WOODWARD

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Crank Sensor Signal Investigation on Ashok-Leyland 6 liter CNG Engine using the OH4.0 Platform

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Purpose:

To determine the root cause of the crank signal irregularity observed on the Ashok-Leyland 6 liter CNG engine using the OH4.0 platform (SECM-48 hardware). This irregularity was previously described in Report 92149R003 by Doug Leone. Testing described in Report 92149R003 focused primarily on target wheel and sensor influence on waveform shape. This report focuses primarily on electrical interaction between the Bosch variable reluctance sensor and the SECM-48 interface circuitry.

Background:

The Ashok-Leyland engine uses a 60-2 encoder signal from the flywheel. The signal is generated by holes drilled into the outer diameter of the flywheel (prior experience has been with target wheels that have milled teeth which produce a more uniform signal). The sensor is mounted on the flywheel housing on an adapter.

The sensor is a Variable Reluctance Bosch sensor PN 0 281 002 214 as shown in figure 1. The sensor has the following key electrical properties:

Winding resistance at 20C: 860 +/- 10% ohms
Inductance at 1 kHz: 370 +/-15% mH

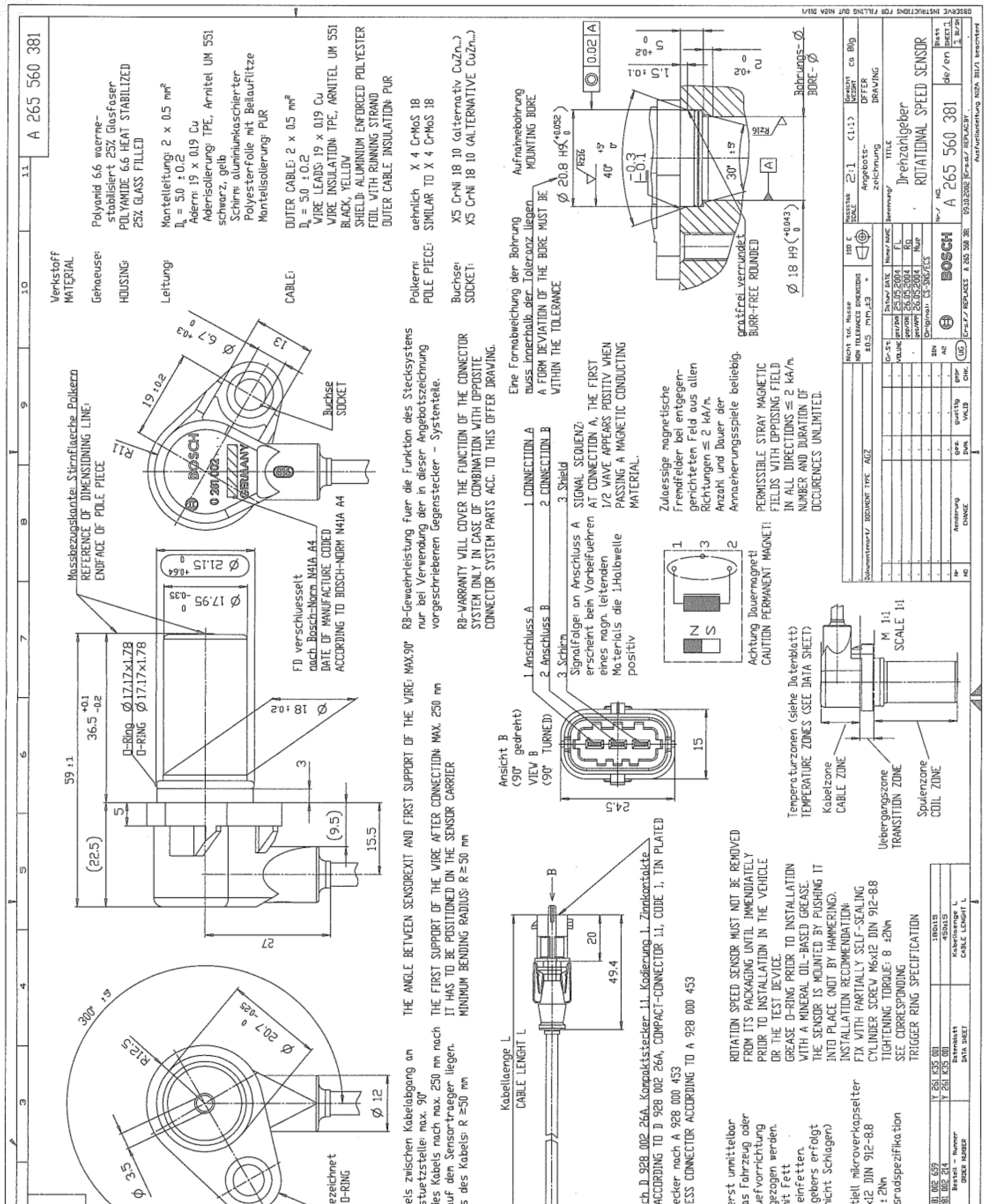

Figure 1: Bosch Variable Reluctance Sensor

When the engine is operated at low engine speeds, the sensor produces a relatively uniform signal such as the one shown in figure 2:

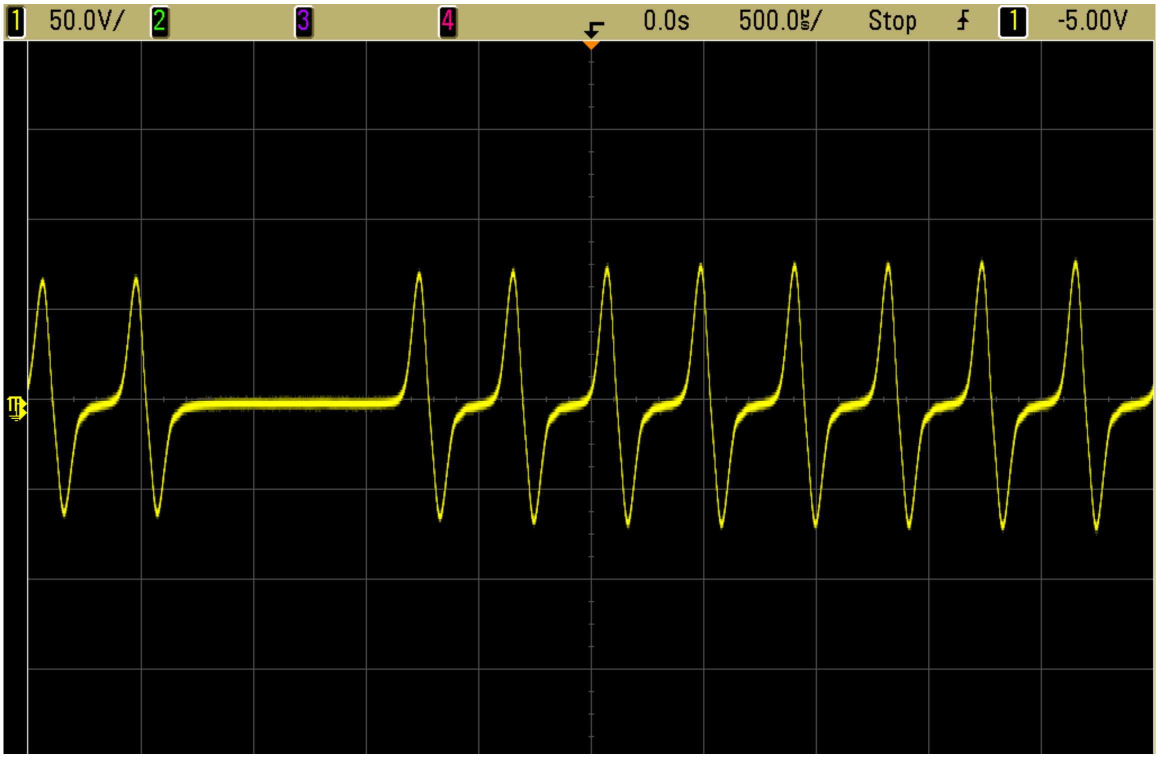

Figure 2: Normal Crank signal waveform – missing tooth gap shown.

At higher engine speeds (e.g. 2400 rpm) the waveform develops a hump on the rising edge as shown in figure 3. The hump occurs above ground voltage. This waveform irregularity has been shown to induce encoder faults on the SECM-48.

