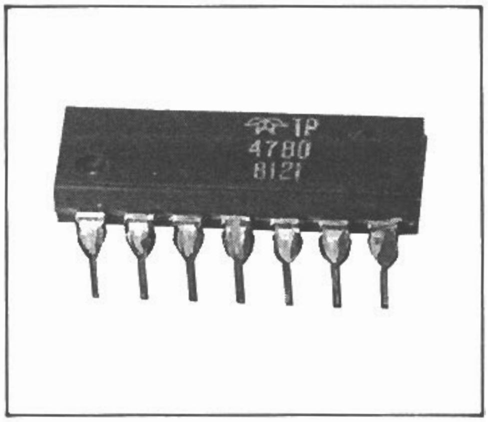
100kHz General Purpose CMOS Frequency to Voltage, Voltage to Frequency Converters

4780
4781

The 4780 and 4781 are general purpose, low cost, monolithic voltage to frequency/frequency to voltage converters that combine bipolar and CMOS technology on the same substrate. As a V/F, these devices are capable of providing an output pulse train that has a frequency which is linearly proportional to the magnitude of the input voltage. As an F/V, these devices will accept virtually any input frequency waveform and provide a linearly proportional output voltage. Operating from a single or dual supply, a complete V/F or F/V system requres the addition of only two capacitors, three resistors and a reference voltage.



Applications Information

Combined V/F and F/V operation, monolithic construction and low cost allow these devices to be used in a variety of general purpose applications. For optimum performance, gain and offset errors typically 10%FS and 0.1%FS respectively, can be externally adjusted to their ideal values. The trim potentiometers used for these adjustments should have a TCR of ± 100ppm/°C or less.

FEATURES

- ± 0.02%FS Max F/V Nonlinearity
- ± 0.01%FS Max V/F Nonlinearity
- ± 25ppm/°C Typ Gain Drift
- Single or Dual Supply Operation
- Current or Voltage Input
- Programmable Scale Factor

APPLICATIONS

- Temperature Sensing and Control
- 13 Bit A/D Conversion
- Motor Speed and Flow Rate Control
- High Noise Immunity Data Transmission
- Ultra Linear Frequency Modulation

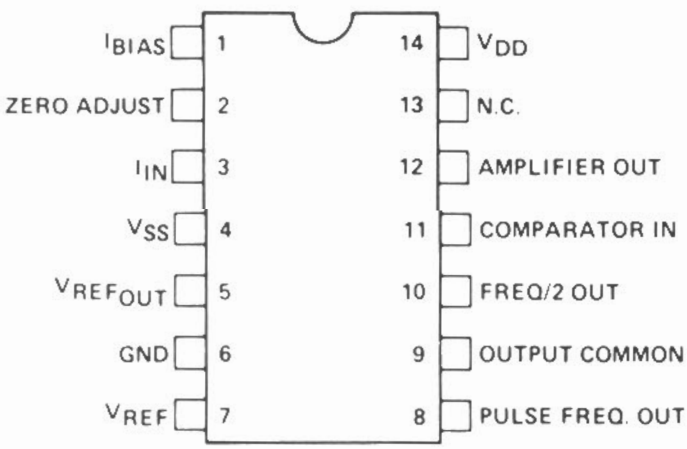


Figure 1. Connection Diagram

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SPECIFICATIONS At 25°C, V_{DD} = +5V, V_{SS} = −5V, V_{GND} = 0, V_{REF} = −5V
R_{BIAS} = 100kΩ, Full Scale = 10kHz, unless otherwise indicated.

