TELEDYNE PHILBRICK

10kHz General Purpose Frequency to Voltage Converter

4722

The 4722 frequency to voltage converter is capable of providing linear conversion of a 0 to 10kHz input frequency to a 0 to +10V output voltage. Thirty percent overrange, ±0.03%FS max nonlinearity and low full scale and zero offset drifts are features that allow the 4722 to be used in a wide variety of data acquisition and signal processing applications. For versatility, the full scale output range may be modified to provide +10V for any frequency from 100Hz to 15kHz, or the zero offset modified so that an FM deviation such as 8kHz ±2kHz will provide a ±10V output. The input circuitry of the 4722 is designed to provide optimum noise immunity with TTL input level changes (0 to +5) of any waveshape. With external passive components, the device can handle signals of virtually any amplitude (i.e. ±30mV to ±100V).

Applications Information

The 4722 will meet all specifications without additional components. Figure 1 describes the connections for normal operation. Theory of operation and the block diagram (Figure A) clearly describe the input/output relationship of the device.

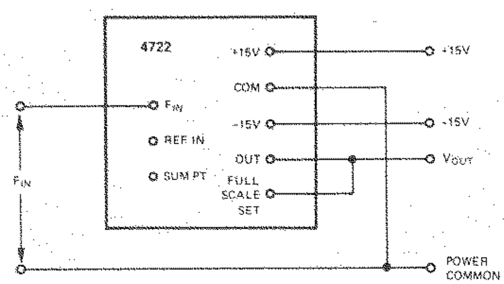


Figure 1. Basic Operational Connections

FEATURES

- ±0.03%FS Max Nonlinearity
- ±0.1%FS Max Zero Offset
- ±50μV/°C Max Zero Offset Drift
- High Noise Immunity

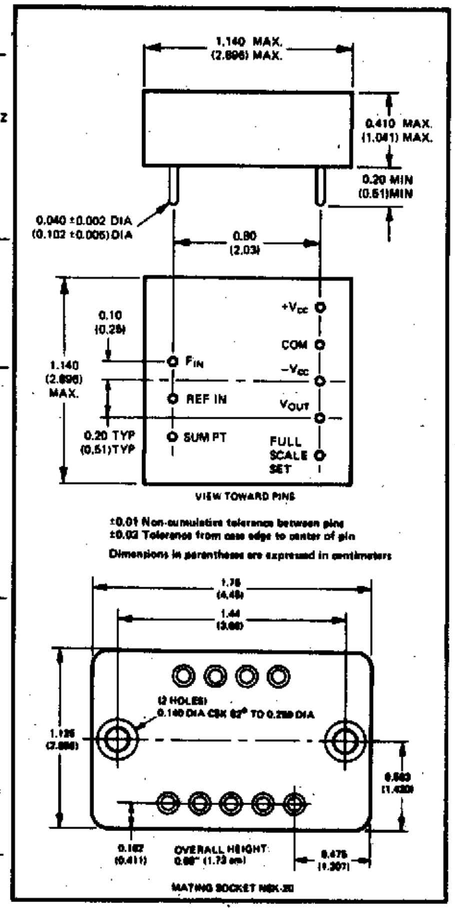
APPLICATIONS

- Frequency, Flow, and RPM Measurements
- FM Demodulation
- FM Telemetry
- Fiber Optic Data Link
- Multi Decade Phase Locked Loops

TELEDYNE PHILBRICK Allied Drive @ Rte. 128, Dedham, Massachusetts 02026
Tel: (617) 329-1600, TWX: (710) 348-6726, Tlx: 92-4439

SPECIFICATIONS @ 25°C, V_{cc} = ±15V ±1%, FS Adj. Pin Connected to V_{out} Pin, Unless Otherwise Indicated

