TELEDYNE PHILBRICK

1MHz, 10kHz, 100kHz High Performance Frequency to Voltage Converters

4706 4708 4710

The 4706, 4708, and 4710 are high performance frequency to voltage converters providing a 0 to ±10V output that is a linear function of the input frequency regardless of its waveshape or amplitude. ±0.005%FS max nonlinearity, thirty percent overrange, low full scale and zero offset drifts, and output offsetting are inherent features that allow these converters to be used in a wide variety of demanding applications including precision analog RPM and flow measurements, low frequency demodulation, and radar. The input is designed for maximum noise immunity when operating with standard TTL signals, but with the addition of several passive components, it will operate with signals from 20mV to several hundred volts (see text).

Applications Information

The high performance and low cost of the 4706 make it an excellent demodulator for a frequency modulated carrier. The unit can be offset so that the carrier corresponds to zero volts and the output reflects only the modulated signal. Other applications include IRIG FM telemetry and magnetic tape recording systems. The 4705 V/F is the recommended modulator for these applications providing high performance and reliability.

The 4708 has the ability to measure and display RPM's on an analog meter from input signals of a pulse-type tachometer sensor. Full scale and offset can be adjusted so that an FM deviation such as 8kHz ±2kHz will provide a ±10V output range. The same technique allows for an expanded RPM scale: 10,000RPM ±100RPM.

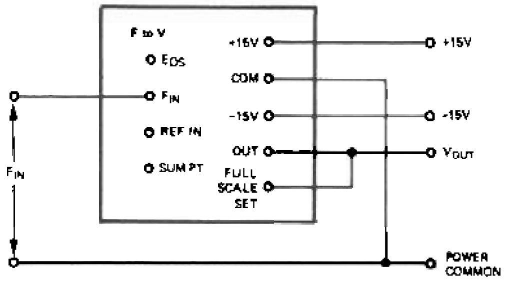
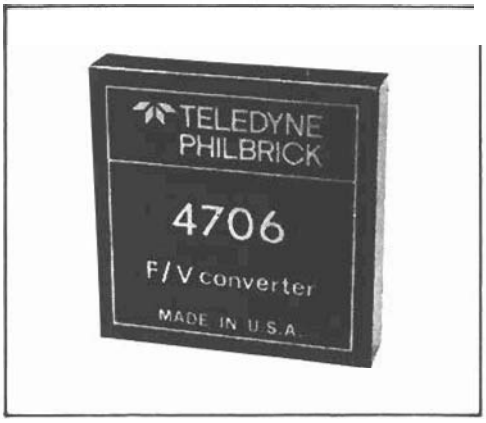


Figure 1. Basic Operational Connections



FEATURES

- Wide Dynamic Range—5 Decades
- ±0.005%FS Max Nonlinearity
- Low Full Scale and Zero Offset Drifts
- ±10V Output
- High Noise Immunity

APPLICATIONS

- Precision Analog RPM Measurement
- Precision Analog Flow Measurements from Pulse-Type Flow Meters
- Precision Low Frequency (FM) Demodulation
- Doppler Sonar and Radar Disk and Tape Recorder Wow and Flutter Measurement

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SPECIFICATIONS @ 25°C, V_{CC} = ±15 V unless otherwise indicated. FS Adjust Pin connected to V_{OUT} Pin.

