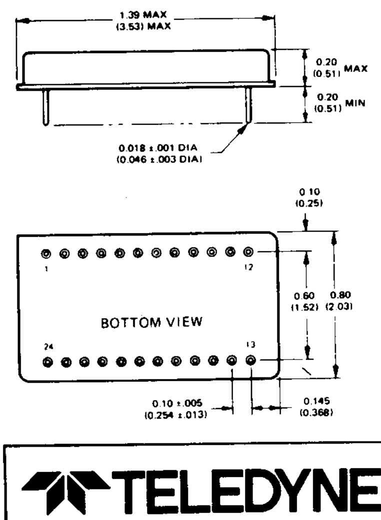
1MHz Precision Frequency to Voltage Converter

4736

The 4736 is a high performance, high reliability frequency to voltage converter capable of providing a 0 to + 10V output range which is linearly proportional to a 0 to 1MHz input frequency range regardless of its waveshape. Offering 30% overrange, ±0.1% max full scale error and ±0.008%FS max nonlinearity error, the 4736 completes the high performance frequency to voltage hybrid product line which includes the 4732 (10kHz) and 4734 (100kHz).

Improvements over existing designs contribute to the 4736's high accuracy and low drift specifications. A precision charge dispenser (see Block Diagram) incorporates a unique switching circuit that controls the frequency response by transferring a measured amount of charge to the output amplifier via a frequency variable filter.

Designed specifically for data acquisition and signal processing, other applications for the 4736 include monitoring and regulating speed, frequency and flow rate. When used in conjunction with a 4735 V/F, the 4736 establishes a foundation for a high performance fiber optic data link or a magnetic tape recording system offering high noise immunity. Housed in an industry-standard, hermetically sealed, metal dual-in-line package, the 4736 is specified over the 0°C to + 70°C temperature range. For military/space applications, the 4736-83 is available for fully specified operation over the − 55°C to + 125°C temperature range and screened to the high reliability requirements of MIL-STD-883, Method 5008.

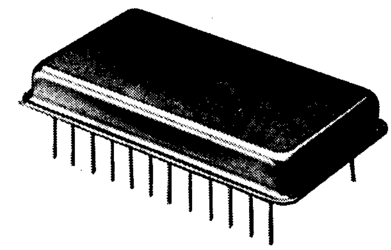


PIN DESIGNATIONS

1.	N.C.	13.	N.C.
2.	N.C.	14.	N.C.
3.	N.C.	15.	N.C.
4.	N.C.	16.	N.C.
5.	$-V_{ps}$	17.	N.C.
6.	N.C.	18.	N.C.
7.	N.C.	19.	N.C.
8.	ZERO ADJUST	20.	$+V_{ps}$
9.	SUM POINT	21.	N.C.
10.	OUT	22.	COMMON
11.	FULL SCALE	23.	REF IN
12.	FULL SCALE ADJ.	24.	F_{IN}

RECOMMENDED SOCKET: Augat Socket No. 324-AG2D or equivalent.

(Dimensions in parentheses are expressed in centimeters.)



FEATURES

- 0 to 1MHz Guaranteed Frequency Range
- ±0.008%FS Max Nonlinearity
- High, 10^{11} // 4pF, Input Impedance
- Low Zero Offset and Gain Drifts

APPLICATIONS

- Precision RPM, Flow and Frequency Measurements
- FM Telemetry
- Data Transmission
- Fiber Optic Link

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ABSOLUTE MAXIMUM RATINGS

+ 15V Supply (+ V_{ps}, Pin 20)	+ 22 Volts
− 15V Supply (− V_{ps}, Pin 5)	− 22 Volts
Frequency Input Voltage (Pin 24)	± 15 Volts
Reference Input (Pin 23)	± 12 Volts
Threshold (external set range)	± 12 Volts
Operating Temperature Range (case)	− 55°C to + 125°C
Specified Temperature Range (case)	
4736	0°C to + 70°C
4736-83 (Note 2)	− 55°C to + 125°C
Storage Temperature Range	− 65°C to + 150°C

SPECIFICATIONS (T_A = + 25°C, ± V_{ps} = ± 15V unless otherwise indicated).