	Typical	Guaranteed
FULL SCALE (FS)		
Ideal Transfer Function		V_{out} = +10 V X f_{in}/10 kHz
Full Scale Factor (V_{out} for 10 kHz f_{in})		+9.9 V ± 1.0%
or (f_{in} for +10 V_{out}) trimmable to 10 V for 10 kHz		10.101 kHz ± 1.0%
Functional Range for Specified Non Linearity ①	0 Hz to 13 kHz	0 Hz to 11 kHz
Maximum Full Scale f_{in} with external feedback resistor R_f	20 kHz	15 kHz
NONLINEARITY ±% FS Plus ±% SIGNAL ①		
0 Hz to 11 kHz	0.015 plus 0.015	0.03 plus 0.03
0 Hz to 11 kHz, 0°C to +70°C	0.02 plus 0.02	0.04 plus 0.04
0 Hz to 13 kHz	0.02 plus 0.02	
0 Hz to 15 kHz (R_f = 18 kΩ)		0.05 plus 0.05
OUTPUT		
Offset Voltage, Initial Untrimmed, F_{in} = 0 (trimmable to zero)	±5 mV	±10 mV
Voltage, R_L = 10 kΩ 0 to 70°C	±13 V	±11 V
Current, V_{out} = ±10 V 0 to 70°C	±7 mA	±5 mA
Ripple @ f_{in} = 10 kHz	0.4 V p-p	0.8 V p-p
Offset Scale Factor ②	36 µA/V ±10%	36 µA/V ±20%
Impedance (operational amplifier output)	< 0.02 Ω	0.2 Ω
Response (filter time constant)		2.8 msec ±30%
Feedback Resistor R_f	27 kΩ ±10%	27 kΩ ±20%
INPUT @ F_{IN} PIN		
Threshold (positive or negative going pulses) ③	1.4 V ±200 mV	1.4 V ± 600 mV
Threshold, External Set Range	−13 V to +13 V	−12 V to +12 V
Hysteresis	400 mV	400 mV ±100 mV
Hysteresis, External Set Range	0 to 400 mV	
Levels (TTL Compatable)		
Low	−15 V to + 1.2 V	−12 V to +0.8 V
High	+1.6 V to +15 V	+2 V to + 12 V
Waveform	Any	
Pulse Width, min for specified linearity ④	15 µsec	20 µsec
Impedance	10 Meg Ω	≮1 TTL load
STABILITY OF FULL SCALE FACTOR		
Temperature Coeficient ±ppm/°C	100	300
Power Supply Sensitivity ±ppm/% ΔV_{cc}	220	800
Drift per Day (±ppm of FS)	100	
Drift per Month (±ppm of FS)	500	
Warm Up Time to 0.01% of FS	2 sec	
STABILITY OF ZERO OFFSET VOLTAGE		
Temperature Coeficient	±25 µV/°C	±50 µV/°C
Power Supply Sensitivity ± µV/% ΔV_{cc}	50	100
Drift per Day	±30 µV	
Drift per Month	±100 µV	
POWER REQUIREMENT		
Voltage Range Rated Specs	±15 V ±5%	±12 V to ±18 V
Current (±Icc) @ Vcc = ±15 V	±12 mA	±16 mA
ENVIRONMENT/RELIABILITY		
Operating Temperature		0°C to 70°C
Storage Temperature ABSOLUTE MAX		−55°C to +85°C
MTBF (per mil HDBK-217)	815,000 Hrs	



NOTES

① Nonlinearity is deviation from ideal transfer function when Full Scale Factor has been trimmed to +10.000 V and Output Offset Voltage to 0.000 V for convenience in testing.
② Current into Summing Point to offset V_{out}.
③ The 4722 input circuit is a differential comparator preset to operate with TTL pulses.
④ Time between threshold crossings

Input Protection: f_{in} & Ref In may be shorted to ±Vcc indefinitely without damage.

Output Protection: Output may be shorted indefinitely to ground without damage

Zero & Full Scale Trim

If greater accuracy is required, the 4722 Zero and Full Scale output are trimmed as shown in Figure 2. TO TRIM: Connect f_{in} pin to common and adjust the zero trim potentiometer (R_1) to provide 0.00 V at the output. Connect f_{in} to a frequency source set at 10.000 kHz. Adjust the Full Scale Trim variable resistor to provide +10.000 V at V_{out}. (Carbon composition trim components may be used.)

