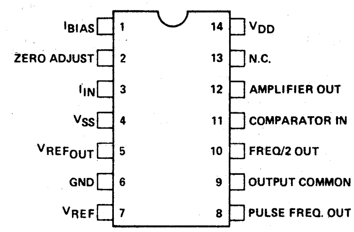
ARCHER®

TECHNICAL DATA

AN EXCLUSIVE RADIO SHACK SERVICE TO THE EXPERIMENTER

Catalog Number 276-1790

The 9400 is a low-cost Voltage-Frequency/Frequency-Voltage converter which can accept a variable analog input signal and generates an output pulse train whose frequency is in linear proportion to the input voltage. The 9400 can also accept virtually any input frequency waveform and provides a voltage output in linear proportion to the input. The 9400 operates on single or split supply voltages. A complete V/F or F/V system requires the addition of two capacitors, three resistors, and a reference voltage. The 9400 utilizes both bipolar and MOS transistors. At the inputs, MOS transistors are used 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.



CAUTION:
Static discharge to any lead of this device may cause permanent damage. Store in aluminum foil or inserted in conductive foam. Use grounded soldering irons, tools, and personnel when handling devices. Avoid synthetic fabrics. It is recommended that the device be inserted into socket before applying power.

Absolute Maximum Ratings

Storage Temperature	−65° C to +150° C
Operating Temperature	0° C to 70° C
$V_{DD} - V_{SS}$	18V
I_{IN}	10mA
V_{OUT}max − V_{OUT} common	25V
$V_{REF} - V_{SS}$	−1.5V
Package Dissipation	500mW
Lead Temperature (Soldering, 10 seconds)	300° C

FEATURES

Voltage-to-Frequency

10Hz to 100kHz Operation
±0.01% Typ. Linearity to 10KHz
±25ppm/°C Typ. Gain Temperature Stability
Open Collector Output
Output can Interface with any Form of Logic
Pulse and Square Wave Outputs
Programmable Scale Factor
Low Power Dissipation (27mW Type.)
Single Supply Operation (8V to 15V)
Dual Supply Operation (±4V to ±7.5 V)
Current or Voltage Input

Applications

Voltage-to-Frequency

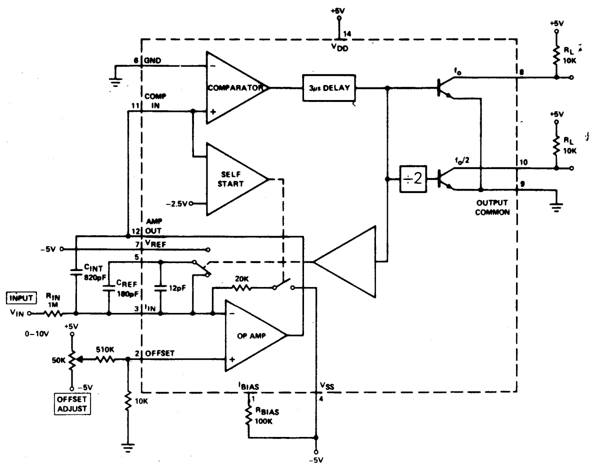
Temperature Sensing and Control
μP Data Acquisition
Instrumentation
13 Bit A/D Converters
Digital Panel Meters
Analog Data Transmission and Recording
Phase Locked Loops
Medical Isolation
Transducer Encoding
Alternate to 555 Astable Timer

