Automating Signal Conditioning Setup Through Integration with Sensor Information

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Abstract

Caterpillar Inc. has been testing construction and mining equipment using Computerized Analysis Vans for two decades. During our latest van upgrade, we chose to move to PCM/FM from FM/FM mainly to increase the channel count. We also replaced our old signal conditioning that used span and balance potentiometers with computer programmable signal conditioning. This new signal conditioning requires that the gain and balance point be calculated for every channel on each test. The formulas for these calculations depend on the sensor, the signal conditioning card used, and the test requirements. Due to the number and variety of machines tested at the Caterpillar Proving Grounds, these calculations needed to be automated. Using a few initial parameters and the information from our sensor calibration database, each channel's balance point, gain, and expected slope are calculated. This system has increased productivity, accuracy, and consistency over manually calculating these parameters. This paper covers the sensor database, the calculated parameters and an overview of the way the system works.

KEYWORDS

PCM (Pulse Code Modulation), Automation, Signal Conditioning

INTRODUCTION

Caterpillar's machine testing operation consists of two proving grounds; the principle proving ground in Peoria, Illinois and the other near Tucson, Arizona. Caterpillar uses its several PCM/FM acquisition and analysis vans to test construction and mining equipment at the two proving grounds and at customer job sites all over the continental United States and Canada. Last year, we performed more than 225 tests, with the vans. The duration of these tests varied from one day to three weeks, including setup time. This heavy test load is the reason we needed to streamline the transition from one test to another.

DISCUSSION

In 1993, Caterpillar Inc. started upgrading its old FM/FM analysis and acquisition van fleet to PCM/FM. Do to the lack of a turnkey PCM/FM system that integrated the bit synchronizer, the PCM decommutator, and the signal conditioning, we decided to purchase the subsystems from the different vendors and write software to integrate them. Our first version of the software to integrate the subsystems, was basically a set of forms to enter information that describes the test and the parameters to be measured. The data entered into these forms was simply posted into the databases of the PC based bit synchronizer and decommutator from one vendor and the signal conditioning from another. The gain, balance point, and excitation had to be determined and entered into the forms for each channel, so these parameters could be put into the database for the signal conditioning. We improved the signal conditioning setup by creating and using a database to describe each transducer. The information from this database was used to program some of the signal conditioning parameters and to calculate others, like gain and balance point.

In our first version of the van software, we discovered that going from a potentiometer based system to a completely programmable system was difficult for our technicians. They did not understand how to calculate the gain for a strain gage based transducer and the number of programmable parameters overwhelmed them. With some training, the technicians became proficient with the signal conditioning setup. The next hurdle was not so easy to solve. The test schedule was so aggressive, the technicians did not have the time to hand calculate the gains for each channel and still get the test run in the scheduled time. The signal conditioning also had the capability of shifting the measurement range to match the range requested, by setting the balance point. Better alignment of the input range with the range requested improves the resolution and in some cases the accuracy of the resulting measurement. We wanted to take advantage of this resolution improvement, which meant the technician would have to spend more time calculating the information to setup the signal conditioning. We needed to find a way to reduce the time the technicians were spending calculating and entering the signal conditioning setup parameters. We felt the only way this could be done was to automate these calculations.

After seeing the need to automate the signal conditioning setup, we had to figure out how this could be done. It was decided to design a database to store all the information needed to set up each transducer and describe its output. We also looked for other calculations that would help make the complete system easier to use and more “fool proof”. We decided to calculate what we call expected slope. Expected slope is just that, it is the slope expected based on characteristics of the transducer and the signal conditioning’s programmed excitation, gain, and balance point. All the information needed to do the calculations and set up the signal conditioning would be stored and retrieved based on a Sensor ID that was assigned to each transducer. The resulting database contains the following fields: Sensor ID, Serial Number, Sensor Type, Range, Assigned Location, Cal Value, Cal Units, Cal Equivalent Units, Zero Equivalent Value, Cal Equivalent Value(1st order) ,2nd order, 3rd order, 4th order, 5th order, zero type, cal type, Bridge Type, Bridge Resistance, Excitation Voltage, Last Calibration Date, Calibration Due Date, Calibration Interval, and Comment.