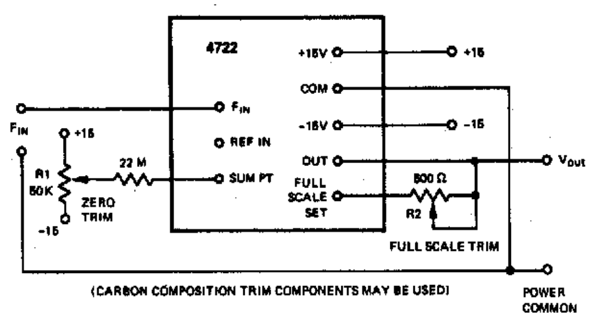


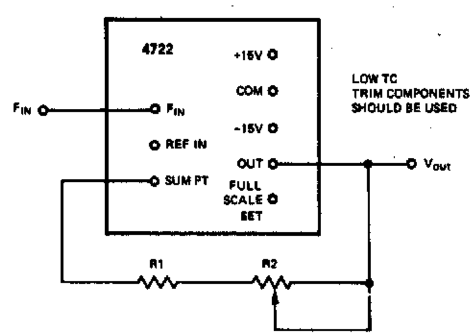
Figure 2. Zero and Full Scale Trim

Full Scale Factor Change

The Full Scale Factor of the 4722 may be set to provide +10 V out for any f_{in} between 100 Hz and 20 kHz by connecting a resistor, R_f, between the Summing Point pin and the V_{out} pin.

$$R_f \text{ (in ohms)} = \frac{2.7 \times 10^8}{\text{Desired Full Scale } f_{in} \text{ (in Hertz)}} \quad (\pm 20\%)$$

Depending on the accuracy required, R_f can be a single fixed resistor or a fixed resistor plus a variable trim resistor. This is shown in Figure 3. When this technique is used, Full Scale Set and V_{out} must not be connected together. (Use low temperature coefficient trim components.)



$$R_f = R_1 + R_2 = \frac{2.7 \times 10^8}{\text{DESIRED FULL SCALE } F_{IN} \text{ (In Hz)}} \quad (\pm 20\%)$$

TYPICAL VALUES

F_{IN}	R1	R2
0.1 kHz	2.2 M	0.5 M
1.0 kHz	220 K	60 K
20 kHz	11 K	2.5 K

Figure 3. Full Scale Factor Set

THEORY OF OPERATION

The 4722 is an example of a sophisticated design concept reduced to a low cost BUT reliable device. The input circuit is a comparator (A1) whose output switches between +14 V and-14 V each time the polarity of the voltage between the f_{in} pin and the Ref In pin reverses. Two consecutive reversals represent one cycle or pulse of frequency.

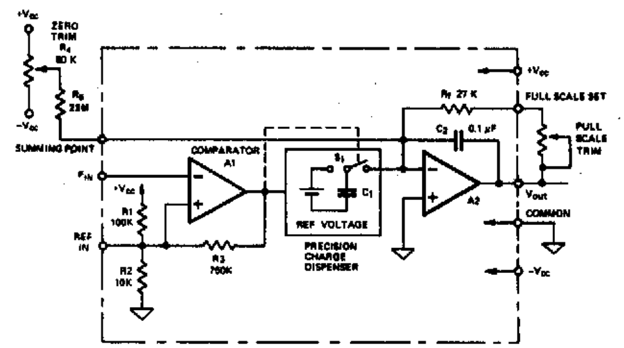


Figure A. 4722 Simplified Block Diagram

Each pair of reversals causes solid state switch S1 in the Precision Charge Dispenser to alternately connect C1 between a precision reference voltage and the summing point of op amp A2. Each time it is connected to the Reference, a fixed amount of charge Q is dumped into C1, according to the basic equation Q = CV.