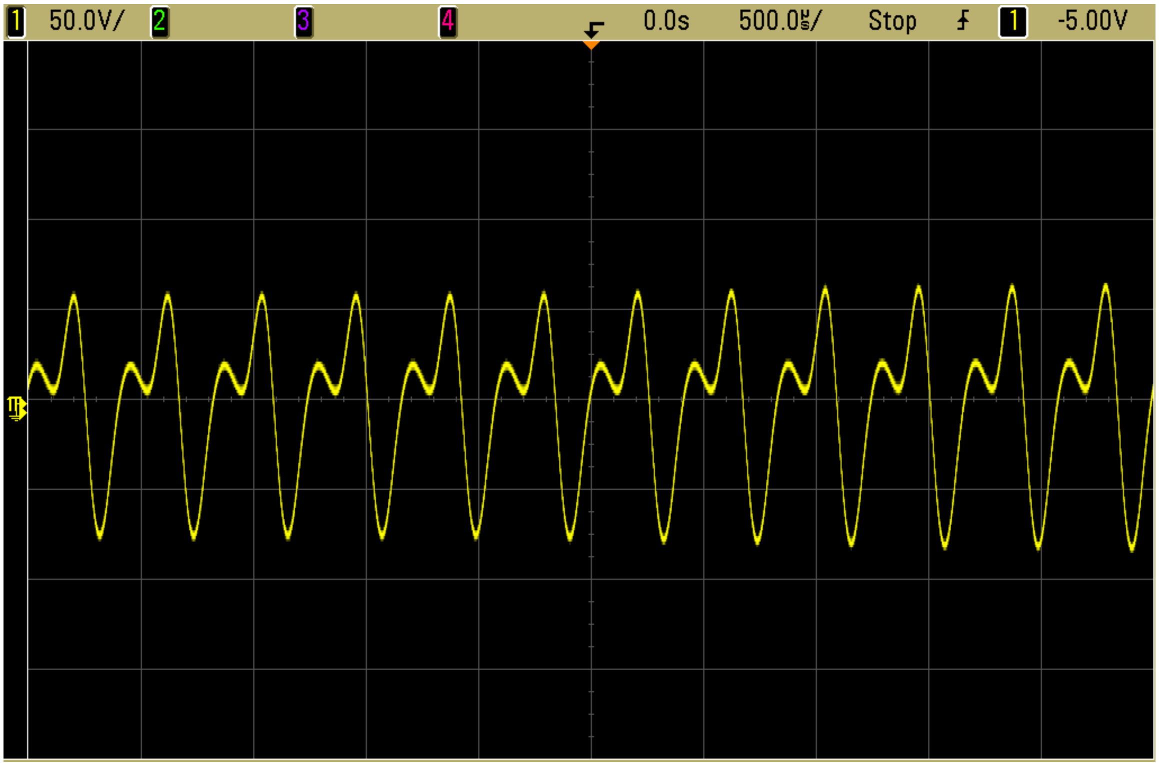

Figure 3: Waveform at 2400 rpm

Report 92149R003 showed the signal could be corrected by changing to a lower impedance sensor.

The SECM-48 employs the crank sensor interface circuit shown in Figure 4. This is a dual purpose interface, suitable for use with either variable reluctance or Hall-Effect sensors. The LM-1815 circuit provides the variable reluctance interface while the MC74HC1G135 circuit provides the Hall-Effect interface. The Q230 transistor circuit provides a pullup for use with open-collector Hall-Effect sensors – this circuit is turned off when used with variable reluctance sensors. This circuit is similar, but not identical, to the crank sensor interface circuit used in the PCM-128 – refer to Figure 5.