The balance point is where in the input range you want zero voltages to be for internal type balancing. For an external balance, the balance point is where in the input range you want the incoming voltage from the transducer to be shifted or offset during a balance. The balance point is often called an offset by other signal conditioning manufacturers, but we are using the term balance point for consistency with our present signal conditioning vendor. We use the balance point to increase the resolution of our measurements by aligning the range with the limits requested by the requesting engineer. An example of where shifting the balance point is advantageous is a pressure transducer. The requested measurement range is usually more positive than negative, so we shift the input range of the signal conditioning card to have more range in the positive direction. In this example, the resolution with the range shift is about twice as fine as it would have been if the transducer was balanced at the traditional middle of the Analog to Digital converter (A/D) range.

The gain is calculated with a 5% pad on each end of the range to provide an overload buffer. The overload buffer gives us a standard way to handle channels with a requested unidirectional engineering unit range. A measurement with a unidirectional range, like 0 to 100, causes a problem when using the balance point to take advantage of the entire A/D range and the transducer’s zero shifts slightly negative. This zero shift, without an overload buffer, would move the input voltage out of the A/D's range thus forcing us to re-calibrate the channel. The overload buffer was added to prevent this problem. The gain calculation uses the requested engineering range, the balance point, data for the signal conditioning chosen, and information from the transducer database, like excitation, bridge resistance, and calibration value. After the desire gain is calculated, the closest gain that is lower than the calculated gain and in the list of valid gains for the signal conditioning card is selected.

The expected slope is used as a calibration check. Expected slope is expressed in Engineering Units per A/D count. We calculate the expected slope based on the programmed gain, balance point, and excitation voltage and transducer. During calibration if the resultant slope is not within 1% of the calculated expected slope the software warns the test operator of a possible error. Comparing the expected slope to the calibration slope is valuable for any transducer not being calibrated with a fixed slope calibration. Expected slope uncovers most problems with strain gage based transducers using a shunt calibration, because it verifies that the gain, calibration resistor, excitation, and the gage wiring are all working correctly.

The resulting system is structured so that the requesting engineer creates a list, using a windows based program we wrote, of parameters to be measured, the range, and the associated units for each channel. This list is given to the test scheduler, in electronic form, when the engineer signs up for the test. The instrument technician sets up the test based on the list of parameters submitted and records the Sensor ID used for each channel. The Sensor ID is then entered into the software along with the signal conditioning system and the type of signal conditioning card being used for each channel. Using the information about the transducers from the database, the pretest information from the engineer requesting the test, and the signal conditioning information, the software calculates the gain, balance point and the expected slope for each of the channels. All the setup information for the signal conditioning, both calculated and not, is inserted into the database for the signal conditioning. The test operator uses the software supplied with the signal conditioning to download the setup information to the signal conditioning. This method helps eliminate signal conditioning setup errors and saves between 15 and 20 minutes for a 32 channel test when compared to calculating these parameters and manually entering the setup information for each channel one-by-one.

Conclusion

We have been using the transducer database and the software that performs the calculations for about one year and are very pleased with the results. Our technicians are now spending more time setting up and running tests and less time calculating gains and balance points. Having the database of signal conditioning configuration information for each transducer guarantees that the excitation for that seldom used transducer is correct. We feel the effort and time put into this project has paid for itself in increased productivity and consistency and helps eliminate human error. The database and the automated calculations both simplifies the Standard Operating Procedure for each transducer and adds traceability to measurements, required by ISO 9000 certification. More information on Caterpillar’s test operation can be found in references 1 and 2.

References

1. Chapman, James E. “The Use of Telemetry in Heavy Equipment Testing at Caterpillar Inc.“ ITC 1997 Conference Proceedings.

2. Jury, Owen T. “The Design of Telemetry Acquisition and Analysis Vans for Testing Construction and Mining Equipment” ITC 1997 Conference Proceedings.