When connected to the summing point of A2, C1 is discharged. The greater the frequency, the greater the average current (I_{in}) into the summing point of A2. A2 is a current to voltage converter, where $V_{out} = -I_{in}R_f$. Thus V_{out} is a function of the discharge current of C1 and the frequency of discharge. C2 filters these current pulses to minimize ripple.

Full Scale Factor is set with R_f, and the output is offset by current into the summing point.

INPUT CIRCUIT – The threshold level at which comparator A1 switches is set at the Ref In pin by resistors R1, R2, and R3. It is made more positive by shunting R1 to a positive voltage such as $+V_{CC}$ and more negative by connecting a resistor between Ref In and a negative voltage. The hysteresis is lowered from 400 mV to zero by connecting a resistor in parallel with R2 and changing the external impedance at the Ref In pin between open and short.

INPUT SIGNAL CONDITIONING

The frequency input circuit of the 4722 is a comparator, the threshold of which is set at +1.4 V (with approximately 300 mV of hysteresis) to provide maximum noise immunity when operating with TTL type levels. It is suitable for operation with signals of any waveshape which pass through this threshold in alternate directions. For example, a 0 to 2 V peak sine wave, or a ±12 V p-p square wave. (Each alternate pair of threshold crossings is recognized by the 4722 as a cycle or pulse of frequency.) The preset threshold is altered for larger or smaller signals by changing the voltage at the Ref In pin. (See Figure A in Theory of Operation.)

Operation with CMOS Logic

To obtain the maximum noise immunity of which a particular logic type is capable, the threshold must be changed to be approximately halfway between the upper and lower logic levels. Figure 4A shows a 12 kΩ, 5% resistor connected between Ref In and +15 V to provide a threshold of +6 V (a typical CMOS level.) Zero and Full Scale trim techniques remain unchanged. Decrease R_1 to increase threshold voltage and thus noise immunity.

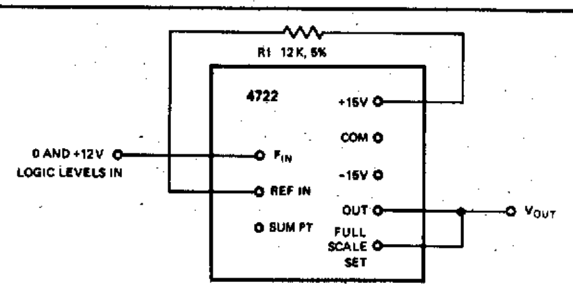


Figure 4A. 4722 Input Conditioned for Typical CMOS

Operation With Signals Less Than +2 V Peak

Connect a 100 kΩ, 5% resistor between Ref In and -15 V. This will set the threshold at ZERO Volts with hysteresis of approximately ±100 mV. Thus an input signal is any alternate pair of level shifts exceeding ±100 mV (200 mV p-p). For input signals less than 200 mV p-p, connect a 2 kΩ resistor between the Ref In and Common. This will lower the hysteresis (and noise immunity) to ±20 mV or 40 mV p-p. See Figure 4B. A 1 kΩ resistor will provide 20 mV of hysteresis which is the minimum recommended value. When operating in this mode the 4722 input is a zero crossing detector.

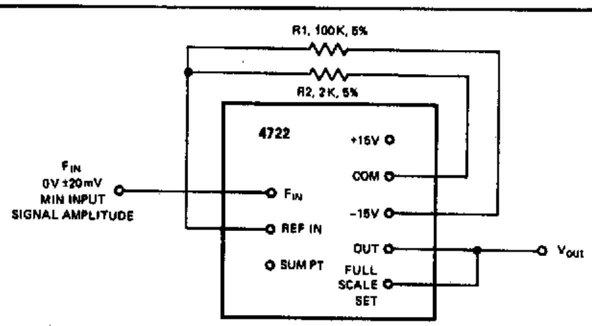


Figure 4B. Input Conditioned to Provide Threshold Voltage of Zero Volts with 40 mV Hysteresis

Operation With AC Signals With DC Offset

When the f_{in} signal is small and impressed on a dc level or common mode voltage (e.g., +9 V ±400 mV), it should be capacitively coupled to the f_{in} pin as shown in Figure 4C. If the dc voltage is large (100 Vdc ±1 V signal) the input should be additionally protected against transients with diodes as in Figure 4D.