	10 kHz – 4708		100 kHz – 4710		1 MHz – 4706	
	TYPICAL	GUARANTEED	TYPICAL	GUARANTEED	TYPICAL	GUARANTEED
FULL SCALE						
Ideal Transfer Function, V_{OUT} =	–––	10 V · f_{IN}/10 kHz	–––	10 V · f_{IN}/100 kHz	–––	10 V · f_{IN}/1 MHz
Full Scale Factor (V_{OUT} for FS f_{IN}), trimmable to +10 V	–––	+9.9 V ± 0.05 V	–––	9.9 V ± 0.05 V	–––	9.9 V ± 0.05 V
NONLINEARITY ①						
Range for Specified Nonlinearity	0 Hz to 13 kHz	100 Hz to 11 kHz	0 Hz to 130 kHz	1000 Hz to 110 kHz	0 Hz to 1.3 MHz	1000 Hz to 1.1 MHz
Minimum Pulse Width for Specified Nonlinearity ②	20 μsec	–––	3 μsec	–––	0.3 μsec	–––
Nonlinearity ± %FS plus ± % Signal, 50% Duty Cycle	–––	0.007 plus 0.013	–––	0.007 plus 0.013	–––	0.008 plus 0.02
4710-02			–––	0.005 plus 0.01		
OUTPUT						
Initial Offset Voltage, f_{IN} = 0 (trimmable to 0)	–––	±5 mV	–––	±5 mV	–––	±10 mV
Voltage/current (mA)	±12/+20, –2	±10/+20, –2	±12/+20, –2	±10/+20, –2	±12/+20, –2	±10/+20, –2
Ripple @ Nominal FS f_{OUT}	170 mV RMS	1 V p-p	170 mV RMS	1 V p-p	170 mV RMS	0.2 V p-p
Offset Scale Factor ±25% μA/V ③	–––	42	–––	42	–––	60
Impedance (op amp output)	<0.05 Ω	–––	< 0.05 Ω	–––	< 0.05Ω	–––
Response (filter time constant)	240 μsec	–––	24 μsec	–––	2.4 μsec	–––
INPUT @ f_{IN} PIN – COMPARATOR (See Figure A)						
Threshold (positive or negative going pulses)	+1.4 V ± 200 mV	+1.4 V ± 600 mV	+1.4 V ± 200 mV	+1.4 V ± 600 mV	+1.4 V ± 200 mV	+1.4 V ±600 mV
Threshold (external set range)	–––	–12 V to +12 V	–––	–12 V to +12 V	–––	–12 V to +12 V
Hysteresis	400 mV	400 mV ± 100 mV	400 mV	400 mV ± 100 mV	400 mV	400 mV ± 100 mV
Hysteresis (external set range)	0 to 400 mV	–––	0 to 400 mV	–––	0 to 400 mV	–––
Preset TTL Levels, Volts (Low/High)	–––	–12 to +0.8/+2 to +12	–––	–12 to +0.8/+2 to +12	–––	–12 to +0.8/+2 to +12
Waveform	Any	–––	Any	–––	Any	–––
Impedance	1 Meg Ω	< 1 TTL Load	3000 Ω	< 1 TTL Load	100 KΩ	< 1 TTL Load
STABILITY OF FULL SCALE FACTOR (FS)						
Temperature Coefficient ±PPM/°C	25	50	25	50	75	150
4710-02			10	15		
Power Supply Sensitivity ±PPM/% ΔV_{CC}	–––	500	–––	750	–––	500
Drift: Per Day/Per Month ±PPM of FS	10/30	–––	10/30	–––	100/200	–––
STABILITY OF ZERO OFFSET VOLTAGE						
Temperature Coefficient ± μV/°C	–––	50	–––	50	–––	100
Power Supply Sensitivity ± μV/% ΔV_{CC}	–––	100	–––	100	–––	100
Drift: Per Day/Per Month ± μV	30/100	–––	30/100	–––	30/100	–––
POWER REQUIREMENT						
Voltage Range	±12 V to ±18 V	±14 V to ±16 V	±12 V to ±18 V	±14 V to ±16 V	±12 V to ±18 V	±14 V to ±16 V
Current V_{OUT} = Zero	–––	±20 mA	–––	±23 mA	–––	36 mA
ENVIRONMENT/RELIABILITY						
Operating Temperature	Abs. max. case temp., +85°C	0 to +70°C	–25 to +85°C	0 to +70°C	–25 to +85°C	0 to +70°C
Storage Temperature	–––	–55 to +85°C	–––	–55 to +85°C	–––	–55 to +100°C
Input Protection: f_{IN} & Ref In may be shorted to $\pm V_{CC}$ indefinitely without damage.						
Output Protection: Output may be shorted indefinitely to ground without damage. Do not connect output to $-V_{CC}$.						

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 Time between threshold crossings. Contact the factory for applications with shorter pulses.
③ Current into $+I_{IN}$ Pin to offset output.

Zero & Full Scale Trim

If greater accuracy is required, 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 (R1) 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}. (Cermet trim components should be used.)

