Application Note Number 200

Models 441A and 441AL Frequency-to-voltage Applications

What is a Frequency-to-voltage Converter?
Antilock-brake System Testing
Turbine-engine Overspeed Detection
Troubleshooting a Transmission
Diagnosing the Start-up Characteristics of a Vehicle's Air-conditioning Compressor

What is a Frequency-to-voltage Converter?

Simply put, an F-to-V converter is a fancy tachometer that produces an analog output that represents the frequency of an applied ac input signal. Ideally, the conversion process should be precise, fast, and easy to program. In addition, it should accept a variety of input frequency signals from sine wave to pulse, with or without dc offset. It should also provide a low-impedance output signal, filtered where necessary, which can be used by a variety of load equipment from recording equipment to A-to-D converters to data-acquisition systems.

All this is offered by the Ectron Models 441A and 441AL. These miniature instruments combine the latest electronic microcontroller technology with surface-mount construction to produce a true breakthrough in frequency-to-voltage products. Indeed, this instrument represents a worthy addition to the Ectron line of 400 Series products that have provided exceptional performance and reliability in rugged applications for the past 25 years.

The input-signal conditioner of these converters automatically provides stable operation for a wide range of pulse-, square-, and sine-wave signals from under 10 mV to 100 V in amplitude. The conversion function is provided by a fast, crystal-controlled microcontroller, which also interprets programming instructions from the front-panel controls. A selectable output filter allows the user to tailor the output response versus noise to best suit the application.

Input frequency range is from 1 Hz to 50 kHz (or from 60 rpm to 3,000,000 rpm for one pulse per revolution). The output voltage range is from –10 V to +10 V. Adjustable "input frequency to output voltage" set points allow the user to closely bracket the frequency of interest. For example, an input frequency could have a range from 0 Hz to 3000 Hz but the frequency of interest is only from 500 Hz to 1500 Hz. The Models 441A and 441AL can be set to provide an output of 0 V for an input frequency of 500 Hz and an output of 10 V for an input frequency of 1500 Hz. Thus, the output signal would change 1 V for a frequency change of 100 Hz. If desired, a frequency of 500 Hz could even be set to an output of –5 V and 1500 Hz to produce +5 V if this matches with the output load device.

The Models 441A and 441AL offer another unique function: the digital periodic filter. Many pulse signals are generated by cogged wheels where the cogs are not spaced evenly. As a result, the frequency of the resulting signal varies even when the rpm is constant. When the digital periodic filter is set to the number of cogs in the wheel, cancellation of this variation occurs; and the unwanted output noise is eliminated.

The front-panel display shows the input frequency with five-digit resolution as well as the digital periodic setting. All user settings are held in nonvolatile memory.

Input power is 10.5 V dc to 32 V dc and is isolated from input and output signals. For vehicle operation, standard 12 V or 24 V vehicle power is used for power.

With an input frequency range of 1 Hz to 50 kHz and an output voltage range of –10 V to +10 V, the Models 441A and 441AL offer precise frequency-to-voltage conversion for almost any application.

Antilock-brake System Testing

The Ectron Model 441A frequency-to-voltage converter is ideally suited to provide precise wheel-speed data on vehicles equipped with antilock-brake (ABS) and traction-control (TCS) systems. Designed for poor environmental conditions, this instrument is able to ignore temperature variations, vibration and shock, and considerable EMI interference. EMI filtering is incorporated in all input, output and power leads.

The speed sensor for some antilock-brake systems utilizes a 47-tooth pickup ring mounted on the hub of each of the four wheels of the vehicle. This pickup produces approximately ten pulses per mile-per-hour of wheel speed. At 1 mph, the amplitude of the signal is approximately 150 mV peak-to-peak. Unfortunately, the leads carrying this signal also contain from 1 V to 3 V of noise and usually include a dc offset produced by the ABS-TCS electronics. Furthermore, any connection to these leads must not cause loading or in any way affect the operation of the vehicle. Here, the Model 441A is a help in having a differential input, a 200 kΩ input resistance, and isolation from output, power, and case grounds.