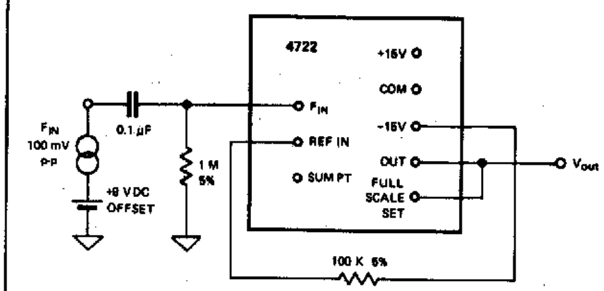


Figure 4C. 4722 Input Conditioned for Small AC Signal with DC Offset

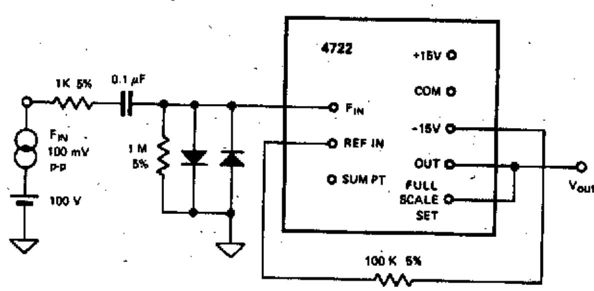


Figure 4D. 4722 Input Conditioned for Small AC Signal Impressed on Large DC Voltage

Signals greater than $\pm V_{CC}$ peak to peak may be treated in a similar manner or attenuated with a simple resistive divider and the threshold level set by the technique of Figure 4A & B.

OUTPUT SIGNAL CONDITIONING

The output of the 4722 can be conditioned to provide +10 V out for any maximum f_{in} from 100 Hz to 20 kHz (see Figure 3). In addition, V_{out} can be offset (that is, zero volts out for a particular f_{in}) to provide Scale Expansion and/or bipolar output voltages.

Output Offsetting

Many 4722 applications measure a range of frequencies that do not include zero, but require zero volts out for a minimum f_{in}. For example, the pulse train from a tachometer in a motor speed control circuit might be 5000 to 10,000 pulses per second providing +5 V to +10 V from the 4722.

To obtain 0 to +5 V, V_{out} must be OFFSET 5 V negative by injecting a current of +36 µA into the Summing Point pin for each volt of negative offset required (Figure 5A).

36 µA/V (± 20%) is the Offsetting Scale Factor. It may be developed as shown in Figure 5A by connecting R_{offset} beween the Summing Point pin and $+V_{CC}$ per the equation:

$$R_{offset} = \frac{V_{CC}}{(V_{offset})(\text{Offset Scale Factor})}$$

$$= \frac{15}{5 \times 36 \times 10^{-6}} = 83\,k\Omega$$

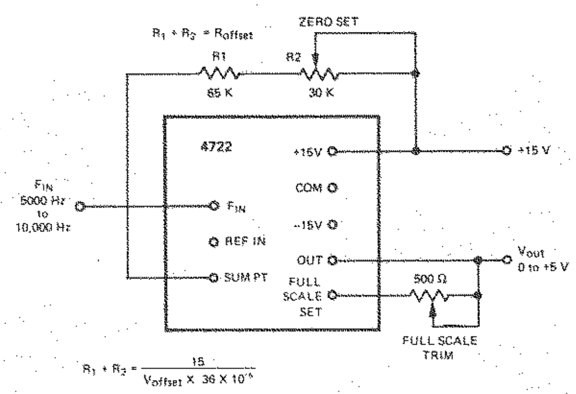


Figure 5A. 4722 with Output Offset of −5V to Provide 0 to +5V Output for 5 kHz to 10 kHz F_{in}

Bipolar Output

If an output voltage of -2.5 V to +2.5 V is required for 5 kHz to 10 kHz f_{in}, the output may be offset a total of -7.5 V by driving additional + current into the Summing Point pin.

