

MODEL 441AL PRECISION FREQUENCY-TO-VOLTAGE CONVERTER



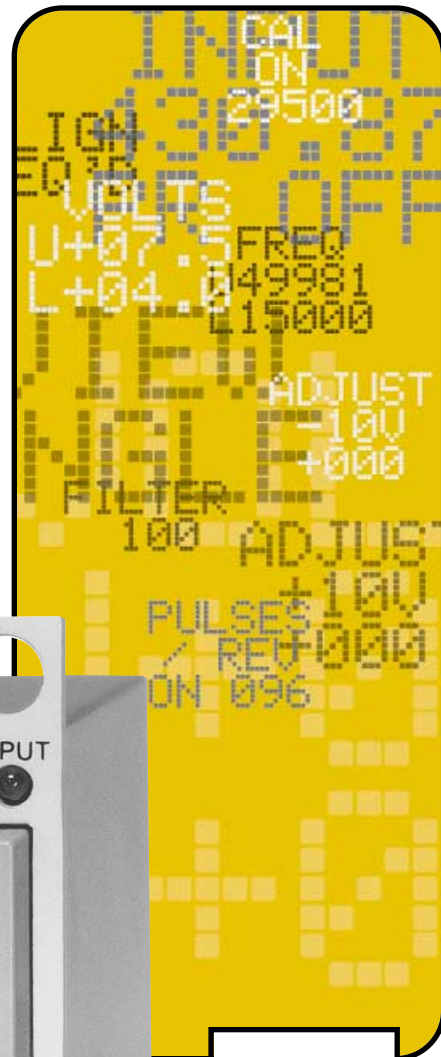
FEATURES

- 1 Hz to 50 kHz Frequency Range
- Optimized for 5 V Logic Level Input Signals
- Millisecond Start-up*
- Millisecond Response to Frequency Change*
- Adjustable Input Filtering and Sensitivity
- Front-panel Display of Frequency to 5 Digits
- Digital Periodic Filter
- Crystal-controlled Accuracy
- Precise Control of Output Voltage vs. Input Frequency
- Miniature size
- Rugged construction

*For input frequencies over 1 kHz

APPLICATIONS

- Turbomachine Analysis/Control
- Drive-line Analysis
- Fast-response Governor Studies
- Engine Overspeed Monitor/Controller
- Accurate Flow-meter Monitoring
- Precise Tachometer
- ABS Evaluation
- Analysis of Synchro Gear-box Problems
- Clutch-response Evaluation



**With
Exclusive
Digital
Periodic
Filter**

GENERAL DESCRIPTION

The Model 441AL produces an analog output that precisely represents the frequency of an applied input signal. Signal conditioning within the instrument allows the frequency-determining algorithm to precisely follow the input signal frequency even under fast start-up or rapid frequency changes. Adjustable "input frequency to output voltage" set points allow the user to 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 five-digit resolution. All operating parameters are set using the display and one other front-panel control. Three selections of input sensitivity and input bandwidth are provided to minimize signal dropout to allow continuous, accurate signal monitoring despite noise and signal level perturbations. The input signal conditioner accepts logic-level signals in selectable ranges of 0-5 V, 0-25 V, and 0-100 V. Three choices of input bandwidth are provided to enhance stable operation under varying signal conditions.

The unique digital periodic filter cancels unwanted output variation caused by an input signal that varies in frequency in a periodic manner.

FEATURES

Start-up characteristics of turbomachinery and high acceleration or deceleration equipment can now be analyzed. Similar to the popular Model 441A, the Model 441AL incorporates an input amplifier optimized for logic-level signals. While the 441A can reliably condition frequency signals down to 10 mV or less, the 441AL provides almost instant start-up characteristics for those applications where capturing data during the first few milliseconds is critical.

The Model 441AL combines the latest 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 family of 400 Series products that have provided exceptional performance and reliability in rigorous applications for the past 25 years.

Designed into the Model 441AL are rapid response to any change in frequency, low output noise that is independent of input frequency, and input-signal conditioning that provides proper triggering for transducers with logic-level outputs. Included is a selectable digital filter, which eliminates output noise due to the effects of an input signal whose frequency varies in a periodic manner. Setting the digital filter to the number of input pulses per revolution of a rotating device eliminates the periodic variation and provides a much more precise frequency conversion.

Gone is the clutter of switches, knobs, pots, etc. associated with other frequency-to-voltage converters. All that has been replaced with two easy-to-use, front-panel controls: the display and the encoder.

The backlit digital display/push button has the dual function of display and screen selection. Seven easy-to-use setup screens, six less frequently used screens, and the operate screen are accessible at the touch of the display.

