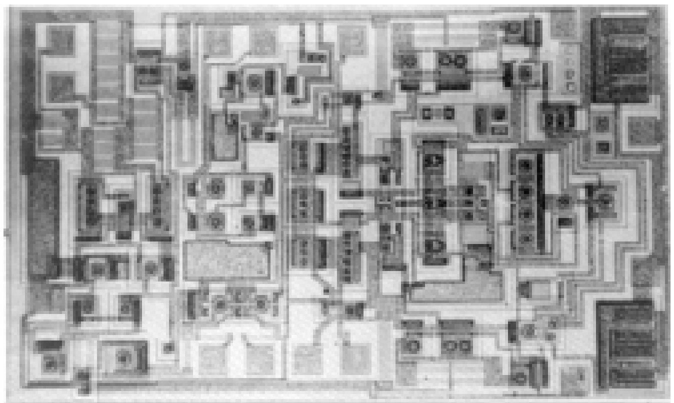
VERSATILE MONOLITHIC V/f OR I/f CONVERTER

AD537 is Easy to Use, Works from Single Supply Outputs to Beyond 100kHz; T/f Conversion Inherent

by Dave Kress and Barrie Gilbert



The AD537 is a self-contained monolithic voltage-to-frequency converter fabricated on a single 74 x 118 mil (1.9 x 3mm) silicon chip and mounted in a hermetically-sealed 14-pin ceramic dual in-line package (DIP). It contains (Figure 1), an input amplifier, a precision oscillator system, a reference generator, and a high-current output stage. Only a single external resistor and capacitor are needed to determine the scale factor. Its three versions are AD537J/K (0° to +70°C) and AD537S (-55° to +125°C).

The great strength of the AD537's design lies in the ease of application to a wide variety of instrumentation, communication, and systems uses (eight applications appear on pages 7 & 8). Both positive and negative input voltages, with full-scale values from 100mV to >10V – and current inputs – are easily accommodated. A single external capacitor programs square waves, at full-scale frequencies from <100Hz to >100kHz (+50% overrange).

Square waves are generally more useful than the variable-duty-cycle output pulse-train from most V/f converters. A square wave requires less equivalent bandwidth for transmission and avoids bias-distortion effects in ac-coupled transmission- or recording-media. Since chip dissipation is independent of frequency, thermally-induced nonlinearities under load are avoided.

A unique feature of the AD537 is its pair of reference outputs – a low-drift 1.00V reference, which can be used to drive resistive sensors or provide a precise level for additive input constants; and a 1mV/°K reference voltage that is directly proportional to absolute temperature (at +25°C, its output is 298mV), allowing the AD537 to be used as a direct temperature-to-frequency (hence digital) transducer. The independent reference outputs, though "soft", can be used for other circuit functions during normal VFC use.