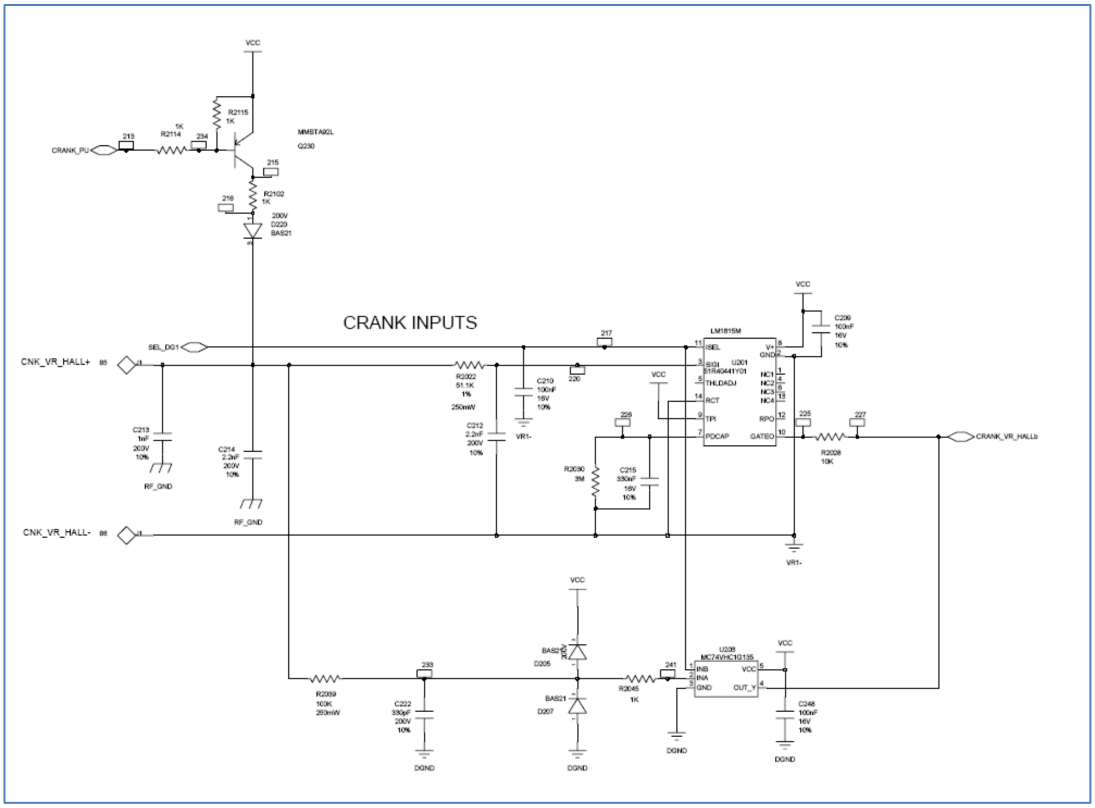

Figure 4: Crank Sensor Interface in SECM-48

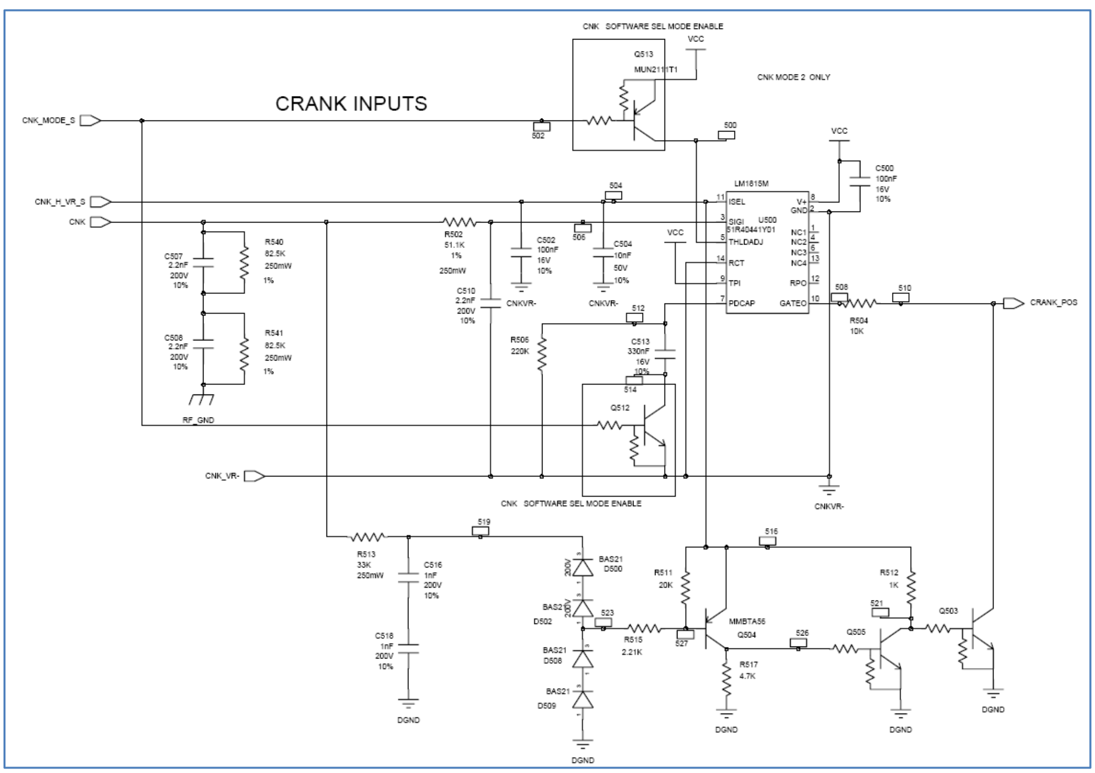

Figure 5: Crank Sensor Interface in PCM-128

As part of this investigation, the problem was discussed with Jack Boatman, hardware engineer for MotoTron – supplier of both the SECM-48 and the PCM-128. Jack suggested that the waveform irregularity may be due to a tuned R-L-C (Resistor – Inductor- Capacitor) circuit behavior.

Test Results:

The engine was operated at 2400 rpm where the waveform irregularity is normally observed. The following tests were performed and results obtained:

Series Resistor: A 10K ohGas Mixer 19mmm series resistor was placed between the Bosch crank sensor and the SECM-48. This was found to eliminate the signal irregularity. This resistor was left in place for the remainder of the tests.

Test PCM-128 for similar behavior: The flywheel housing was modified to accept a second Bosch crank sensor in order to permit evaluation of the sensor interface without disrupting engine control with the main SECM-48. A PCM-128 was wired to the second Bosch sensor. The PCM-128 did NOT display the signal irregularity. The PCM-128 has different circuitry for the Hall-Effect sensor, no pull-up circuitry, and slightly different RF decoupling.

SECM-48 Interface Investigation: A second SECM-48 was wired to the second Bosch sensor. Components were selectively removed from the crank signal interface circuit of the SECM-48 in an attempt to isolate the source of the signal irregularity. A component would be removed and the signal waveform evaluated on-engine. The findings were as follows:

> R2102: removing this component disconnected the input circuitry from the Hall-Effect pullup circuit. This was shown to have no influence on the waveform.
>