V/F Electrical Characteristics

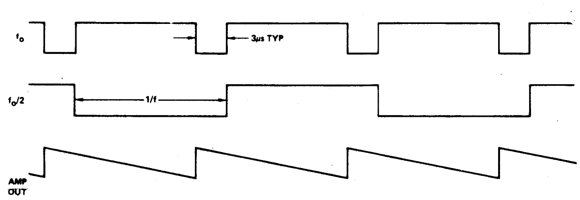
Parameter	Definition	Min	Typ	Max	Units	Conditions
Accuracy Linearity (10KHz)	Output deviation from straight line between normalized zero and full scale input		0.01	0.05	% Full Scale	
Linearity (100KHz)			0.1	0.25	% Full Scale	
Analog Inputs I_{IN} Full Scale	Full scale analog input current to achieve specified accuracy		10		μA	
I_{IN} Overrange	Overrange current			50	μA	
Response Time	Setting time to 0.01%		2		Cycles	
Digital Outputs V_{SAT}	Logical "O" output voltage			0.4	V	Full Temp. Range I_{OUT} = 10mA
V_{OUT}Max−V_{OUT}Common	Voltage range between output and common			18.0	V	I_{OUT} = 10μA
Pulse Frequency Output Width			3.0		μsec	
Supply Current, Quiescent	Current required from pos. or neg. supply during operation		2.0	6.0	mA	Full Temp. Range V_{IN} = −0.1V
Reference Voltage $V_{REF} - V_{SS}$	Range of voltage reference input	−1.0			V	
Supply Sensitivity	Change in full scale gain vs supply voltage change		0.025	0.1	%/V	$V_{SS}\pm1V$, $V_{DD}\pm1V$

Unless otherwise specified, V_{DD} = +5V V_{SS} = −5V, V_{GND} = 0, V_{REF} = −5V, R_{BIAS} - 100KΩ, Full Scale = 10KHz, T_A = 25°C unless Full Temp. Range is specified.

NOTE: I_{IN} connects the summing junction of an operational amplifier. Voltage sources cannot be attached directly but must be buffered by external resistors.



10Hz to 10KHz V/F Converter



Output Waveforms

1. To adjust f_{min}, set V_{IN}=10mV and just the 50K offset for 10Hz out.
2. To adjust f_{max}, set V_{IN}=10V and adjust R_{IN} or V_{REF} for 10KHz out.
3. To increase f_{OUT}MAX to 100KHz change C_{REF} to 15pF and C_{INT} to 75pF.
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).

V/F Circuit Description

The 9400 operates on the principal 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 voltage 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.

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 effect the linearity of the V/F. It must simply be long enough for full charge transfer to take place.

The 9400 contains a "self-start" circuit to assure that the V/F will always operate properly when power is first applied.

Pin Functions

1. **R_{BIAS}** — Specifications for the 9400 are based on R_{BIAS} = 100K ±10% unless otherwise noted. R_{BIAS} may be varied between the range of 82K $\leq R_{BIAS} \leq$ 120K.

2. **Zero Adjust** — The non-inverting input of the operational amplifier. The low frequency set point is determined by adjusting the voltage at this pin.

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

5. **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.

7. **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.

8. **Pulse Freq 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.

9. **Output Common** — The emitters of both the freq/2 out and the pulse freq 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.

10. **Freq/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.

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

12. **Amplifier Out** — The output stage of the operational amplifier. 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.

V/F Design Information

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

$$\text{FREQUENCY OUT} = \frac{V_{IN}}{R_{IN}} \times \frac{1}{(V_{REF})(C_{REF} + 12\text{pF})}$$

External Component Selection

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

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

Example:

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

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:

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

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

C_{REF} — Exact value 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 as close as possible to pins 5 and 3.

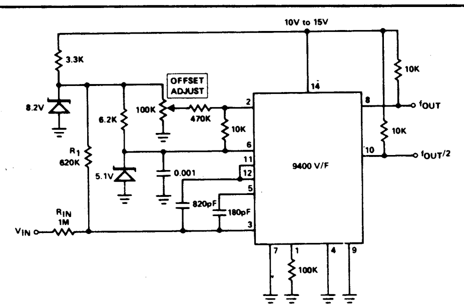
V_{DD}, V_{SS} — Power supplies of $\pm$5V are recommended. For high accuracy requirements 0.05% line and load regulation and 0.1μF disc decoupling capacitors located near the pins are recommended.

Adjustment Procedure — Figure 1 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 followed for a 10KHz full scale frequency.