PARAMETER	MIN.	TYP.	MAX.	UNITS
FREQUENCY INPUTS				
Full Scale Frequency Range		0 to 1M		Hertz
Overrange		30		%FS
Threshold, positive going pulses		1.4 ± 10%		Volts
Hysteresis	300	400	500	mV
Hysteresis, external set range		0 to 400		mV
Logic Levels (Note 3)		TTL Compatible		
Pulse Width (+ 2V Pulse)	75			nsec
Waveform		Any		
Impedance		10^{11} // 4		Ω // pF
ANALOG OUTPUTS				
Output Voltage Range		0 to + 10		Volts
Overrange		30		%FS
Output Load Current (Notes 1, 4)	− 2, + 20			mA
Output Impedance			0.05	Ohms
TRANSFER CHARACTERISTICS				
Nonlinearity, 1.1kHz to 1MHz		± 0.003	± 0.008	%FS
Ripple: 100Hz		80	200	mVp-p
100kHz		450	700	mVp-p
1MHz		80	150	mVp-p
Offset Error		± 1	± 5	mV
Offset Scale Factor, ± 25%		+ 10		μA/V
Full Scale Error (pin 11 to pin 10)		± 0.05	± 0.1	%
Adjusted (pin 12 to pin 10)		± 0.1	± 0.3	%
STABILITY				
Nonlinearity: 4736 (0°C to + 70°C)		± 0.005	± 0.015	%FS
4736-83 (− 55°C to + 125°C)		± 0.008	± 0.05	%FS
Offset Drift: 4736		± 20	± 50	μV/°C
4736-83		± 30	± 80	μV/°C
Offset Power Supply Sensitivity		± 10	± 20	μV/%ΔV_{ps}
Gain Drift: 4736		± 40	± 50	ppm/°C
4736-83		± 70	± 100	ppm/°C
Gain Drift: per day/week		20/60		μV
Gain Power Supply Sensitivity		± 40	± 80	ppm/%ΔV_{ps}
DYNAMIC CHARACTERISTICS				
Step Response Time (± 0.5%FS, 500Ω load)				
0Hz to 1MHz		60		μsec
1MHz to 200kHz		70		μsec
1MHz to 0 Hz		95		μsec
POWER SUPPLIES				
Power Supply Range		± 13 to ± 17		Volts
Current Drains: + 15V Supply		+ 35		mA
− 15V Supply		− 35		mA
Power Consumption		1050		mW

Notes: 1. Not Short Circuit Protected to ± V_{ps} or ground.
2. Processed to MIL-STD-883, Method 5008.
3. TTL compatible; i.e., Logic "0" = 0.8V max, Logic "1" = 2.4V min.
4. Output will sink a minimum of − 2mA and source a minimum of 20mA.

THEORY OF OPERATION

The F to V converter is an example of a sophisticated design concept reduced to a low cost BUT reliable device. The input circuit is a comparator (A_1) whose output switches between +1 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.

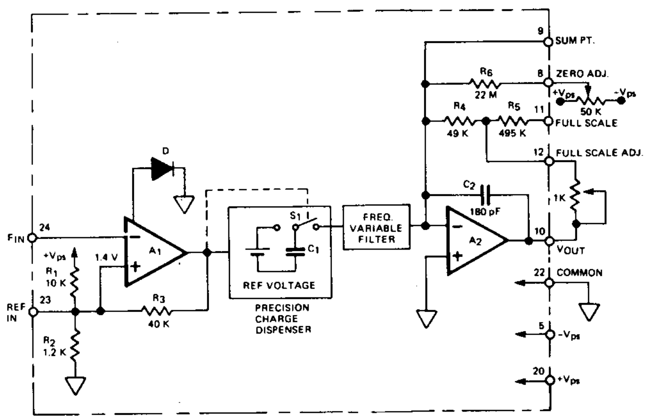

Figure 1. F to V Simplified Block Diagram

Each pair of reversals causes solid state switch S_1, in the Precision Charge Dispenser, to alternately connect C_1 to the precision reference voltage and the summing point of op amp A_2 through a frequency variable filter. See Figure 1. Each time C_1 is connected to the Reference, a fixed amount of charge Q is dumped into C_1 according to the basic equation $Q = CV$.