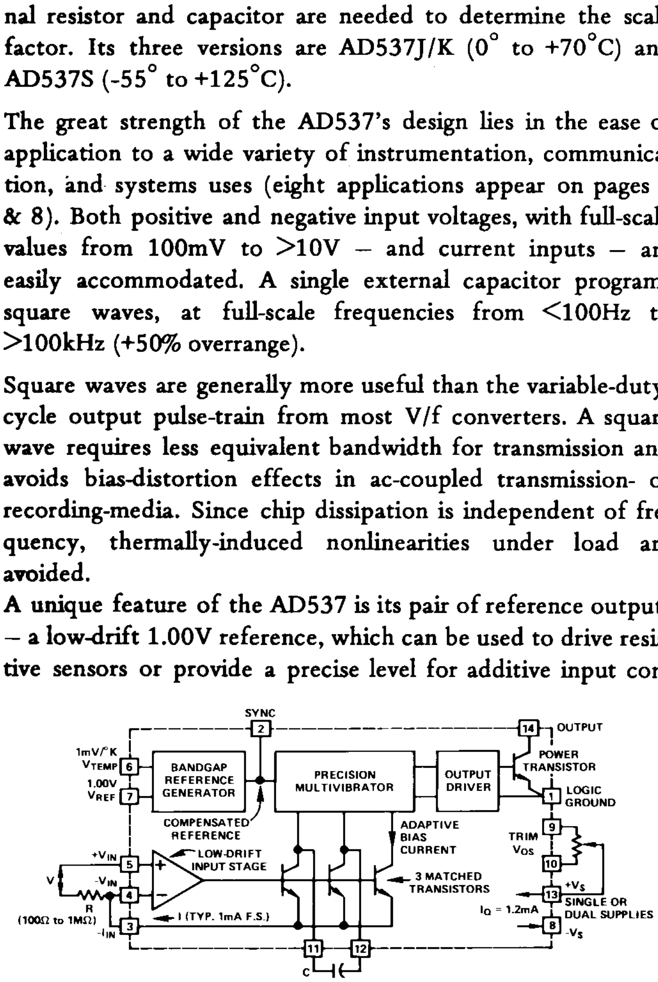


Figure 1. Block diagram of the AD537.

The AD537 operates well with most standard power-supply configurations – for example, a single +4.5 to +36V supply – permitting applications in an all-digital system without requiring a separate analog supply. It functions equally well with standard split supplies (±5V to ±18V). Considerably lower-powered than other VFC's, it needs only 1.2mA of quiescent current, a useful feature for remote-sensing or battery-powered applications.

The SYNC terminal (pin 2) permits external control; the AD537 can be synchronized to a system frequency or inhibited at will. This feature and the open-collector output stage permit multiplexing of several AD537's on a single line-pair in a wired-or configuration.

Many new applications areas, previously closed to IC V/f converters, will be opened by the AD537's flexibility, its convenient 14-pin DIP, and its "IC-type" pricing ($9.50 in 100's (J)).

HOW IT WORKS (Figure 1)

The versatile input amplifier, used as an op amp, scales the input signal and converts it to the appropriate drive-current level for the oscillator. The input specs are excellent: ±1mV offset, 5μV/°C drift, 100nA bias current, and 250MΩ non-inverting-input impedance. A PNP input stage allows the input signal level to go all the way down to the $-V_S$ single-supply (ground) level and up to ($+V_S$ - 4) volts.

The key element of the design is a precision astable multivibrator. The timing current, supplied by the input, is split precisely among the 3 matched NPN transistors, 2 of which sink the drive current through the timing capacitor. The 3rd transistor drives the bias network for the oscillator – thus all sections of this stage are adaptively biased to match the timing current, reducing nonlinearities due to β and r_E to <0.02%. The switching system and bias transistors force a current of precisely I/3 in alternating directions through the timing capacitor, which integrates the current. The primary switching transistors compare the capacitor voltage to a level determined by the bandgap reference generator; regenerative switching occurs when the capacitor voltage reaches that level. The reference level has a temperature variation that compensates for the tempco of the switching transistors. Brought to pin 2 (SYNC), this level can be perturbed at multiples of system frequency for synchronization or switched to the supply to inhibit oscillation.

The design of the reference-generator is similar to that of the AD580 2.5V Reference . Besides the temperature-compensating level for the oscillator, it also supplies externally a low-tempco 1.00V reference and a thermometric voltage, which can be used in direct temperature-to-frequency conversion (page 8), as an ambient temperature reference in systems applications, and for compensating temperature coefficients in the timing circuitry.

The driver converts the oscillator's differential output to a floating switched current, which drives the uncommitted output power-transistor. This configuration offers great flexibility. The output can be taken from either the collector or the emitter of the output transistor; usually, the emitter is grounded and the output is taken from the collector (with a pullup resistor to $+V_S$). Logic common (pin 1) need not be held at either analog input common, or at power-supply common; it can be floated anywhere between $-V_S$ and $(+V_S - 4V)$, with a return to $-V_S$. This means that a direct connection can be made to virtually any type of logic with any supply combination. The digital supply can be up to 36V above $-V_S$, regardless of $+V_S$.