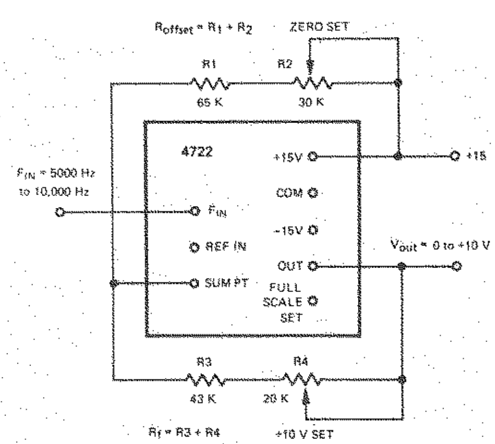


Figure 5B. 4722 with Output Offset and Scale Expansion to Provide 0 to +10V Output for 5 kHz to 10 kHz F_{in}

Scale Expansion and Output Offset

If the application requires 0 to +10 V out for a reduced range of input frequencies such as 5 kHz to 10 kHz input, the Full Scale Factor must be expanded by adding external resistor R_f between the Summing Point pin and the output.

R_f (in Ohms) = G X 27,000, where G is the GAIN of the 4722:

$$G = \frac{\Delta V_{out}(\text{Volts})}{\Delta f_{in}\,(\text{kHz})}$$

In the example, ΔV_{out} = 10 V − 0 V = 10 V, and Δf_{in} = 10 kHz − 5 kHz = 5 kHz; therefore, G = 10/5 = 2, and R_f = 2 X 27,000 = 54 kΩ.

The transfer function (output voltage for a given input frequency) has also been multiplied by G, and the OFFSET SCALE FACTOR must be divided by G. For G = 2, 5 kHz in provides +10 V_{out} and 10 kHz in demands +20 V_{out}. The output must now be offset −10 V (from +10 V to 0) by driving +18 μA/V (1/2 of 36 μA/V) into the Summing Point pin (Figure 5B).

$$R_{offset} = \frac{V_{CC}}{(V_{offset})(\text{Offset Scale Factor}/G)}$$

$$= \frac{15}{10 \times 18 \times 10^{-6}} = 83\,k\Omega$$

Scale Expansion and Bipolar Output

If an output voltage of −5 V to +5 V is required for 5 kHz to 10 kHz input, the output is offset a total of −15 V (from +10 to −5) with additional current into the Summing Point pin (at the Offset Scale Factor).

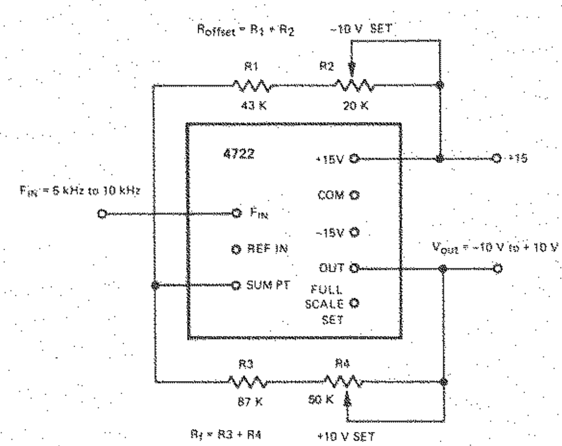


Figure 5C. 4722 with Bipolar Output and Expanded Scale

A final example, Figure 5C, shows the scale expanded and offset to provide an output of −10 V to +10 V for an input of 5 kHz to 10 kHz.