When connected to the summing point of A_2, C_1 is discharged. The greater the frequency, the greater the average current (I_{in}) is that goes into the summing point of A_2. A_2 is a current to voltage converter, where $V_{out} = -I_{in}R_f$. Thus V_{out} is a function of the discharge current of C_1 and the frequency of discharge. C_2 further 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 A_1 switches, is set at the Ref In pin by resistors R_1, R_2, and R_3. It is made more positive by shunting R_1 to a positive voltage such as $+V_{ps}$ and more negative by connecting a resistor between Ref In and a negative voltage. The hysteresis is lowered from 400 mV by connecting Ref Input to Common via another resistor.

OPERATION

How to Use the 4736

When used as shown in Figure 2, the factory trimmed 4736 operates as specified without additional components. Pin 12, the Full Scale Adj. and Pin 11, the Full Scale are both outputs.

Pin 11 can be used when accuracy to ±0.1% F.S. is needed with no external components. Pin 12 is usually used when greater accuracy is required using an external trim, see Figure 3. (Note: R_1 and R_2 should have low value temperature coefficients.)

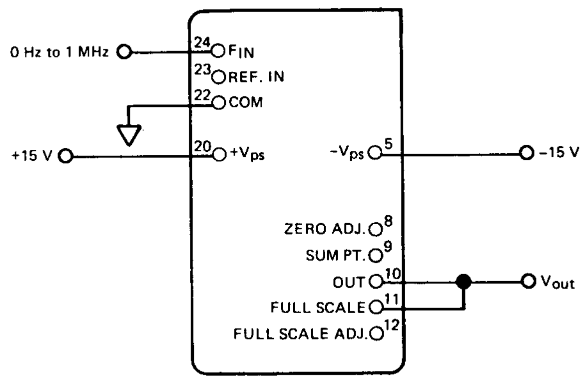

Figure 2. Basic Operational Connections

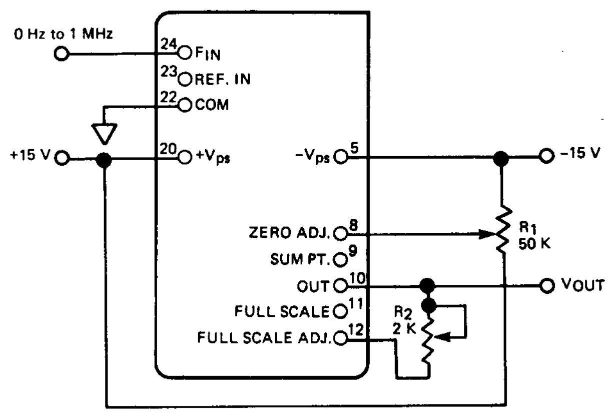

Figure 3. Zero and Full Scale Trim

Trim Procedure, 4736

1. Connect F_{in} pin to Common and adjust R_1 to provide 0.0000 V at V_{out}, see Figure 3.
2. Connect F_{in} to a frequency source set at 1 MHz. Adjust R_2 to provide 10.0000 at V_{out}.
3. Repeat (1) and (2) precise zero and Full Scale set.

Full Scale Factor Change

The Full Scale Factor of the F to V may be set to provide +10 V_{out} for any F_{in} between 1% and 200% of Full Scale by connecting a resistor, R_f, between the Summing Point pin and V_{out} pin, see Figure 4.

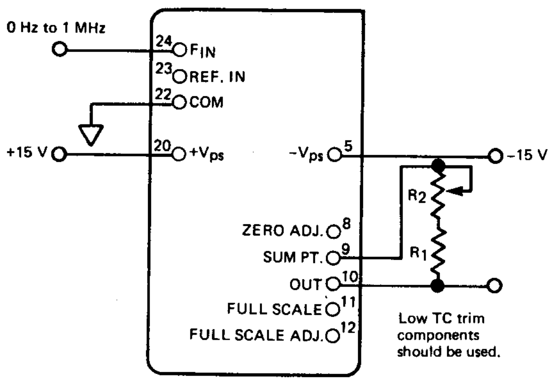

Figure 4. Full Scale Factor Set

$$R_f = R_1 + R_2 = \frac{5 \times 10^{10}}{\text{Desired Full Scale } F_{in} \text{ (in Hz)}} (\pm 20\%)$$

Input Signal Conditioning

The F to V frequency input circuit is a comparator, the threshold of which is set at +1.4 V (with approximately 400 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 square wave or a ±5 V p-p sine wave. (Each alternate threshold crossing is recognized by the F to V 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 1.) Ref In should not exceed 12 V, otherwise internal damage will occur.