1. Set V_{IN} to 10mV and trim the zero adjust circuit to obtain a 10Hz output frequency.

2. Set V_{IN} to 10.000V and trim either R_{IN}, V_{REF}, or C_{REF} to obtain a 10KHz output frequency.

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



Variable Supply Voltage with Offset Adjust

FREQUENCY-TO-VOLTAGE

Features

DC to 100KHz Operation
$\pm$0.02% Typ. Linearity to 10KHz
Op Amp Output
Programmable Scale Factor
High Input Impedance (>10MΩ)
Accepts any Voltage Wave Shape

Applications

Frequency Meters/Tachometer
Speedometers
Analog Data Transmission and Recording
Medical Isolation
Motor Control
RPM Indicator
FM Demodulation
Frequency Multiplier/Divider
Flow Measurement and Control

F/V Electrical Characteristics

Unless otherwise specified, V_{DD} = 5V, V_{SS} = V_{REF} = −5V, R_{BIAS} = 100KΩ, V_{TND} = 0V, T_A = 25°C.

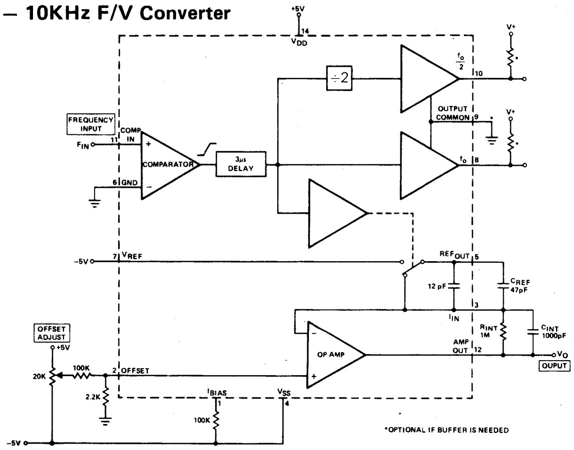
Parameter	Definition	Min.	Typ	Max	Conditions
Accuracy					
Non-Linearity (% FS)	Deviation from ideal transfer function as a percentage of full scale voltage		0.02		10Hz to 100KHz
Input Freq. Range (Hz)	Frequency range for specified non-linearity	10		100K	5μs min. pos. pulse width and 0.5μs min. negative pulse width
Frequency Inputs					
Positive Excursion (V)	Voltage required to turn comparator on	0.4		V_{DD}	$T_r = T_f$ = 20ns
Negative Excursion (V)	Voltage required to turn comparator off	−0.4		−2V	$T_r = T_f$ = 20ns
Min. Pos. Pulse Width (μs)	Time between threshold crossings		5.0		$T_r = T_f$ = 20ns
Min. Neg. Pulse Width (μs)	Time between threshold crossings		0.5		$T_r = T_f$ = 20ns
Input Impedance (ohms)		10M			
Analog Outputs					
Output Voltage (V)	Voltage range of op amp output for specified non-linearity		V_{DD}−1		R_L 2KΩ
Output Loading (ohms)	Resistive loading at output of op amp	2K			

F/V Circuit Description

The 9400, 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.

DC — 10KHz F/V Converter



F/V Design Information

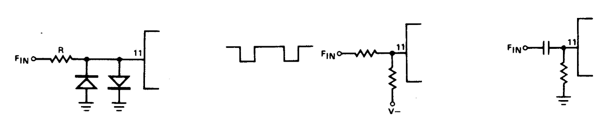
Input/Output Relationships — The output voltage is related to the input frequency (F_{IN}) by the transfer equation:

$$V_{OUT} = [V_{REF}\, C_{REF}\, R_{INT}]\, F_{IN}$$

The response time to a change in F_{IN} is equal to $R_{INT}\, C_{INT}$. The amount of ripple on V_{OUT} is inversely proportional to C_{INT} and the Input Frequency.

Input Voltage Levels — The input signal must cross through zero in order to trip the comparator. In order to overcome the hysteresis the amplitude must be greater than $\pm$200mV. If the comparator input voltage exceeds −2.5V then the op amp output will go to its maximum positive output voltage for the duration of the overvoltage.

If the input voltage has a wide amplitude variation, then a pair of back to back diodes may be used to limit the voltage to $\pm$0.7V.