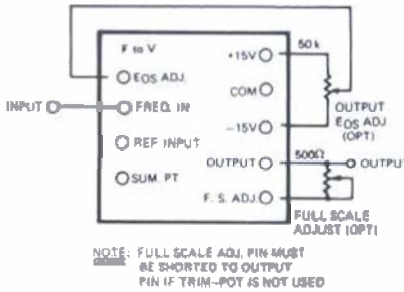


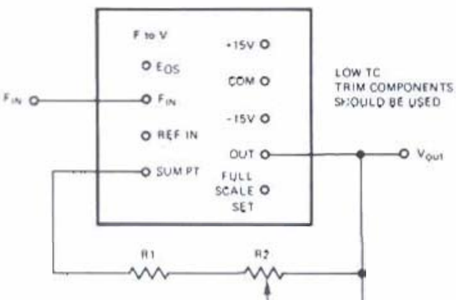
Figure 2. Full Scale and E_{os} Adjustment

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 the V_{out} pin.

$$R_f \text{ (in ohms)} = \frac{\begin{array}{l} 2.4 \times 10^{10} \text{ (4706)} \\ 2.4 \times 10^{9} \text{ (4710)} \\ 2.4 \times 10^{8} \text{ (4708)} \end{array}}{\text{Desired Full Scale } f_{in} \text{ (in Hertz)}} \quad (\pm 20\%)$$

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 for the 4708. When this technique is used, Full Scale Set and V_{out} must not be connected together. (Use low temperature coefficient trim components.)



$$R_f = R_1 + R_2 = \frac{2.4 \times 10^{8}}{\text{DESIRED FULL SCALE } F_{in} \text{ (in Hz)}} \quad (\pm 20\%)$$

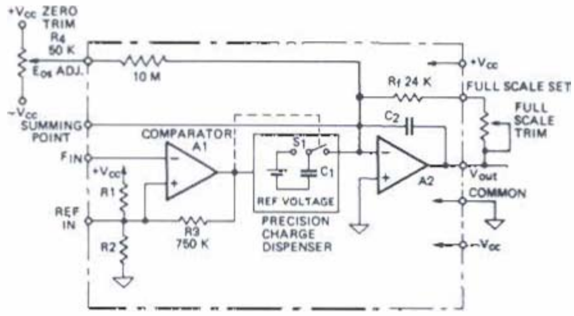
TYPICAL VALUES

F_{in}	R1	R2
0.1 kHz	2.2 M	0.5 M
1.0 kHz	220 K	50 K
20 kHz	11 K	2.5 K

Figure 3. Full Scale Factor Set

THEORY OF OPERATION

The F to V 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.



CIRCUIT VALUES

	R1	R2	C2
4706	10 K	1 K	220 pF
4708	100 K	10 K	0.01 µF
4710	10 K	1 K	0.001 µF

Figure A. F to V 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.

Request AN-20, AN-22, and AN-32 for additional information.

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 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 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 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.

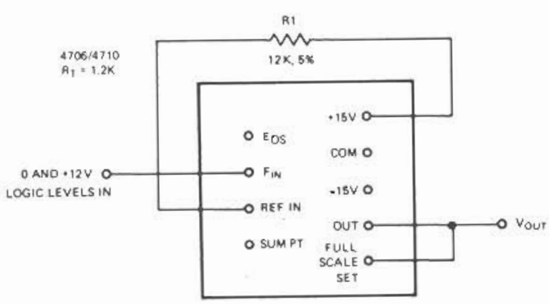


Figure 4A. 4708 Input Conditioned for Typical CMOS

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 F to V input is a zero crossing detector.

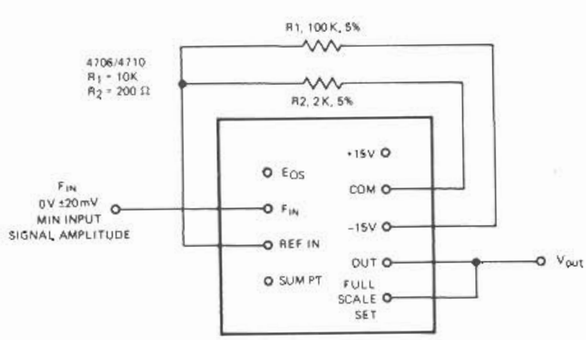


Figure 4B. 4708 Input Conditioned to Provide Threshold Voltage of Zero Volts with 40 mV Hysteresis

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.