	TYPICAL		GUARANTEED	
V/F CHARACTERISTICS				
INPUT				
I_{IN} Full Scale	+10μA		---	
I_{IN} Overrange max.	---		50μA	
NONLINEARITY % FULL SCALE	4780	4781	4780	4781
10Hz to 10kHz	.01	.004	.05	.01
10Hz to 100kHz	.1	.04	.25	.08
STABILITY OF FULL SCALE GAIN				
Temperature Coefficient ① ±ppm/°C	±25	±25	±40	±40
Supply Sensitivity, V_{SS} = ±1V, V_{DD} = ±1V, %/V	.025	.025	.1	.1
INPUT OFFSET				
ZeroOffset (I_N = 0)	±10mV	±10mV	±50mV	±50mV
Zero Offset Temperature Coefficient ①	±25μV/°C	±85μV/°C	±50μV/°C	±50μV/°C
OUTPUT				
V_{OUT} Low (Logic "0"), ① max., I_{OUT} = 10mA	---	---	.4V	---
V_{OUT} Max. $-V_{OUT}$ Common, max., I_{OUT} = 10μA	---	---	18V	---
Pulse Frequency Output Width	3μs	---	---	---
F/V CHARACTERISTICS				
FREQUENCY INPUT, T_r = T_f = 20ns				
Positive Excursion, min.	---	---	.4V	---
Negative Excursion, min.	---	---	−.4V	---
Min. Positive Pulse Width	5μs	---	---	---
Min. Negative Pulse Width	.5μs	---	---	---
NONLINEARITY % FULL SCALE	4780	4781	4780	4781
10Hz to 100kHz ②	.02	.01	.05	.02
OUTPUT				
Output Voltage Range for Specified Nonlinearity, R_L ⩾2kΩ	V_{DD} −1	---	---	---
Min. Output Loading	---	---	2kΩ	---
INPUT IMPEDANCE, min.	---	---	10MΩ	---
V/F/V CHARACTERISTICS				
POWER SUPPLY	4780		4780	
I_{DD} Quiescent ① (V_{IN} = −.1V)	2mA		6mA	
I_{SS} Quiescent (V_{IN} = .1V)	−1.5mA		−6mA	
V_{DD} Supply Range	---		4V to 7.5V	
V_{SS} Supply Range	---		−4V to −7.5V	
V_{REF} $-V_{SS}$, min.	---		−1V	
TEMPERATURE RANGE			4780/4781	
Operating (°C)			0 to +70	
Storage (°C)			−65 to +150	
ABSOLUTE MAXIMUM RATINGS				
V_{DD} $-V_{SS}$	---		18V	
I_{IN}	---		10mA	
V_{OUT} max. $-V_{OUT}$ Common	---		25V	
$V_{REF}$$-V_{SS}$, negative max.	---		−1.5V	
Package Dissipation	---		500mW	
Lead Temperature (Soldering, 10s)	---		300°C	

① Over Operating Temperature Range (0°C to +70°C, 4780/81)
② 5μs min. Positive Pulse Width and 0.5μs min. Negative Pulse Width

HANDLING PRECAUTIONS

The 4780/4781 is a CMOS bipolar device and must be handled correctly to prevent damage. Package and store only in conductive foam, anti-static tubes or other conductive material. Use proper anti-static handling procedures. Do not connect in circuits under "power on" conditions, as high transients may cause permanent damage.