> R2045: removing this component disconnected the input circuitry from the Hall-Effect interface circuit. This was shown to have no influence on the waveform.

D205 removing this component eliminated overvoltage signal clipping before the Hall-Effect circuit. This was shown to have no influence on the waveform.

D207 removing this component eliminated undervoltage signal clipping before the Hall-Effect circuit. This was shown to have no influence on the waveform.

C213: This 1 nF capacitor to RF_GND is provided for R-F decoupling. Removing this capacitor was shown to change the shape of the waveform slightly – moving the hump closer to ground.

C214: This 2.2 nF capacitor to RF_GND is provided for R-F decoupling. Removing this capacitor was shown to eliminate the waveform irregularity.

External capacitor: Adding a 1 nF external capacitor across the crank sensor input was shown to cause the irregularity to re-appear. Adding a 2 nF external capacitor across the crank sensor input was shown to increase the size of the irregularity. This was done several times to demonstrate a cause-and-effect relationship.

Open Circuit Investigation: The second Bosch crank signal was disconnected from the SECM-48.

Open circuit: Open circuit waveform is shown in Figure 6 (same as Figure 2). No waveform irregularity was present.

1nF: A 1nF external capacitor was placed across the sensor, resulting in the waveform shown in Figure 7. The irregularity was present.

2.2nF: A 2.2nF external capacitor was placed across the sensor, resulting in the waveform shown in Figure 8. The irregularity was present with greater amplitude than seen with the 1nF capacitor.

1nF+ 2.2nF: 1nF and 2.2nF external capacitors were placed across the sensor, resulting in the waveform shown in Figure 9. The irregularity was present. Overall signal amplitude was reduced from the waveform seen with the single 2nF capacitor.

