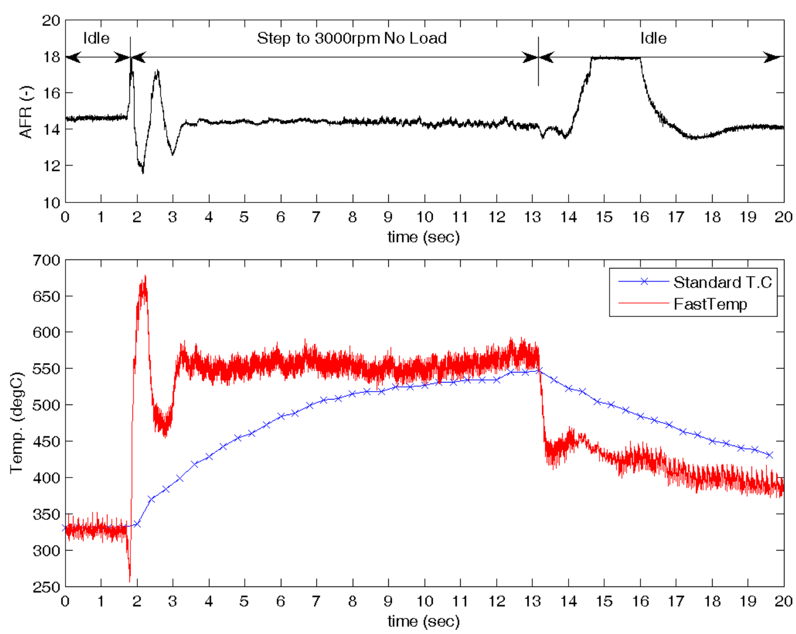

Figure 2: No Load RPM Step

Results – cont'd

Subsequent temperature dynamics up to 3.5 seconds into the test are a result of increasing mass flow rate with engine speed, stoichiometry dynamics, and ignition timing dynamics due to ECU compensation. Of note in Figure 2 is the fact that the standard thermocouple probe shows none of the significant transient response characteristics of FastTemp, and takes approximately 11 seconds to come to a steady-state value. At 13 seconds into the test, the throttle is again closed, causing an immediate drop in the FastTemp output to 400°C. This leads to a fuel-cut by the ECU at 14 seconds. The 'fur' seen in the FastTemp signal is cylinder-to-cylinder temperature measurements, as will be seen later.

Another example of the FastTemp response compared to a standard thermocouple is shown in Figure 3, during an engine start event. From the start of the test to 0.2 seconds the engine is not running, but is fully hot soaked. At 0.2 seconds, cranking occurs, with a subsequent decrease in exhaust temperature measured by FastTemp, as no fuel is injected (confirmed by the AFR remaining pinned at 18:1 AFR). At 0.5 seconds, the engine begins to fire, as shown by a sudden increase in exhaust gas temperature to 350°C, and AFR beginning to decrease to less than 18:1 AFR at 1 second. Finally at 1.2 seconds, the exhaust temperature reaches a nearly steady DC value of 300°C, as the ECU begins to control AFR to approximately 15:1.

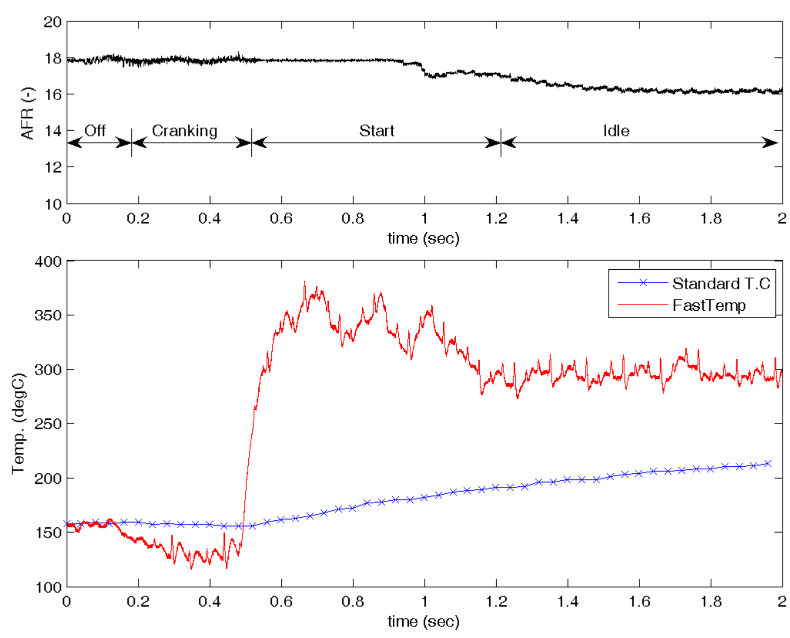

Figure 3: Warm Engine Start

Results – cont'd

With the time scale of Figure 3 it is possible to begin to see the full bandwidth capability of FastTemp with the periodic spikes in the FastTemp signal representing the individual firing events of individual cylinders. As in the previous case, during the test case of Figure 3, the standard thermocouple output response is unable to capture any significant transient temperature information during this test condition.

A further expanded time scale plot is shown in Figure 4. The test condition is a steady 3000 rpm idle. During this test both the AFR and standard thermocouple data shows no transient information. However, the FastTemp output shows individual cylinder firing events. Due to the asymmetry in the exhaust configuration, and cylinder-to-cylinder differences in the combustion process, it is possible to see the temporal exhaust gas temperature as measured by FastTemp. Depending on the mounting location of the thermocouple, thermal transient information can be significantly different. Note that this is possible with a standard 1/16" diameter fully shielded K-Type thermocouple probe. With FastTemp and a standard, rugged thermocouple, both temporal and spatial variations in exhaust gas temperature can be measured and potential problem areas discovered.

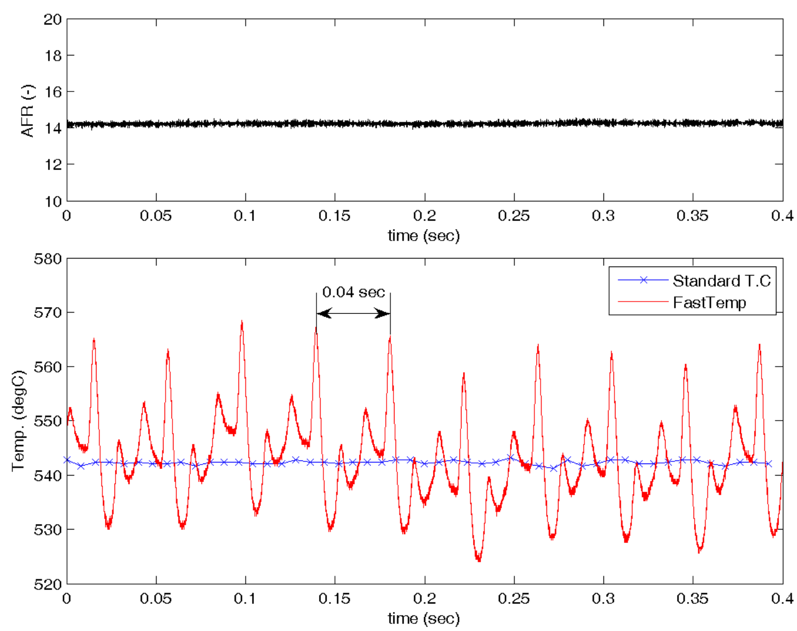

Figure 4: Close Up View, No Load 3000rpm (2 rev. takes 0.04 sec)