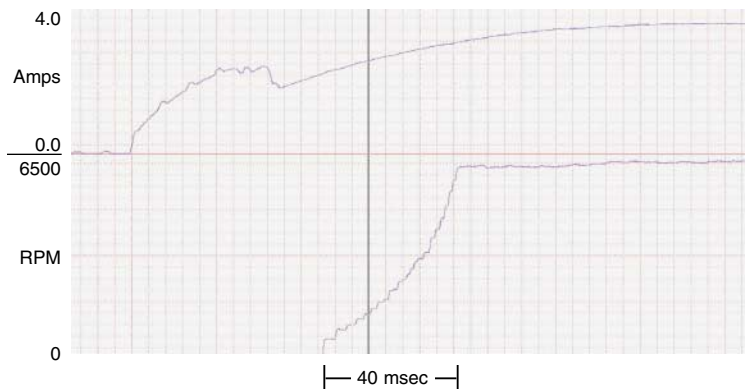
The encoder, a rotary/push-button control, has the dual function of character selection and change. The user can easily configure the Model 441AL to any specific application desired.

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

Because the Model 441AL operates from any dc power from 10.5 V to 32 V, uses the same connector, and has the same pin assignments for signal input, output, and power as all other Ectron 400 Series products, it can be used — even intermixed — with Models 352, 418, T418, 428, 441A, and 451 amplifiers and conditioners in all standard Ectron enclosures designed for these products.

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

This 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 operating temperatures. Application problems included a noisy input frequency waveform representing drive rpm, a requirement for a response time of a few milliseconds, and non-ideal laboratory conditions. He decided on the Ectron Model 441AL because it more than met his fast response needs, it allowed control of input frequency response and sensitivity 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 here are the current applied to clutch (top waveform) and below is the compressor rpm, the output of the Model 441AL. The shaft of the compressor accelerates from 0 to 6,500 rpm in about 40 ms. The delay from start of current to start of the compressor rotation, some 55 ms is clearly shown (each minor division is equal to 5 milliseconds). The response of the Ectron converter (1 ms for frequencies over 1 kHz) easily reproduces the desired acceleration of the pump. Note that the pump continues to accelerate until it reaches full speed.

SPECIFICATIONS

INPUT

Configuration: Differential with a common-mode-voltage rating of up to 100 V dc or peak ac.

Impedance: 200 k Ω in parallel with 300 pF nominal.

Frequency Range: 1 Hz to 50 kHz.

Sensitivity and Filtering: Three steps of input sensitivity and three steps of input filtering are provided to optimize input signal-to-noise ratio.

Amplitude Ranges: 5-V, 25-V, or 100-V nominal logic levels, either polarity.

Minimum Pulse Width: 5 μ s with Input B/W set to MAX

Maximum Risettime: No limit. However, output noise may increase

Trigger Polarity: Falling Edge

Trigger Point: 30% of nominal logic level, typical

Hysteresis: 30% of nominal logic level, typical

OUTPUT

Voltage: The linear range of the analog output is from -10 V to $+10$ V with up to 10 mA current. The output limits are approximately ± 10.5 V. Output voltage versus frequency is determined by voltage and frequency set points.

Uncertainty:
Within ± 0.0022 V + $\left(\frac{f_{in}}{2 \times 10^4} \times \frac{V_U - V_L}{f_U - f_L} \right)$
where f_{in} is the input frequency and V_U and V_L and f_U and f_L are the upper and lower voltage and frequency settings of the instrument, respectively.

Resolution: For input frequencies above 1 kHz, resolution in volts at the output is:

$$0.0012 \text{ V or } \left(\frac{f_{in}^2}{1500F} \times \frac{V_U - V_L}{f_U - f_L} \right)$$

whichever is greater, where f_{in} is the input frequency, F is $f_{in}/1000$ rounded down to the nearest integer, V_U and V_L are the voltage setting and f_U and f_L are the frequency settings.

For input frequencies at or below 1 kHz, the resolution at the output is:

$$0.0012 \text{ V or } \left(\frac{f_{in}^2}{1.5 \times 10^6} \times \frac{V_U - V_L}{f_U - f_L} \right)$$

whichever is greater, where f_{in} is the input frequency, V_U and V_L are the voltage setting, and f_U and f_L are the frequency settings.

Impedance: Less than 1 Ω at dc.

Noise: Less than or equal to 10 mV p-p independent of input frequency. (Measured with a bandwidth of 0.1 Hz to 1 MHz.) For slower rise-time signals such as sine waves, output noise depends on input-signal noise and amplitude since accurate timing is hampered by noise.