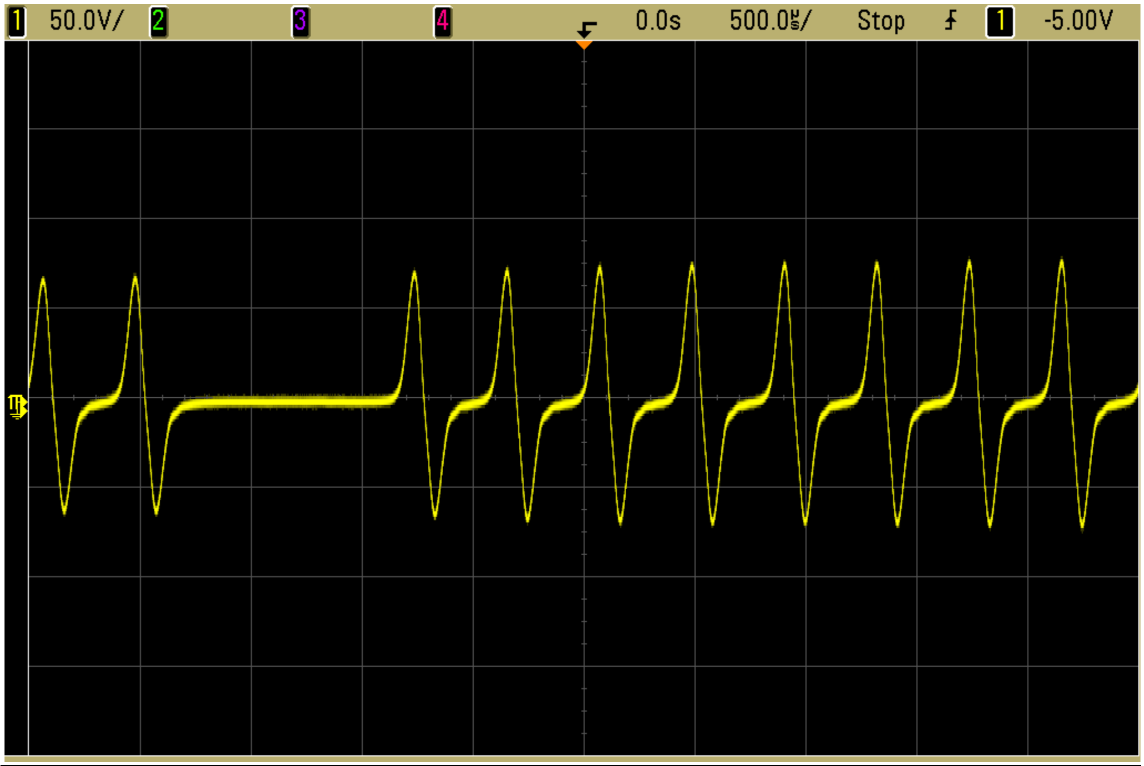

Figure 6: Open Circuit Bosch Crank Sensor.