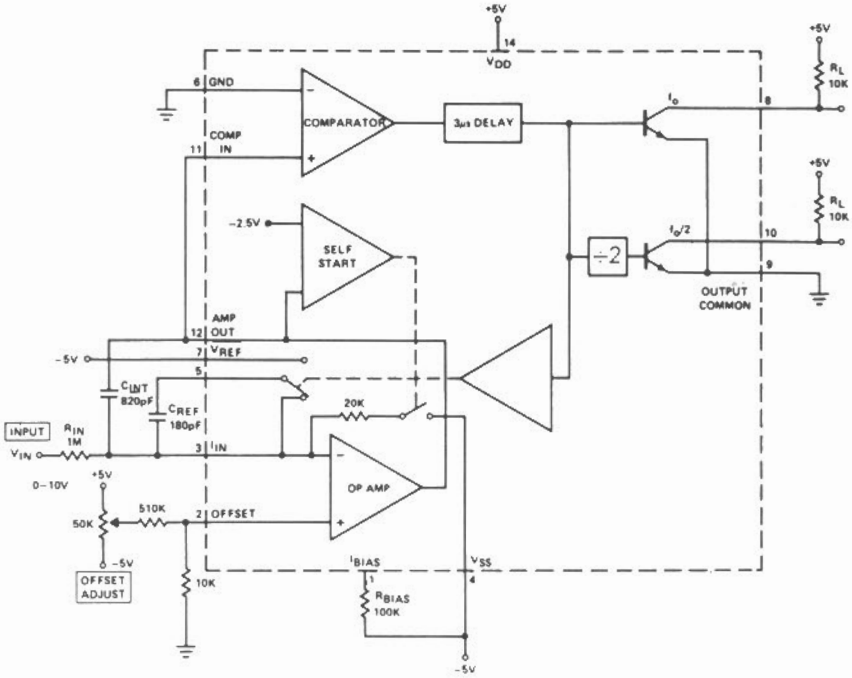
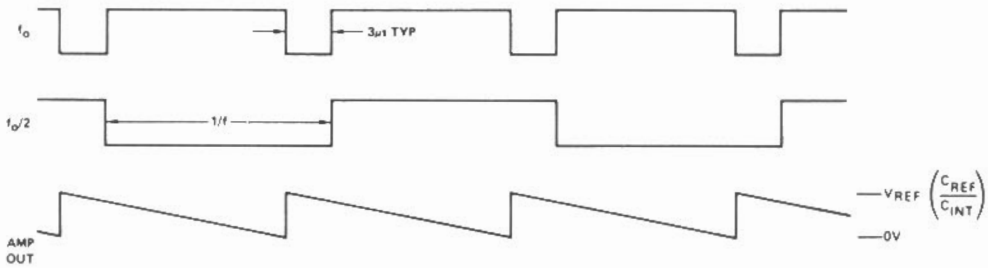


Figure 2. 10 Hz to 10 kHz V/F Converter



1. To adjust f_{min}, set V_{IN} = 10 mV and adjust the 50 K offset for 10 Hz out.
2. To adjust f_{max}, set V_{IN} = 10 V and adjust R_{IN} or V_{REF} for 10 kHz out.
3. To increase f_{OUT} MAX to 100 kHz change C_{REF} to 27 pF and C_{INT} to 75 pF.
4. For high performance applications use high stability components for R_{IN}, C_{REF}, V_{REF} (metal film resistors and glass film capacitors). Also separate the output ground (Pin 9) from the input ground (Pin 6).

Figure 3. Output Waveforms

V/F CIRCUIT DESCRIPTION

The 4780/4781 V/F converter operates on the principle of charge balancing. The input voltage (V_{IN}) is converted to a current (I_{IN}) by the input resistor. This current is then converted to a charge by the integrating capacitor and shows up as a linearly decreasing voltage at the output of the op amp. The zero crossing of the output is sensed by the comparator causing the reference voltages to be applied to the reference capacitor for a time period long enough to virtually charge the capacitor to the reference voltage. This action reduces the charge on the integrating capacitor by a fixed amount ($q = C_{REF} \times V_{REF}$) causing the op amp output to step up a finite amount.

At the end of the charging period, C_{REF} is shorted out, dissipating the stored reference charge so that when the output again crosses zero, the system is ready to recycle. In this manner, the continued discharging of the integrating capacitor by the input is balanced out by fixed charges from the reference voltage. As the input voltage is increased, the number of reference pulses required to maintain balance increases causing the output frequency to also increase. Since each charge increment is fixed, the increase in frequency with voltage is linear. In addition, the accuracy of the output pulses does not directly affect the linearity of the V/F. It must simply be long enough for full charge transfer to take place.