The 1 V to 3 V of noise on the signal leads requires low-pass filtering to provide an adequate signal-to-noise ratio for the Model 441A. The input filter controls of the Model 441A, three steps of filtering and three steps of sensitivity, nearly always can produce usable signals for good data. For especially noisy conditions, a passive filter can be added ahead of the Model 441A. The filter components should be shielded from rf pickup.

Because typical 12 V vehicle power is very noisy with frequency components up to 10 MHZ or higher and voltage

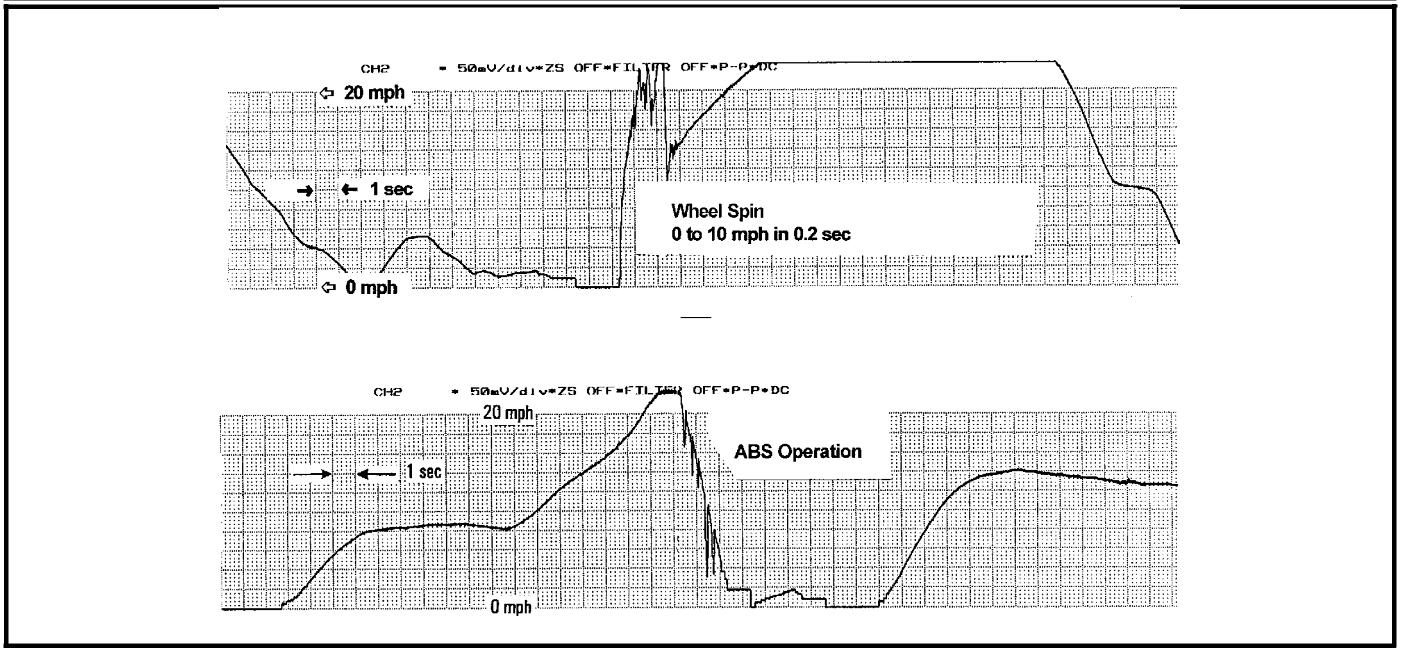

Figure 1

spikes of several volts, it may be necessary to add EMI filtering to the power leads or use separate battery power. Connection should be made at the battery using twisted-pair wires placing the filter close to the power connector of the Ectron enclosure. Both leads should be filtered with the filter common connected to a braided ground connection that is connected to chassis ground.