Operation with CMOS Logic

To obtain the maximum noise immunity of which a particular logic type is capable, the threshold should be set approximately halfway between the upper and lower logic levels. Figure 5 shows a 2.0 kΩ, 5% resistor connected between Ref In and +15 V to provide a threshold of +6 V. Zero and Full Scale trim techniques remain unchanged.

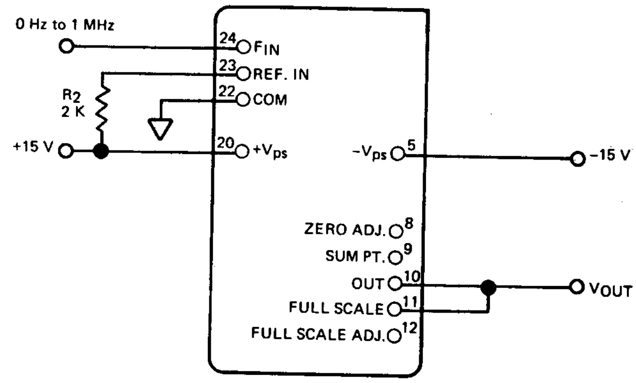

Figure 5. Input Conditioned For Typical CMOS

Operation with Signals Less Than +2 V Peak

Connect a 11 kΩ, 5% resistor between Ref In and −15 V. This will set the threshold at zero Volts with hysteresis of approximately 340 mV. Thus an input signal is any alternate pair of level shifts exceeding 340 mV.

For input signals less than 500 mV, connect a 200 Ω resistor between the Ref In and Common. This will lower the hysteresis (and noise immunity) to 60 mV (see Figure 6).

A 100 Ω resistor will provide 30 mV of hysteresis which is the minimum recommended value. When operating in this mode the F to V input is a zero crossing detector.

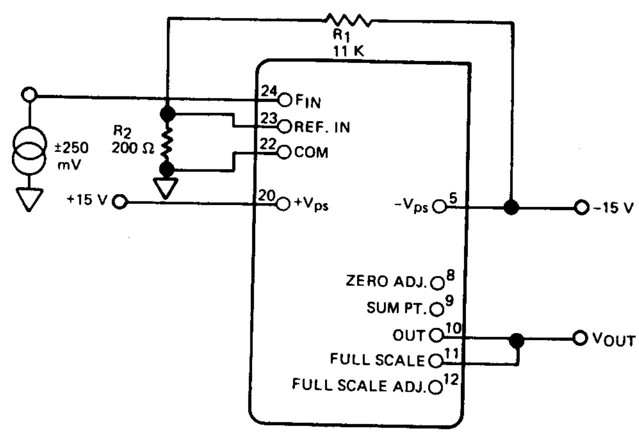

Figure 6. Input Conditioned to Provide Threshold of Zero Volts with 60 mV Hysteresis

Operation with AC Signals with DC Offset

When the F_{in} signal is small and impressed on a DC level of common mode voltage (e.g., +9 V DC ±500 mV AC), it should be capacitively coupled to the F_{in} pin as shown in Figure 7. If the DC voltage is large (100 V DC ±1 V signal), the input should be additionally protected against transients with diodes as in Figure 8.