The 4780/4781 contains a "self-start" circuit to assure that the V/F will always operate properly when power is first applied. In the event that during "power-on" the op amp output is below the comparator threshold and C_{REF} is already charged, a positive voltage step will not occur. The op amp output will continue to decrease until it crosses the −2.5 volt threshold of the "self-start" comparator. When this happens, a resistor is connected to the op amp input, causing the output to quickly go positive until the 4780 is once again in its normal operating mode.

The 4780/4781 utilizes both bipolar and MOS transistors on the same substrate, taking advantage of the best features of each. MOS transistors are used at the inputs to reduce offset and bias currents. Bipolar transistors are used in the op amp, for high gain, and on all outputs for excellent current driving capabilities. CMOS logic is used throughout to minimize power consumption.

PIN FUNCTIONS

Comparator Input – In the V/F mode, this input is connected to the amplifier output (pin 12) and triggers the 3 μs pulse delay when the input voltage passes its threshold. In the F/V mode, the input frequency is applied to the comparator input.

Pulse Frequency Out – This output is an open-collector bipolar transistor providing a pulse waveform whose frequency is proportional to the input voltage. This output requires a pull up resistor and interfaces directly with MOS, CMOS and TTL logic.

Frequency/2 Out – This output is an open-collector bipolar transistor providing a square wave that is one-half the frequency of the pulse frequency output. This output requires a pull up resistor and interfaces directly with MOS, CMOS, and TTL logic.

Output Common – The emitters of both the f/2 out and the pulse frequency out are connected to this pin. An output level swing from the collector voltage to ground or to the V_{SS} supply may be obtained by connecting to the appropriate point.

R_{BIAS} – Specifications for the 4780/81 are based on R_{BIAS} = 100 kΩ ±10% unless otherwise noted. R_{BIAS} may be varied between the range of 82 kΩ $\leqslant R_{BIAS} \leqslant$ 120 kΩ.

Amplifier Out – A negative going ramp signal is available at this pin in the V/F mode. In the F/V mode, a voltage proportional to the frequency input is generated.

Zero Adjust – This is the noninverting input of the operational amplifier. The low frequency set point is determined by adjusting the voltage at this pin.

I_{IN} – This is the inverting input of the operational amplifier and the summing junction when connected in the V/F mode. An input current of 10 μA is specified for nominal full scale, but an overrange current up to 50 μA can be used without detrimental effect to the circuit operation.

V_{REF} – A reference voltage from either a precision source or the V_{SS} supply may be applied to this pin. Accuracy will be dependent on the voltage regulation and temperature characteristics of the circuitry.

V_{REF} OUT – The charging current for C_{REF} is derived from the internal circuitry and switched by the break-before-make switch to this pin.

V/F DESIGN INFORMATION

Input/Output Relationships – The output frequency is related to the analog input voltage (V_{IN}) by the transfer equation:

$$\text{FREQUENCY OUT} = \frac{V_{IN}}{R_{IN}} \times \frac{1}{(V_{REF})(C_{REF})}$$

External Component Selection

R_{IN} – The value of this component is chosen to give a full scale input current of approximately 10 μA.

$$R_{IN} \cong \frac{V_{IN}\ \text{FULL SCALE}}{10\ \mu A}$$

Example:

$$R_{IN} \cong \frac{10\ V}{10\ \mu A} = 1\ M\Omega$$

Note that the value is an approximation, and the exact relationship is defined by the transfer equation. In practice, the value of R_{IN} typically would be trimmed to obtain full scale frequency at V_{IN} FULL SCALE (see adjustment procedure). Metal film resistors with 1% tolerance or better are recommended for high accuracy applications because of their thermal stability and low noise generation.

C_{INT} – Exact value not critical but is related to C_{REF} by the relationship:

$$3\ C_{REF} \leqslant C_{INT} \leqslant 10\ C_{REF}$$

Improved stability and linearity is obtained when $C_{INT} \geqslant 4\ C_{REF}$. Low leakage types are recommended, although mica and ceramic devices can be used in applications where their temperature limits are not exceeded. Locate these as close as possible to pins 12 and 3.