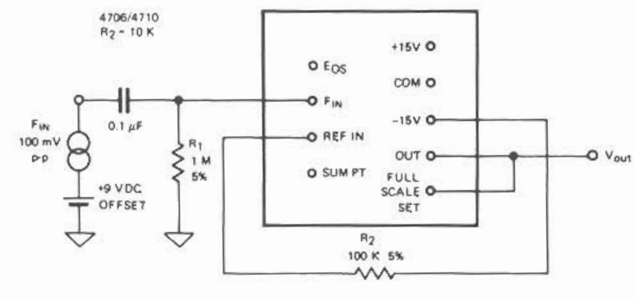


Figure 4C. 4708 Input Conditioned for Small AC Signal with DC Offset

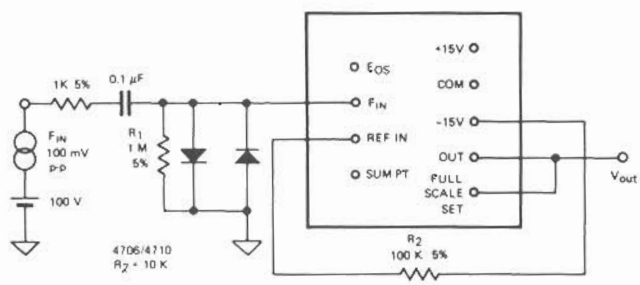


Figure 4D. 4708 Input Conditioned for Small AC Signal Impressed on Large DC Voltage

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 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 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

(The 4708 is used as an example, but all F to V's perform similarly.)

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 5000 to 10,000 pulses per second providing +5 V to +10 V from a 4708.

To obtain 0 to +5 V, V_{out} must be OFFSET 5 V negative by injecting a current of +48 µA into the Summing Point pin for each volt of negative offset required (Figure 5A). 40 µA/V (± 25%) is the Offsetting Scale Factor. It may be developed as shown in Figure 5A by connecting R_{offset} between the Summing Point pin and $+V_{CC}$ per the equation:

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

$$= \frac{15}{5 \times 40 \times 10^{-6}} = 75\,k\Omega$$

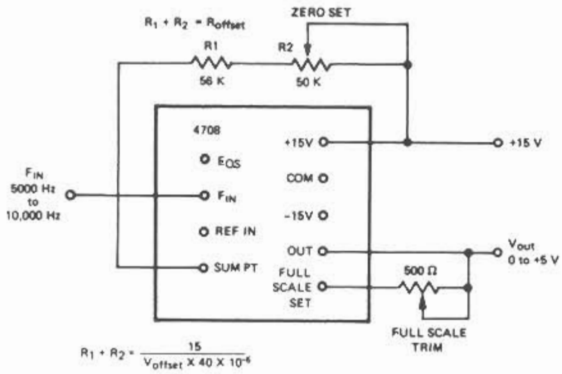


Figure 5A. 4708 with Output Offset of –5 V to Provide 0 to +5 V Output for 5 kHz to 10 kHz F_{in}

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.

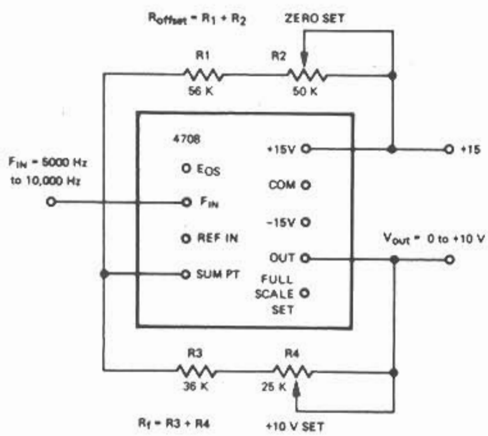


Figure 5B. 4708 with Output Offset and Scale Expansion to Provide 0 to +10 V Output for 5 kHz to 10 kHz F_{in}

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 24,000, where G is the GAIN of the F to V.

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

In the 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 24,000 = 48 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 = 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 +20 μA/V (1/2 of 40 μA/V) into the Summing Point pin (Figure 5B).

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

$$= \frac{15}{10 \times 40 \times 10^{-6}} = 75\,k\Omega$$

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).

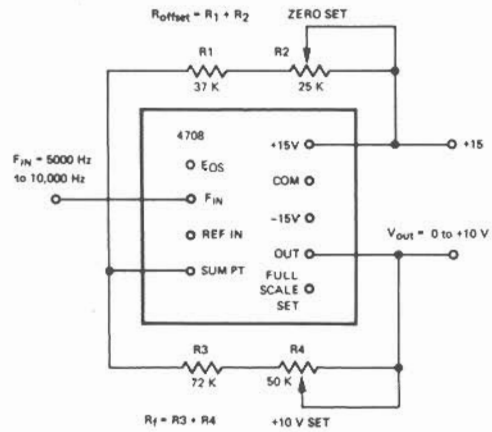


Figure 5C. 4708 with Bipolar Output and Expanded Scale

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:

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

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

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

$$R_f = G \times 24{,}000 = 4 \times 24{,}000 = 96\,k\Omega$$

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.