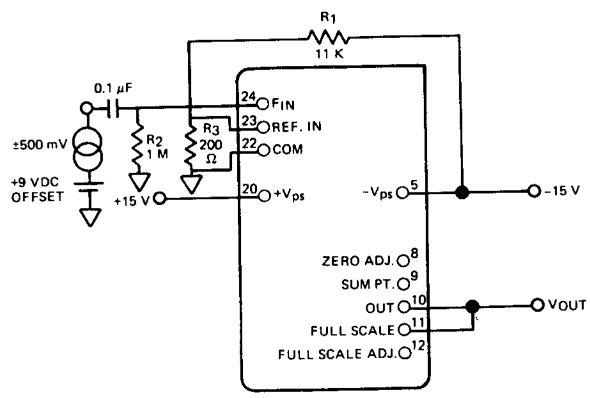

Figure 7. Input Conditioned for Small AC Signal with DC Offset

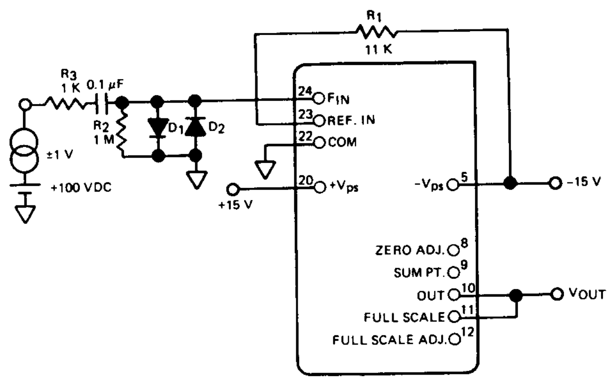

Figure 8. Input Conditioned for Small AC Signal Impressed on Large DC Voltage

Signals greater than ±Vps 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 5 and 6.

Output Signal Conditioning

The output of the F to V can be conditioned to provide +10 V_{out} for any maximum F_{in} from 1% to 200% of Full Scale (see Figure 4). 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 F to V 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 500,000 to 1,000,000 pulses per second providing +5 V to +10 V from the F to V.

To obtain 0 to +5 V, V_{out} must be Offset 5 V negative by injecting a current of +10 μA into the Summing Point pin for each volt of negative offset required (Figure 9).

10 μA/V (±25%) is the Offsetting Scale Factor. It may be developed as shown in Figure 9 by connecting R_{offset} between the Summing Point pin and $+V_{ps}$ per the equation:

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

$$\frac{15}{5 \times 10 \times 10^{-6}} = 300\ k\Omega$$

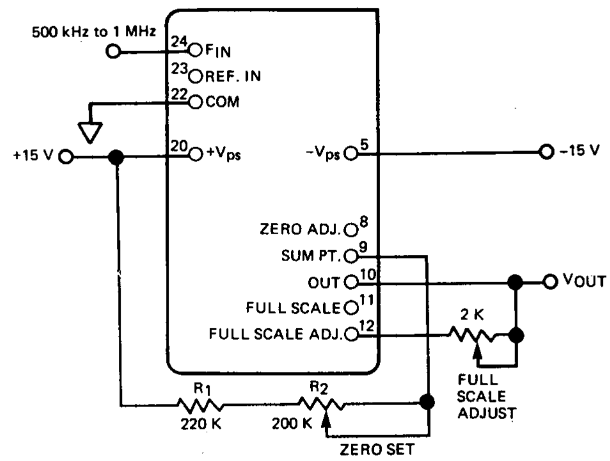

Figure 9. Output Offset of –5 V to Provide 0 to +5 V for 500 kHz to 1 MHz F_{in}

Bipolar Output

If an output voltage of –2.5 V to +2.5 V is required for 500 kHz to 1 MHz F_{in}, the output may be offset a total of –7.5 V by driving additional + current into the Summing Point pin.

Scale Expansion and Output Offset

If the application required 0 to +10 V_{out} for a reduced range of input frequencies such as 500 kHz to 1 MHz 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 100,000, where G is the Gain of the F to V.

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

In the equation ΔV_{out} = 10 V –0 V = 10 V, and ΔF_{in} = 1 MHz –500 kHz = 500 kHz; therefore, G = 10/500 = 0.02, and R_f = 0.02 X 100,000 = 2 kΩ (±25%).

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 = 0.02, a 500 kHz input provides +10 V_{out}, and a 1 MHz input demands +20 V_{out}.