C_{REF} – Exact value is not critical and may be used to trim the full scale frequency (see input/output relation). Glass film or air trimmer capacitors are recommended because of their stability and low leakage. Locate these as close as possible to pins 5 and 3.

V_{DD}, V_{SS} – Power supplies of ±5 V are recommended. For high accuracy requirements, 0.05% line and load regulation and 0.1 μF disc decoupling capacitors located near the pins are recommended.

Adjustment Procedure – Figure 2 shows a circuit for trimming the zero location. Full scale may be trimmed by adjusting R_{IN}, V_{REF}, or C_{REF}. Recommended procedure is as follows for a 10 kHz full scale frequency.

1. Set V_{IN} to 10 mV and trim the zero adjust circuit to obtain a 10 Hz output frequency.
2. Set V_{IN} to 10.000 V and trim either R_{IN}, V_{REF}, or C_{REF} to obtain a 10 kHz output frequency.

If adjustments are performed in this order, there should be no interaction and they should not have to be repeated.

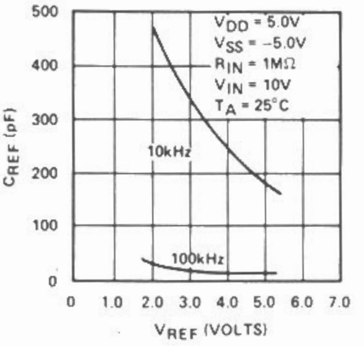
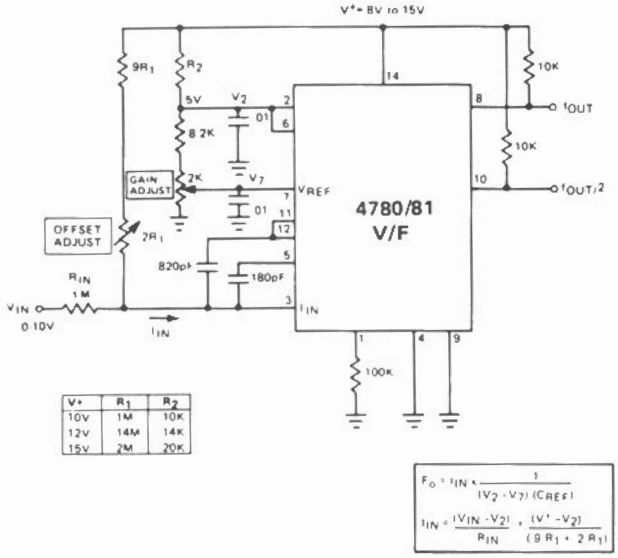