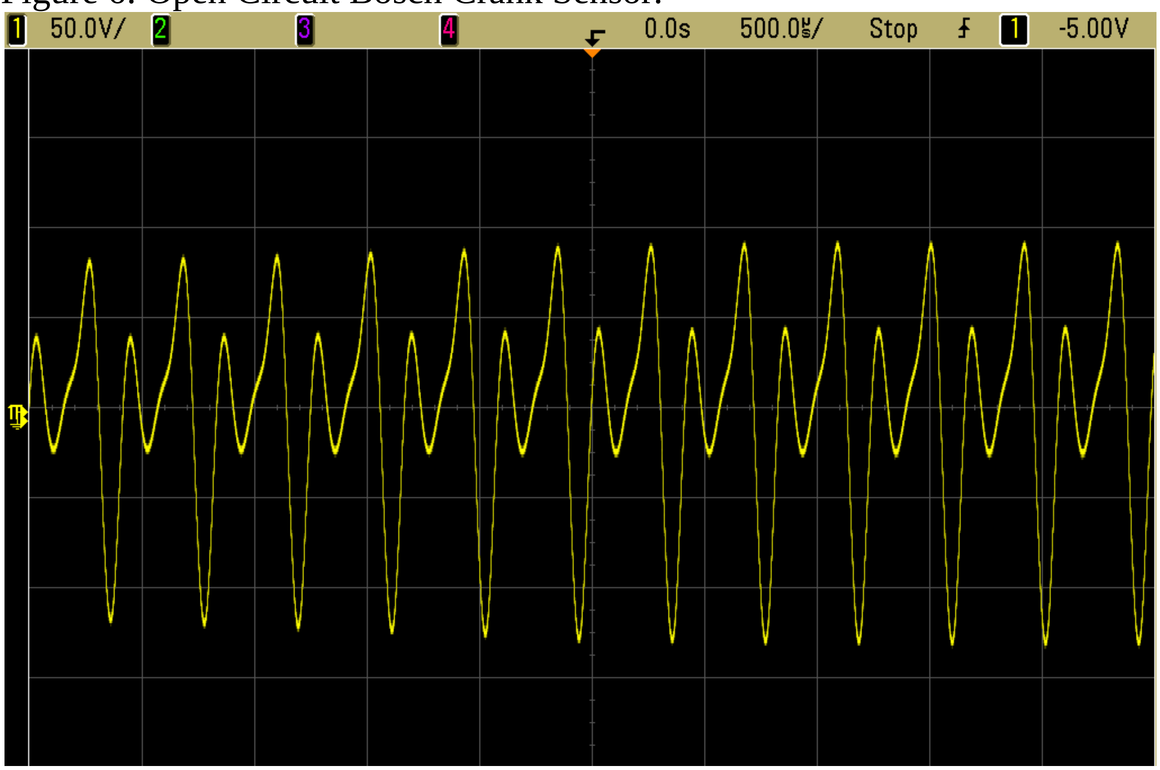

Figure 7: Open circuit Bosch crank sensor with 1 nF capacitor.

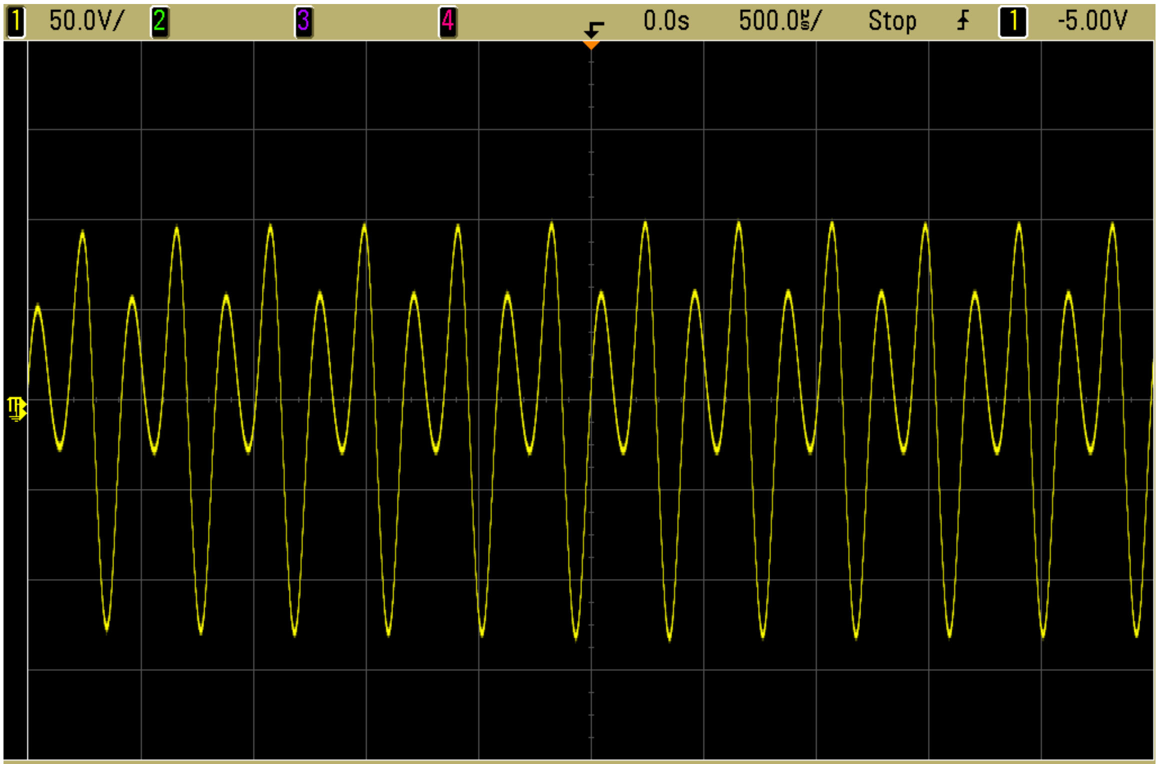

Figure 8: Open circuit Bosch crank sensor with 2.2 nF capacitor.