Results of tests on ABS equipped vehicles performed by Ectron engineers are shown in the above figures. Wheel speed on the monitored wheel is shown in the vertical direction with time as the horizontal scale. Good low-speed operation down to 0.4 mph was obtained. Fast-rise signals caused by wheel spin were recorded (Figure 1) as was ABS operation during panic stops (Figure 2). Only slow-speed operation is shown here, although performance was tested at up to highway speeds. A major automobile manufacturer used a number of Model 441A's to monitor cold weather behavior of vehicle traction control and antilock-brake systems undergoing testing in winter conditions in northern Michigan. Despite the rigors of the weather and the noisy conditions of the vehicle, results of the tests were very satisfactory.

Turbine-engine Overspeed Detection

Stationary gas turbine engines are used in a variety of applications from pumping fluids or gases to electric power generation. In virtually all applications it is necessary to monitor engine rpm either to detect over or under speed problems or to monitor the load on the engine. A specific application for the Model 441A was overspeed detection. If a turbine under full power loses its load, it can destroy itself in less than one second, so a fast-reacting overspeed detector is vital. Accuracy of the detection point is also important to avoid erroneous shut-down events.

The Model 441A is being used in a number of turbine engine applications. Usually a tachometer output is available with either 1 or 100 pulses per revolution. The engine specifics and test requirements of one application are:

Operating rpm	9,000.
Overspeed rpm	+1% or 9090.
Pickoff gear	100 teeth.
Pulses per second	15,150 at over speed rpm.
Desired response time	2 ms.
Accuracy of detection	0.1% of operating frequency.
Environment	Poor with high acoustic noise, shock, vibration, humidity, and EMI problems.
Mounting	Located under the engine on the engine mount.

The Ectron Model 441A met all of the above specs with no problem. The detection of the overspeed point, 15.15 kHz, is well within its frequency range, as are the response time and accuracy. Because of the packaging and encapsulation of the Model 441A, the environment was also no problem. EMI filters on all input and output leads of this instrument minimize the effects of external rf interference. The Ectron instruments continue to perform well in this application.

Troubleshooting a Vehicle's Drive Train

The manufacturer of a sports car was having drive-train problems during the early production phases of the car. What was needed was a way to monitor the exact speed of rotation of each of the components involved and determine where the variation with respect to the engine's speed occurred.

Each component, including the gears of the manual transmission, was monitored using a Model 441A. To detect gear speed a magnetic pickup was mounted to detect the teeth of the gear. Because of the wide frequency range of the Model 441A and its ability to adapt to virtually any input signal, it was possible to quickly set up the "Ectrons" to do the job. The input-signal conditioning (filtering and sensitivity) was set to maintain good signal reliability for all expected speeds. The output filter was left in the wideband position to maximize the response of the output signal.

The periodic filter function of the Model 441A was set to the number of cogs of the rotating member (or teeth in the gears). Thus, the variation in signal caused by any irregular spacing of the cogs was eliminated.

By monitoring the rotation speed of the engine and comparing it to the rotation speed of the various components in the drive train, it was possible to determine where the variation was occurring. Analysis of these data allowed the engineer to determine the cause of the problem.

Diagnosing the Start-up Characteristics of a Vehicle's Air-conditioning Compressor

An engineer had to analyze the acceleration characteristics of a vehicle air conditioner in order to optimize clutch parameters. His analysis included all engine speeds, compressor loads, and operation temperatures. Application problems included a noisy input-frequency waveform representing compressor rpm, a requirement for a response time of a few milliseconds, and nonideal laboratory conditions. He decided on the Ectron Model 441AL because it more than met his fast-response needs, it afforded conditioning of the input signal, and its rugged construction and small size fit his operating environment.

He used transducers to detect rpm, clutch voltage and current, compressor pressures, etc. Shown in Figure 2 are the current applied to the clutch (top waveform) and the compressor rpm, the output of the Model 441AL. The delay from the start of the current to the start of the compressor rotation (clutch delay) is about 55 ms (each minor division is equal to 5 ms). The shaft of the compressor pump accelerates from 0 rpm to 6,500 rpm in aout 40 ms, as is clearly shown on the bottom waveform. The response of the Ectron converter (1ms) easily reproduces the desired acceleration of the pump. Note that the pump contines to accelerate until it reaches full rpm. The discrete steps at low rpm result from the low pulse rate from the rpm transducer. Smoother response would be produced if this transducer had a higher pulse-count-per-revolution of the compressor.