Figure 4. Recommended C_{REF} vs. V_{REF}

V/F SINGLE SUPPLY OPERATION



V+	R1	R2
10V	1M	10K
12V	14M	14K
15V	2M	20K

$$F_O = I_{IN} \times \frac{1}{(V_2 - V_7)(C_{REF})}$$

$$I_{IN} = \frac{|V_{IN} - V_2|}{R_{IN}} + \frac{(V^+ - V_2)}{(9R_1 + 2R_1)}$$

Figure 5. Fixed Voltage – Single Supply Operation

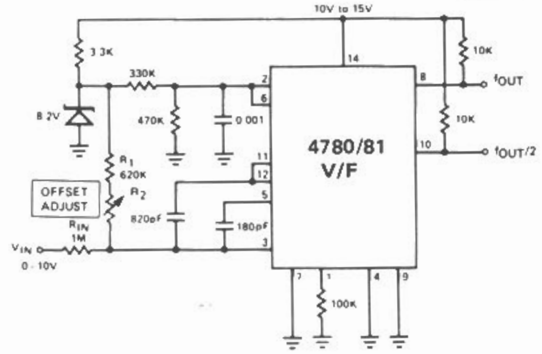


Figure 6. Variable Voltage – Single Supply Operation

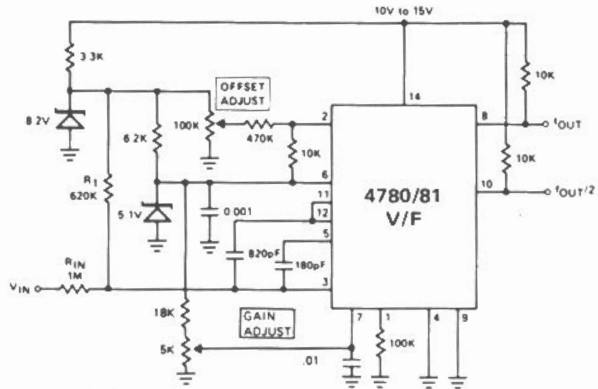


Figure 7. Single Variable Supply Voltage with Offset and Gain Adjust

F/V CIRCUIT DESCRIPTION

The 4780/4781, when used as a frequency to voltage converter, generates an output voltage which is linearly proportional to the input frequency waveform.

Each zero crossing at the comparator's input causes a precise amount of charge ($q = C_{REF} \times V_{REF}$) to be dispensed into the op amp's summing junction. This charge in turn flows through the feedback resistor generating voltage pulses at the output of the op amp. A capacitor (C_{INT}) across R_{INT} averages these pulses into a DC voltage which is linearly proportional to the input frequency.

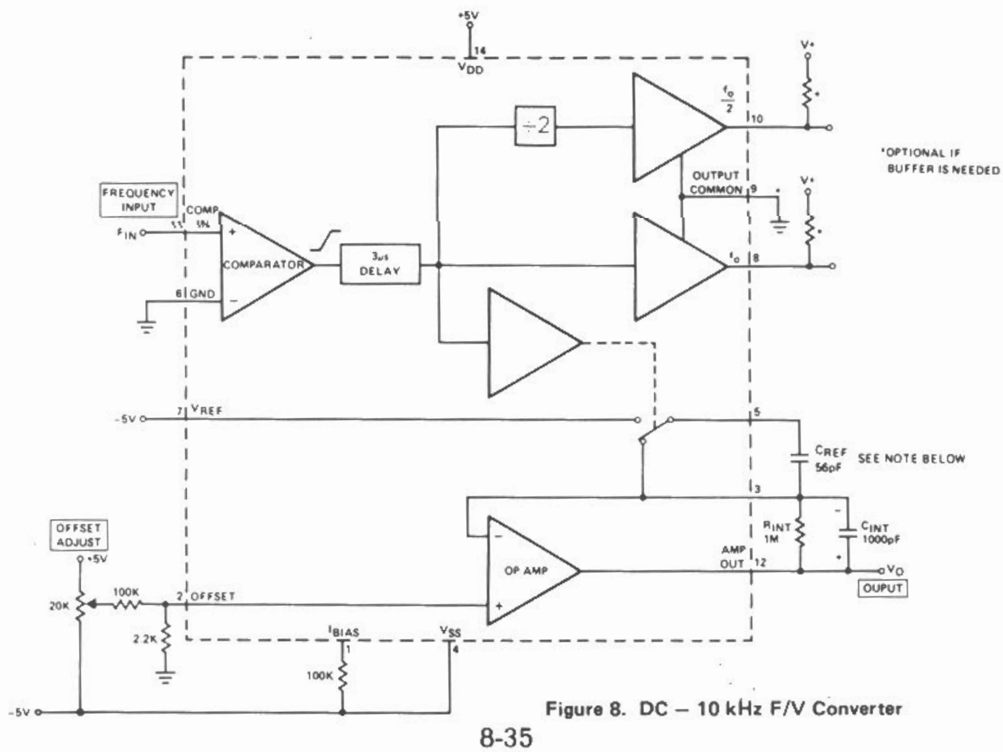


Figure 8. DC – 10 kHz F/V Converter