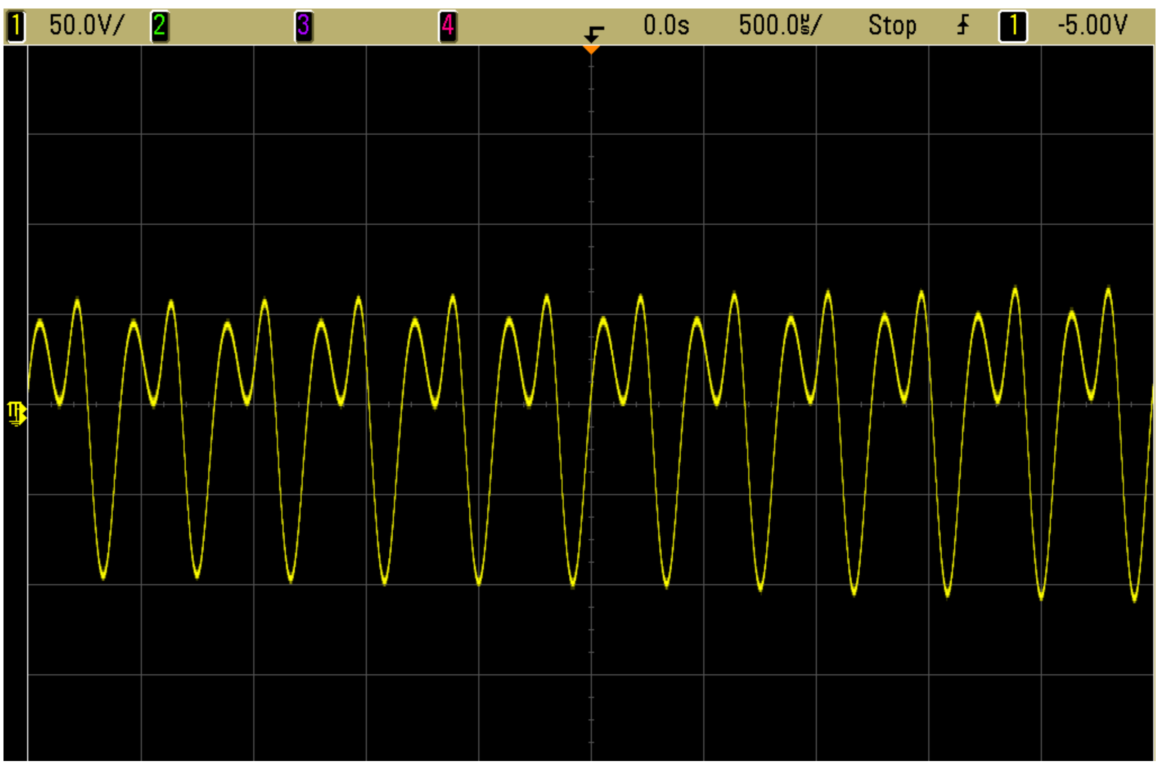

Figure 9: Open circuit Bosch crank sensor with 1nF + 2.2nF capacitors.

Conclusions

1. The root cause of the waveform irregularity is input circuit capacitance contributing to ringing in the R-L-C.

2. Solutions which have been presented to Ashok-Leyland are as follows:

 a) Include 10K ohm resistor in the wiring harness between the sensor and the SECM-48. In general, this is not a desirable thing for wiring harness design, but is an expedient solution.

 b) Modify input circuit in SECM-48. This approach would be costly and may adversely impact release of the system to Ashok-Leyland. EMC compliance would need to be re-confirmed. Unless the changes were validated on all current SECM-48 applications, this would necessitate a custom part for Ashok-Leyland.

 c) Select an alternative crank sensor which is compatible with the SECM-48 input circuitry.

Ashok-Leyland has agreed to add a 10K ohm resistor in the wiring harness.

3. This report should be shared with other Woodward teams working with Variable Reluctance Sensor interface circuits in order to avoid similar problems in future designs and/or applications.