STANDARD APPLICATIONS

Figures 2 and 3 show the most-common basic configurations. For normal positive inputs, pins 3 & 4 are connected together, then via a scaling resistor ($R = V_{IN\ F.S.}/1mA$) to ground. 100% overrange to 2mA is allowed, with somewhat degraded linearity. Only a positive supply is required, even for negative-input applications (but a negative supply can be used for increased input range).

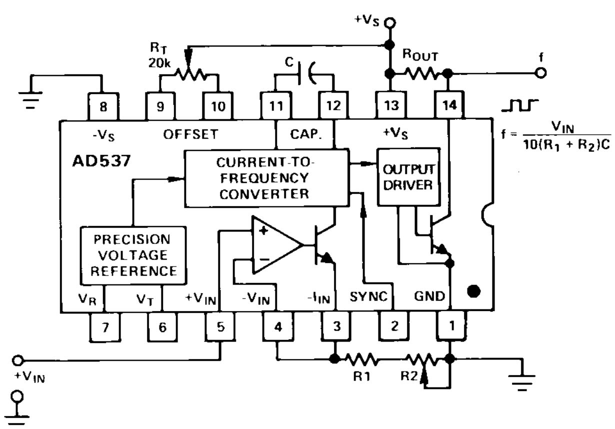


Figure 2. Standard connection for V/f conversion of positive input voltage.

The optional 20kΩ pot is used when trimming the input-amplifier offset. The timing capacitor must be a high-quality polystyrene or NPO ceramic type to minimize nonlinearity due to dielectric absorption. Temperature performance of the circuit is sensitive to the capacitor's tempco. Collector pullup resistance is chosen for sufficient pullup current but minimal power consumption.

For negative inputs (V or I), the positive input is grounded, and the signal source provides the oscillator drive current (Figure 3). The 1kΩ resistor and the diode are required to prevent latching under transient conditions. To accommodate very large negative input levels (even below $-V_S$), select the scaling resistors to give 1mA drive current at full-scale input voltage. The scaling resistors are not used with *current* inputs; calibration for a current source can be provided by a 27kΩ resistor in series with a 200kΩ trimmer from pin 7 to ground.

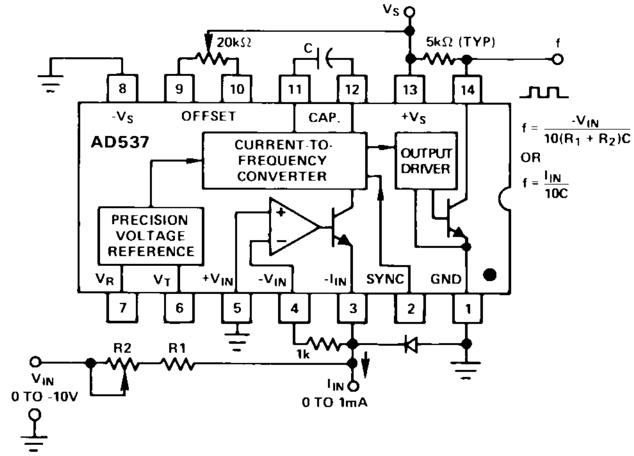


Figure 3. Connection for V/f conversion of negative input voltage or current.

A few salient examples of the wide range of potential applications for the AD537 are shown on the next page.

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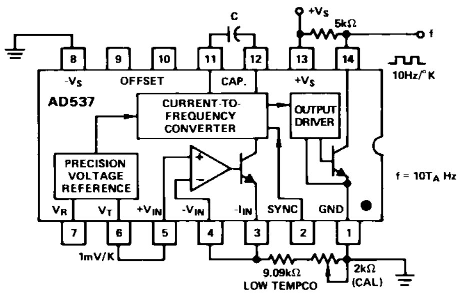
PERFORMANCE CHARACTERISTICS OF THE AD537

(Typical at $+V_S$ = +5 to +15V, $-V_S$ = 0V, T_A = +25°C, unless otherwise indicated)