From the equations above:

$$\Delta V_{out} = 10V - (-10V) = 20V,$$

$$\Delta f_{in} = 10 \text{ kHz} - 5 \text{ kHz} @ 5 \text{ kHz}$$

$$G = \frac{\Delta V_{out}}{\Delta f_{in}} = \frac{20}{5} = 4$$

$$R_f = G \times 27{,}000 = 4 \times 27{,}000 = 108 k\Omega$$

For G = 4, 5 kHz in will demand 20 V_{out}. Therefore, total offset required is 20 V −(−10 V) = 30 V in the negative direction.

$$R_{offset} = \frac{V_{cc}}{(V_{offset})(\text{Offset Scale Factor}/G)}$$

$$= \frac{15V}{30V \times (36 \times 10^{-6})/4} = 55 k\Omega$$

Figure 5D compares these three different 4722 output voltage ranges for 0 kHz to 10 kHz f_{in} with the basic 4722 connections of Figure 2.

F_{in}	V_{out} (Volts) Fig. 2	Fig. 5A	Fig. 5B	Fig. 5C
0	0	-5	-10	NA
5kHz	+5	0	0	-10
10kHz	+10	+5	+10	+10

Figure 5D. Output Circuit Conditioning

OUTPUT RIPPLE FILTERING & RESPONSE TIME

By definition, the 4722 F to V is converting an ac signal to a dc level. Therefore, there must be ripple on the output. This ripple is filtered by an internal RC network consisting of R_f and a 0.1 μf capacitor (see Figure A). Additional filtering is obtained by the addition of an external capacitor between the Summing Point pin and the output. Curves of ripple vs. f_{in} vs. capacity are shown in Figure 6.

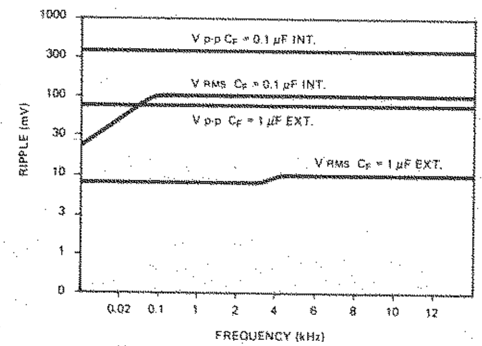


Figure 6. Typical 4722 Ripple vs Frequency vs Filter Capacity

The Response Time of the 4722 (how fast the output voltage changes for a step change in input frequency) is the RC time constant of the ripple filter. Thus if the external 1 μF capacitor is used, the time constant becomes about 25 milliseconds. If faster response with reduced ripple is required, a higher frequency F to V should be used (4704 @ 100 kHz) or a multi-pole sharp cutoff Low Pass Filter should follow the 4722.

APPLICATIONS

The 4722 is designed to operate from conventional op amp power supplies providing plus and minus voltages relative to common. For many applications, however, it can be operated at lower cost from a single available floating supply voltage (24 V to 36 V), and the cost of a supply eliminated. Figure 7 illustrates such an application with a simple tachometer circuit which could provide an input to a motor speed controller.

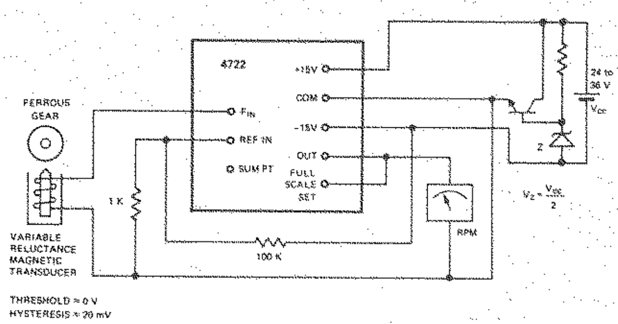


Figure 7. Low Cost RPM Indicator with Single Power Supply

TELEDYNE PHILBRICK Allied Drive @ Rte. 128, Dedham, Massachusetts 02026
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