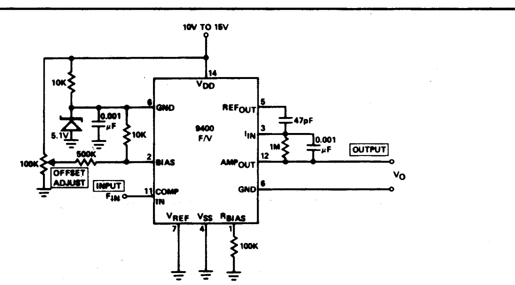
If only a unipolar input signal (F_{IN}) is available, it is recommended that either an offset circuit using resistor be used or that the signal be coupled in via a capacitor.

The output voltage of the op amp is referenced to Pin 6 (GND). So if Pin 6 is used to determine the comparator threshold, the op amp output reference will also be shifted.

For 100KHz maximum input R_{INT} should be decreased to 100KΩ.

Input Buffer — f_o and $f_o/2$ are not used in the F/V mode. However, these outputs may be useful for some applications, such as a buffer to feed additional circuitry. f_o will then follow the input frequency waveform; except that f_o will go high 3μs after F_{IN} goes high. $f_o/2$ will be square wave with a frequency of one half f_o.

If these outputs are not used, then Pins 8, 9 and 10 may be left floating or connected to ground.



F/V Single Supply

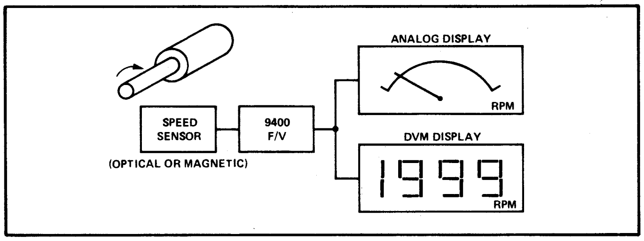
1. The input is now referenced to 5.1V (Pin 6). The input signal must therefore be restricted to be greater than 3 volts (Pin 6 −2V) and less than 10 to 15V (V_{DD}).

If the signal is AC coupled then a resistor (100K to 10MΩ) must be placed between the input (Pin 11) and Pin 6.

2. The output will now be referenced to Pin 6 which is at 5.1V (V_Z). For frequency meter applications a 1mA meter with a series scaling resistor can be placed across Pins 6 and 12.

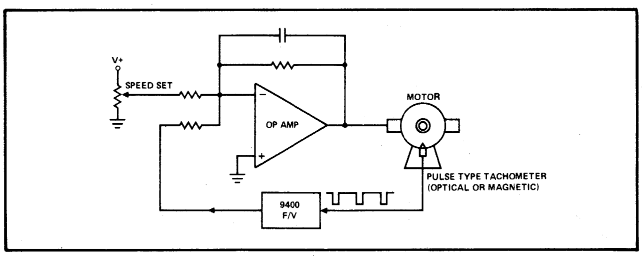
TYPICAL APPLICATIONS

RPM/SPEED INDICATOR



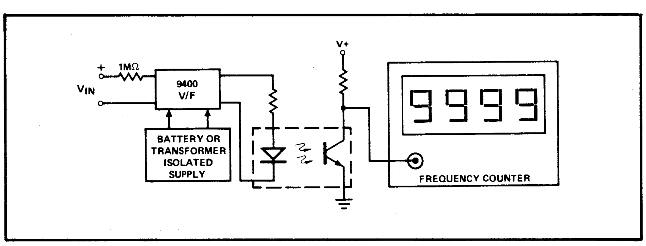
Flow rates and revolutions per second are nothing more than frequency signals since they measure the number of events per time period. Optical and magnetic sensors will convert these flows and revolutions into a digital signal which in turn can be converted to a proportional voltage by the use of an F/V converter. A simple voltmeter will then give a visual indication of the speed.