	J	K*	S
ANALOG INPUT AMPLIFIER (voltage-to-current converter)			
Voltage Input Range:		0 to (V_S + 4)	
Input Bias Current:		100nA	
Input Resistance (Non-Inverting):		250MΩ	
Input Offset Voltage,	5mV *max*	2mV *max*	2mV *max*
vs. Supply:		100μV/V	
vs. Temperature:		5μV/°C	
CURRENT-TO-FREQUENCY CONVERTER			
Frequency Range:		0 to 150kHz	
Nonlinearity			
Positive Voltage Input:	0.15% *max*	0.1% *max*	0.1% *max*
Negative Voltage or Current Input,			
10kHz full scale:	0.1% *max*	0.05% *max*	0.05% *max*
100kHz full scale:	0.2% *max*	0.1% *max*	0.1% *max*
Full-Scale Calibration Error (C_T = 1.000nF, I_{IN} = 1.000mA, f = 100kHz nominal)			
Maximum Error (adjustable to 0):	7%	5%	5%
Temperature Coefficient:	150ppm/°C	50ppm/°C	100ppm/°C
Supply Rejection:		0.01%/V	
OUTPUT INTERFACE			
Circuit:		Open-Collector Output	
Waveform:		Symmetrical Square Wave	
Output Sink Current – Output Low			
V_{OUT} = 0.4V *max*, T_{MIN} to T_{MAX}	20mA *min*	20mA *min*	10mA *min*
Output Leakage Current – Output High			
T_{MIN} to T_{MAX}	200nA *max*	200nA *max*	2μA *max*
Logic Common Level Range:		$-V_S$ to ($+V_S$ – 4) volts)	
Rise or Fall Time, C_T = 0.01μF			
I_{IN} = 1mA:		0.2μs	
I_{IN} = 1μA:		1μs	
POWER SUPPLY			
Voltage, Rated Performance			
Single Supply:		4.5V to 36V	
Dual Supply:		±5V to ±18V	
Quiescent Current:		1.2mA	
TEMPERATURE RANGE, OPERATING	0° to +70°C	-55° to +125°C	-55° to +125°C
PRICE:			
1 – 24:	$13.00	$19.75	$29.00
100+:	$9.50	$13.75	$19.50

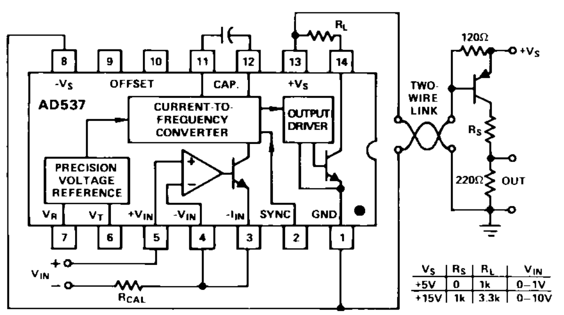
*Specs listed only in this column are common to all three grades.

TEMPERATURE (KELVIN)-TO-FREQUENCY CONVERTER



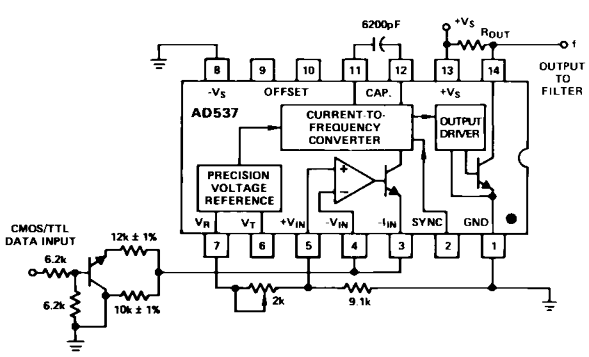
This simple connection results in a direct conversion of temperature to frequency. The 1mV/°K temperature output serves as the input to the buffer amplifier, and the oscillator drive current is scaled to be 298μA at 298°K (+25°C). Use of a 1000pF capacitor results in a corresponding frequency of 2.98kHz. A single-point trim for calibration is normally sufficient to give errors less than ±2°C from -55° to +125°C. An NPO capacitor is preferred to minimize nonlinearity due to capacitance drift.