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

$$= \frac{15V}{30V \times (40 \times 10^{-6})/4} = 50\,k\Omega$$

Figure 5D compares these three different 4708 output voltage ranges for 0 kHz to 10 kHz f_{in} with the basic 4708 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 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 capacitor (C2 in Fig. A). 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 6A and 6B.

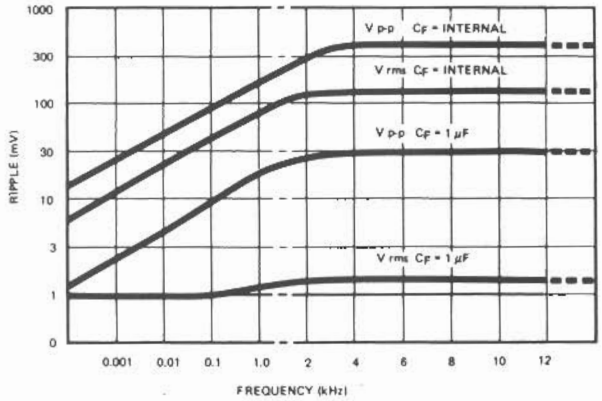


Figure 6A. Typical 4708 Ripple vs Frequency vs Filter Capacity

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

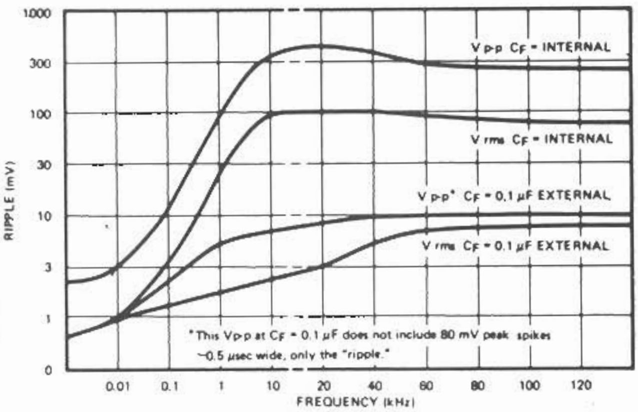
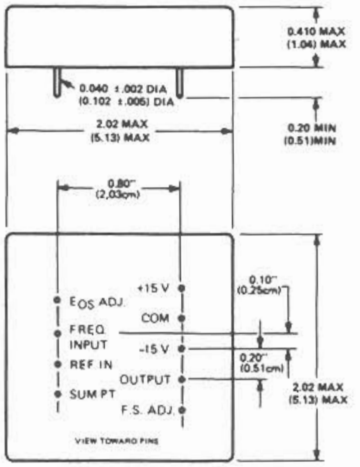


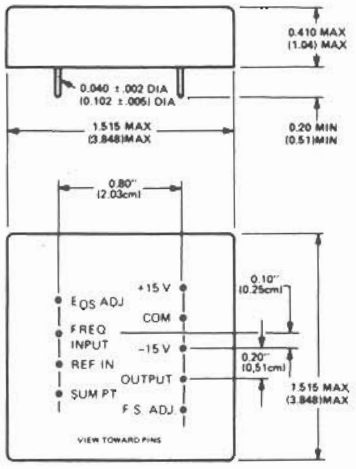
Figure 6B. 4710 Output Ripple vs. Frequency



±0.01 Non-cumulative tolerance between pins
±0.02 Tolerance from case edge to center of pins

All dimensions in parentheses are expressed in centimeters.

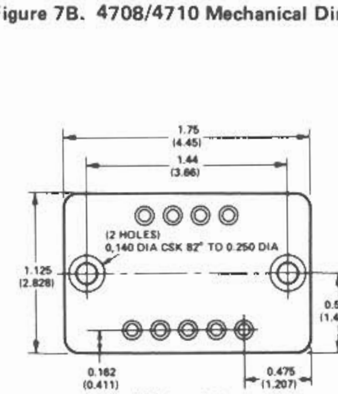
Figure 7A. 4706 Mechanical Dimensions



±0.01 Non-cumulative tolerance between pins
±0.02 Tolerance from case edge to center of pins

All dimensions in parentheses are expressed in centimeters.

Figure 7B. 4708/4710 Mechanical Dimensions



Board Thickness 0.094 (0.238)

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