MOTOR SPEED CONTROL



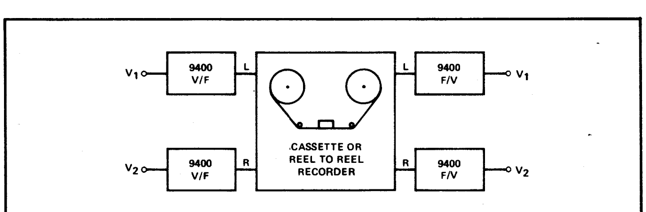
The motor's speed is measured with the F/V, which converts RPM into a proportional voltage. This voltage is used in a negative feedback system to maintain the motor at the controlled setting.

4 DIGIT VOLTMETER W/OPTO-ISOLATED INPUT



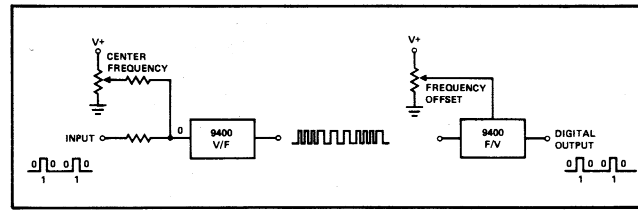
A temperature meter using the voltage output of a probe, such as one of the three shown, can be implemented with the 9400 V/F. The V/F output is simply counted to display the temperature.

DC RESPONSE DATA RECORDING SYSTEM



Low frequency analog data (DC to 10KHz) can be recorded anywhere, stored and then reproduced. By varying the playback speed, the frequency spectrum of the original data can be shifted up or down.

FSK GENERATION AND DECODING



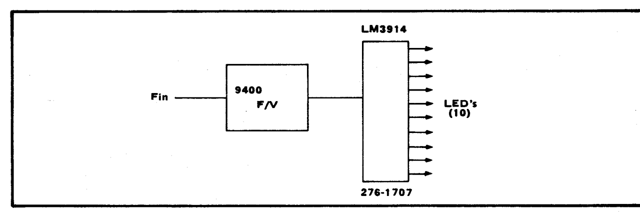
Frequency shift keying (FSK) is a simple means of transmitting digital data over a signal path (two wires, telephone lines, AM transmitters or FM transmitters).

Typically only two frequencies are transmitted. One corresponds to a logical "0" while the other corresponds to a logical "1".

A 9400 V/F will generate these two frequencies when connected as shown above. The potentiometer sets the V/F to the lower frequency. The digital input will then determine which frequency is selected. A "0" selects the lower frequency while a "1" selects the upper frequency.

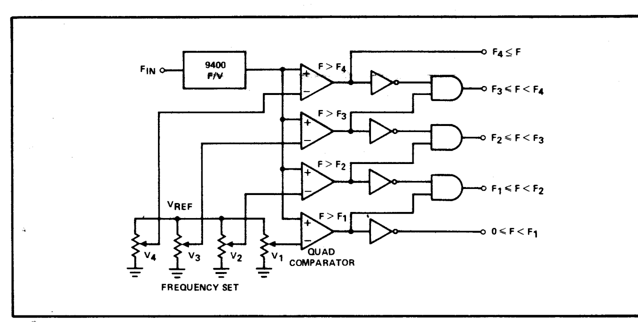
The digital frequency signal is converted back into a digital format by a 9400 used in the F/V mode.

TACHOMETER BAR GRAPH DISPLAY



A tachometer can be constructed by using the 9400 in the F/V mode to convert the frequency information (RPM) into a linearly proportional voltage. This voltage is then compared to one of n comparators (8 in this example). When the voltage exceeds the trip point of a comparator the respective LED will light up and continue to stay lit as long as the voltage exceeds the trip point. This will give a bar graph type display with the height of the bar being proportional to RPM.

FREQUENCY/TONE DECODER



The frequency or tone to be detected is converted into a proportional analog voltage by the 9400 F/V converter. The quad comparators sense when the voltage (frequency) exceeds any of the four preset frequency limits. A logical "1" at any of the five outputs indicates that the frequency is within those limits.

This system is useful for determining which frequency band a signal is in or for remote control where each frequency band corresponds to a different command.

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