Other Model 441A Applications

A number of transducers have a variable frequency as their output. Many of these sensors can be conditioned by the Model 441A if their frequency range is in the "1 Hz to 50 kHz" range. Usually the electronics available with these transducers is a type of frequency-to-voltage converter, although without the accuracy, speed of response, and adaptability of the Model 441A.

Some of these transducers include:

- **Vane-type flowmeter** This device has a wheel with vanes that rotates by the action of the gas or fluid flow. Usually a magnetic pickoff carries a pulse signal whose frequency indicates the rate of flow. The periodic filter of the Model 441A will reduce output noise.
- **Vibrating densitometer** This sensor determines fluid or gas density by a use of a self-oscillating resonant system. The output is an ac signal whose frequency is proportional to density. Accuracy of these transducers can be high, so the precise characteristics of the Model 441A are helpful in maintaining the transducer's inherent accuracy.
- **Vibrating-wire pressure sensor** This type of pressure transducer incorporates a vibrating wire whose tension is varied by the external pressure applied to the device. The wire is put in a closed-loop oscillatory circuit whose output frequency is a function of the pressure being measured. When connected to a Model 441A, an analog output proportional to pressure is produced. By scaling the analog output to cover a small frequency range, high-pressure sensitivity is readily obtained.

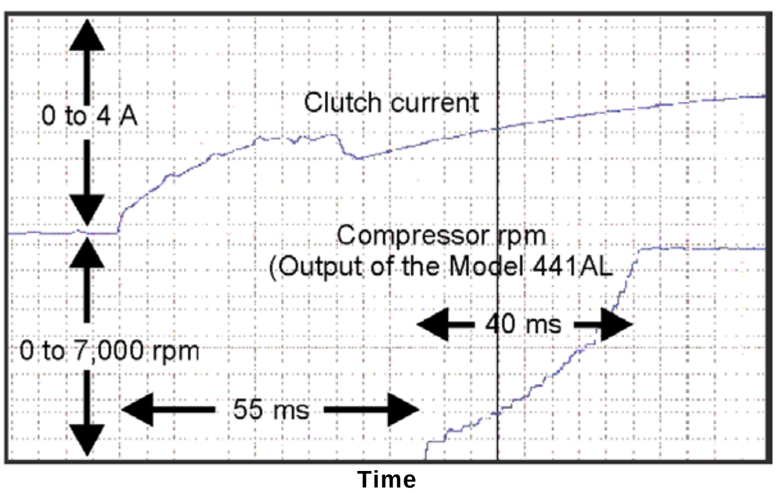

Figure 2

Model 441A Frequency-to-voltage Converter

Features

- 1 Hz to 50 kHz Frequency Range
- Fast Response
- Crystal-controlled Accuracy
- Front-panel Desplay of Frequency to Five Digits
- Precise Control of Output Voltage vs Input Frequency
- Input range of 10 mV to 100 V
- Output Noise Independent of Frequency

Applications

VEHICLE MOTORS, TURBINES

- Engine Monitoring
- ABS Evaluation
- Cruise-control Testing
- Drive-line Analysis
- Overspeed Monitor and Control
- Failure Analysis
- Governor Studies

Model 441A

To see the complete data sheet, go to
www.ectron.com/pdf/441Adatasheet.pdf

General Description

The Models 441A and 441AL produce an analog voltage output that precisely represents the frequency of an applied input signal. Adjustable “input frequency to output voltage” set points allow the user to quickly and closely bracket the frequency of interest

A unique crystal-controlled microcontroller design provides fast response, high conversion accuracy, and low output noise that is independent of frequency. The front-panel display shows the input frequency with up to five-digit resolution. All operating parameters are set using the display, itself a control, and one other front-panel control. The input-signal conditioner automatically provides stable operation for a wide range of pulse-, square-, and sine-wave signals from less than 10 mV to 100 V in amplitude.

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