TRUE TWO-WIRE OPERATION



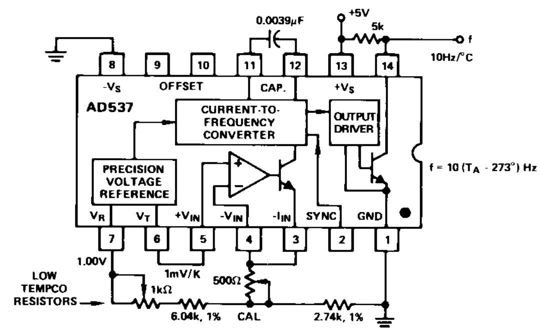
The AD537 can be used for true two-wire operation, as shown here. The frequency information is transmitted as a current signal on the supply line to the device. The signal is converted to a DTL/TTL or CMOS-compatible signal by the single-transistor-termination circuit shown. The excellent supply rejection, high output-drive capability and square-wave output from the AD537 are all advantageous in this application.

BELL SYSTEM 202 DATA ENCODER



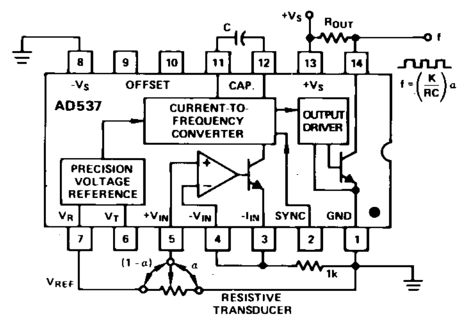
The AD537 is well-suited for frequency-shift modulator and demodulator applications. Requiring little power, it is especially suited to using phone-line power. The Bell-System-202-type data encoder shown here delivers the *mark* frequency of 1.2kHz with the data input *low*. When the input goes *high*, the timing current increases to 165μA and generates the *space* frequency of 2.2kHz. The trim shown provides a ±10% range of frequency adjustment. The output goes to the required bandpass filter before transmission over a public telephone line. A complementary demodulator is easy to implement.

TEMPERATURE (CELSIUS) TO FREQUENCY CONVERTER



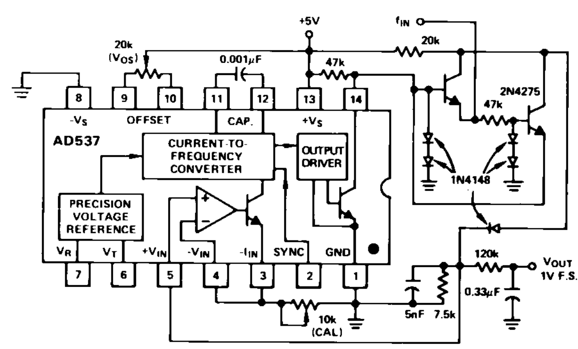
The 1.00V reference output may be combined with the 1mV/°K output to realize various temperature scales. For the Celsius scale, the lower end of the timing resistor must be offset by 273mV. This is easily accomplished, as shown above, and results in an output from 0 to 1kHz for temperatures from 0°C to +100°C. Other offsets and scale factors are equally easy to implement.

INTERFACING RESISTIVE TRANSDUCERS



All types of resistive-element transducers, such as servo-pots, level indicators, thermistors, photosensors, strain gages, and so on, can be directly connected to the AD537. Resistance values from 3kΩ to 100kΩ are easily accommodated. Input-buffer bias-current errors will be noticeable above 100kΩ; values below 3kΩ will load the reference beyond its output capability. The scale correction factor, K, is a function of resistance, varying from 0.65 to 0.98 for values from 3kΩ to 100kΩ.

FREQUENCY-TO-VOLTAGE CONVERTER



The AD537 can also be used as a highly-linear voltage-controlled oscillator in a phase-locked loop to perform *frequency-to-voltage* conversion. The transistor pair shown here operates as an exclusive-or gate to perform the phase comparison. It locks onto the input frequency within two cycles. This configuration requires only 3mA for frequencies up to 10kHz. In most situations, an output buffer will be required to unload the filter. Use 0-to-5V pulses or square waves with 40μs minimum pulsewidth.