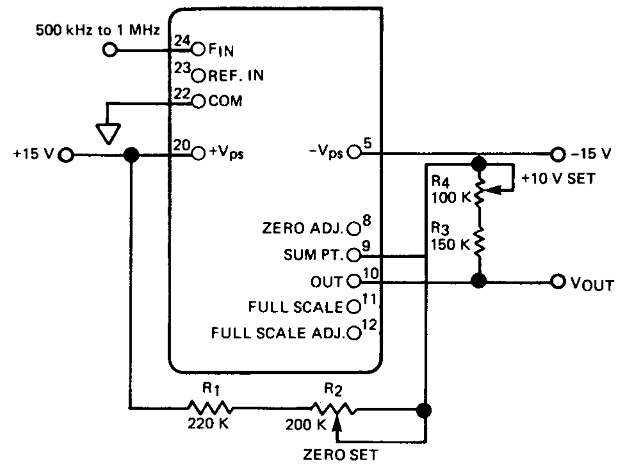

Figure 10. Output Offset and Expansion to Provide 0 to +10 V Output for 500 kHz to 1 MHz F_{in}

The output must now be offset −10 V (from +10 V to 0) by driving +5 μA/V (½ of 10 μA/V) into the Summing Point pin (Figure 10).

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

$$= \frac{15}{10 \times (10 \times 10^{-6})/2} = 300\ k\Omega$$

Scale Expansion and Bipolar Output

If an output voltage of −5 V to +5 V is required for 500 kHz to 1 MHz input, the output is offset a total of −15 V (from +10 to −5) with additional current into the Summing Point pin.

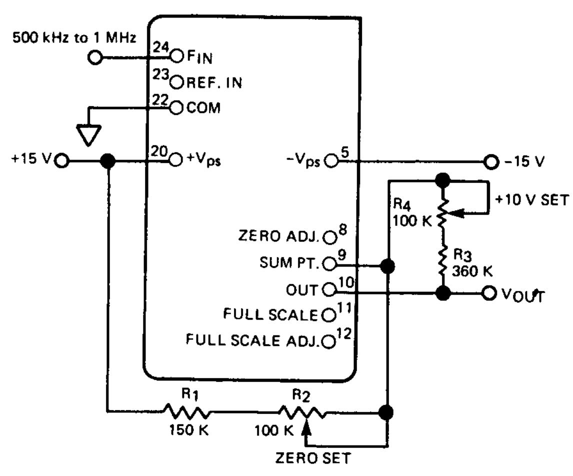

Figure 11. Bipolar Output and Expanded Scale

A final example, Figure 11, shows the scale expanded and offset to provide an output of −10 V to +10 V for an input of 500 kHz to 1 MHz.

From the equations above:

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

$$\Delta F_{in} = 1\ MHz - 500\ kHz = 500\ kHz$$

$$G = \frac{\Delta V_{out}}{\Delta F_{in}} = \frac{20}{500} = 0.04$$

$$R_f = G \times 100.000 = 0.04 \times 100.000 = 4\ k\Omega$$

For G = 0.04, a 500 kHz_{in} will demand a 20 V_{out}. Therefore, total offset required is 20 V −(−10 V) = 30 V in the negative direction.

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

$$= \frac{15\ V}{30\ V \times (10 \times 10^{-6})/0.04} = 200\ k\Omega$$

Figure 12 compares these three different output voltage ranges for 0 Hz to 1 MHz F_{in} with the basic connections of Figure 3.

F_{in}	V_{out}(Volts)			
4736	Fig. 3	Fig. 9	Fig. 10	Fig. 11
0	0	-5	-10	NA
500 kHz	+5	0	0	-10
1 MHz	+10	+5	+10	+10

Figure 12. Output Circuit Conditioning

Output Ripple Filtering and Response Time

By definition, the 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 a frequency variable filter and by an internal RC network consisting of R_f and a capacitor (C_2 in Figure 1). Additional filtering is obtained by the addition of an external capacitor between the Summing Point pin and the output. Typical curves of ripple vs. F_{in} capacity are shown in Figure 13.

The Response Time of the F to V (how fast the output voltage changes for a step change in the input frequency) is the RC time constant of the ripple filter. Thus if an external capacitor is used, the response time is increased. If faster response with reduced ripple is required, a higher frequency F to V should be used or a multi-pole sharp cutoff Low Past Filter should follow the F to V.