Response Time: Response to an abrupt frequency change is $0.005 \text{ s} + 1/f_{in}$, where f_{in} is the frequency of the input, with the filter set to wideband. For other filter frequencies add $5/f_{co}$, where f_{co} is the filter cutoff frequency.

Update Rate: 1 ms or $1/f_{in}$, where f_{in} is the frequency of the input, whichever is a longer period of time.

Filter: Selectable output filter frequencies of 1, 10, and 100 Hz plus wideband (approximately 1.5 kHz). The filter has a two-pole Bessel characteristic.

FREQUENCY-TO-VOLTAGE CONVERSION

Conversion Circuit: Following the input conditioner circuit, a microcontroller converts the input frequency to equivalent analog using a unique algorithm. The output is then scaled to a 14-bit DAC based on the user-controlled frequency and voltage set points.

Upper- and Lower-Frequency Set

Points: These set points determine the input frequency at which the upper- and lower-voltage set points are reached. The frequency set points can be any two frequencies between 0 Hz and 50 kHz with a resolution of 1 Hz. (The upper- and lower-frequency set points can be within 10 Hz of each other.)

Upper- and Lower-Voltage Set Points:

These set points determine the output voltages corresponding to the upper- and lower-frequency set points, respectively. The voltage set points may be any voltage from -10 V to $+10$ V with a resolution of 0.1 V. (The upper- and lower-voltage set points can be within 0.1 V of each other.)

Digital Periodic Filter: Selectable, from 1 to 999 pulses per revolution, this periodic filter eliminates output noise and periodic wander caused by irregularly spaced wheel cogs, unequally spaced pick-ups, run-out problems and periodic amplitude/frequency modulation for input frequencies up to 1 kHz.

CALIBRATION

When in the CAL mode of operation, an internally generated calibration signal can be set to any frequency between 0 Hz and 50 kHz in 1 Hz increments. When enabled, the analog output assumes a value according to the frequency and voltage set points. The calibration signal can be activated only when in the CAL mode. It can be used for system linearity check.

ALIGNMENT

Alignment of the Model 441A is performed using the -10 V and $+10$ V alignment modes. This calibration feature allows field alignment and calibration of the instrument using only a digital voltmeter.

INPUT POWER

Range: 10.5 to 32 V dc unregulated.

Overvoltage Protection: Up to $+60$ V for 15 seconds, $+32$ V and -50 V continuous.

Current (nominal): 150 mA.

ENVIRONMENT

EMI/RFI: Internal RFI filters are provided on all connector leads.

Operating Temperature: 0°C to $+50^\circ\text{C}$.

Storage Temperature: -40°C to $+80^\circ\text{C}$.

Altitude: No limit with adequate heat dissipation.

Static Acceleration Resistance: 200 m/s^2 (approximately 20 g) in any plane.

Shock Resistance: 200 m/s^2 (approximately 20 g), 11 ms in any plane.

Vibration Resistance: 100 m/s^2 (approximately 10 g) in any plane.

DIMENSIONS

Height (panel): 60.2 mm (2.37 in)

Height (case): 50.8 mm (2.00 in)

Width: 28.4 mm (1.12 in)

Depth: 101.6 mm (4.00 in)

Weight: 255g (9 oz.) nominal

Connector: DA-15P (mate DA-15S)

COMPATIBILITY

The Model 441AL will operate in all standard Ectron enclosures designed for Amplifier/Conditioner Models 352, 418, T418, 428, 441A and 451. See page 5.

FRONT PANEL

See page 4 for Model 441AL front panel displays and controls.

RETENTION OF SETTINGS

All settings of the Model 441A are retained in nonvolatile memory unless they are reset to default values by a master reset.

Specifications are subject to change without notice.

FRONT-PANEL DISPLAYS & CONTROLS

Display: The front-panel back-lit LCD display shows the input frequency and status of the periodic filter when in the operate position shown. Five digits of resolution are indicated even at lower frequencies.

When pressed, the display cycles through the following setup screens:

- (1) Upper- and lower-frequency set points
- (2) Upper- and lower-voltage set points
- (3) Periodic filter
- (4) Input sensitivity
- (5) Input bandwidth
- (6) Output filter
- (7) Calibration frequency
- (8)* LCD view angle
- (9)* Alignment, -10 V
- (10)* Alignment, +10 V
- (11) Memory error
- (12) Alignment required
- (13)*Reset

*Screens (8), (9), and (10) are secondary setup screens accessed by pressing the display button for more than one second. When in screen (10), pressing the rotary switch for over one second displays screen (13). When a memory error occurs, screen (11) is displayed. Pressing any control when viewing screen (11) produces screen (12). Unless the -10 V and +10 V alignment settings have been reset following a memory error, screen (12) is displayed whenever the unit is powered up. Screen (13) allows the operator to reset all user-controlled parameters to their default values.

Controls: The display/push button allows the operator to sequence through the various setup screens. The second switch has both push-button and rotary action. The push button moves the cursor to the digit to be changed and the rotary switch is used to change the selected digit. All operating parameters are set using these controls in conjunction with the display.

Input LED: The green LED on the front panel indicates that a valid input signal is present and that the output represents the input frequency.

Screens

Operate position displays the current input frequency using floating-point display and status of digital periodic filter.

```
INPUT
430.87
PR OFF
```

(1) Allows setting of upper- and lower-frequency set points. Frequencies between zero and 50 kHz can be set in 1 Hz increments.

```
FREQ
U50000
L15000
```

(2) Allows setting of upper- and lower-voltage set points. Voltages between -10.0 V to +10.0 V can be set in 0.1 V increments.

```
VOLTS
U+07.5
L+04.0
```

(3) Allows selection of the digital periodic filter and number of periodic pulses, 1 to 999, per revolution.

```
PULSES
/ REV
ON 096
```

(4) Allows one of three input sensitivities, MIN, MID, or MAX, to be selected. MIN 0 to 100-V logic. MID 0 to 25-V logic. MAX 0 to 5-V logic.

```
INPUT
SENS
MAX
```

(5) Allows one of three input bandwidths, MIN, MID or MAX, to be selected. MIN 10 Hz NOM. MID 500 Hz NOM. MAX >50 kHz

```
INPUT
B/W
MID
```

(6) Allows selection of output filter cutoff frequency of 1, 10, or 100 Hz. Wideband (approximately 1.5 kHz) is also available.

```
OUTPUT
FILTER
100
```

(7) Allows setting of calibration frequency between zero and 50 kHz in 1 Hz increments. Calibration can be turned on and off.

```
CAL
ON
29500
```

(8) Allows setting of the optimum display viewing angle.

```
VIEW
ANGLE
```

(9) Allows alignment of the analog section at -10 V using a voltmeter connected to the output.

```
ADJUST
-10V
+000
```

(10) Allows alignment of the analog section at +10 V using a voltmeter connected to the output.

```
ADJUST
+10V
+000
```

(11) This screen is displayed if the data in the internal nonvolatile memory is corrupt. Pressing any front-panel control will clear this screen and reset the internal memory to default values.

```
MEMORY
ERROR
```

(12) After resetting internal memory to default values (either through a memory error or through the RESET screen) and until both the minus and plus ten-volt alignment points have been adjusted, this screen is displayed each time the unit is turned on.

```
ALIGN
REQ'D
```

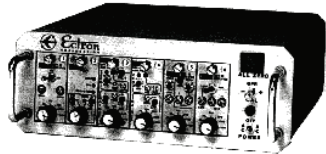
(13) Allows resetting the internal nonvolatile memory to default values.

```
RESET?
PUSH
Y KNOB
```

ENCLOSURES

COMPATIBILITY

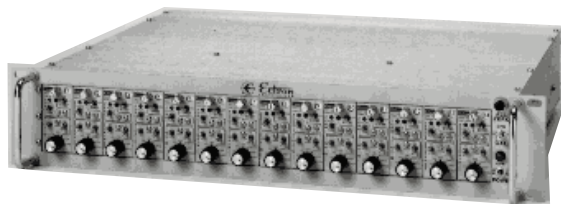
The Model 441AL will operate in all standard Ectron enclosures designed for Models 352, 418, T418, 428, 441A and 451 amplifiers and conditioners. All models can operate singly using a 15 pin "D sub-miniature" mating connector.



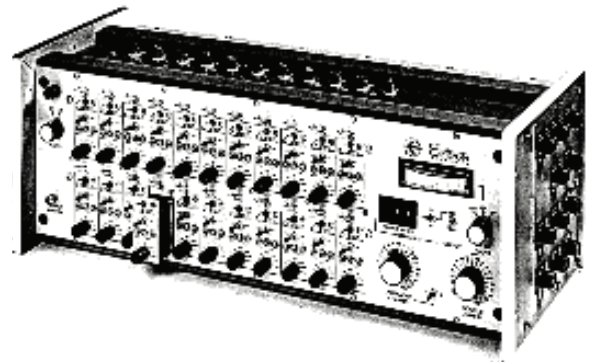
Model E408-6 Six-channel Portable Enclosure



Model 4001 Fourteen-channel Ruggedized Portable Enclosure



Model R408-14 Fourteen-channel Rack-mount Enclosure



Model 4005 Twenty-two-channel Ruggedized Portable Enclosure



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