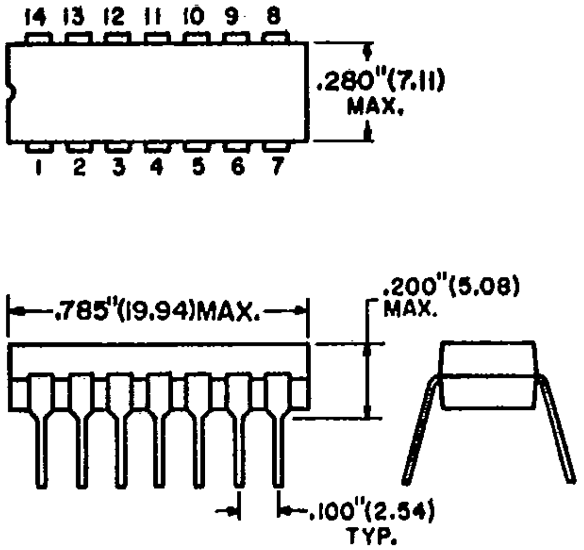
ECG® Semiconductors

ECG995

Frequency to Voltage Converter

Features

- Ground referenced tachometer input interfaces directly with variable reluctance magnetic pickups
- Op amp/comparator has floating transistor output
- 50 mA sink or source to operate relays, solenoids, meters, or LEDs
- Frequency doubling for low ripple
- Tachometer has built-in hysteresis with either differential input or ground referenced input
- ±0.3%linearity typical
- Ground referenced tachometer is fully protected from damage due to swings above V_{CC} and below ground
- Output swings to ground for zero frequency input
- Easy to use; $V_{out} = f_{IN} \times V_{CC} \times R1 \times C1$
- Only one RC network provides frequency doubling
- Zener regulator on chip allows accurate and stable frequency to voltage or current conversion



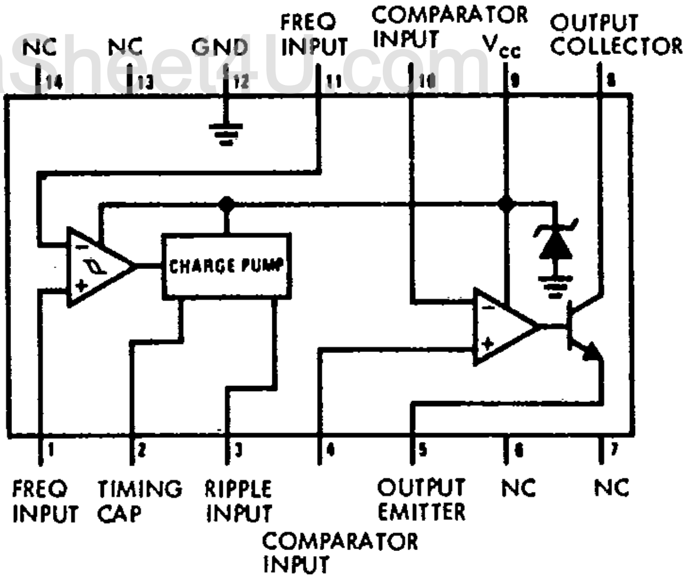
NOTE - PAINT BAND (ON SOME) DENOTES INDEX

The ECG995 is a monolithic frequency to voltage converter with a high gain op amp/comparator designed to operate a relay, lamp, or other load when the input frequency reaches or exceeds a selected rate. The tachometer uses a charge pump technique and its output swings to ground for a zero frequency input.

The op amp/comparator is fully compatible with the tachometer and has a floating transistor as its output. This feature allows either a ground or supply referred load of up to 50 mA. The collector may be taken above V_{CC} up to a maximum V_{CE} of 28 V.

This configuration provides differential tachometer input and uncommitted op amp inputs. With this version the tachometer input may be floated and the op amp becomes suitable for active filter conditioning of the tachometer output.

It is available with an active shunt regulator connected across the power leads. The regulator clamps the supply such that stable frequency to voltage and frequency to current operations are possible with any supply voltage and a suitable resistor.



Applications

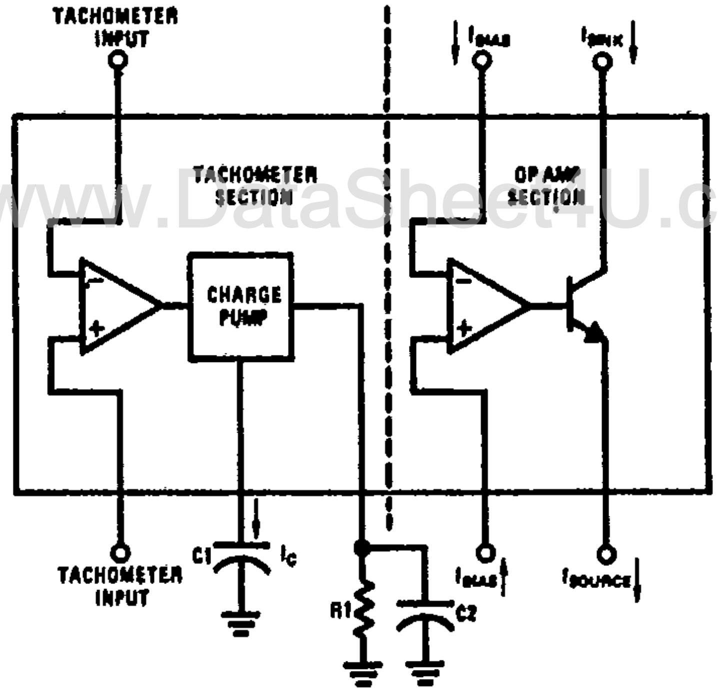
- Over/under speed sensing
- Frequency to voltage conversion (tachometer)
- Speedometers
- Breaker point dwell meters
- Hand-held tachometer
- Speed governors
- Cruise control
- Automotive door lock control
- Clutch control
- Horn control
- Touch or sound switches

Absolute Maximum Ratings (Note 1)

Supply Voltage	28 V
Supply Current	25 mA
Collector Voltage	28 V
Differential Input Voltage	
Tachometer	28 V
Op Amp/Comparator	28 V
Input Voltage Range	
Tachometer	0.0 V to +28 V
Op Amp/Comparator	0.0 V to +28 V
Power Dissipation	500 mW
Operating Temperature Range	−40 to +85°C
Storage Temperature Range	−65 to +150°C

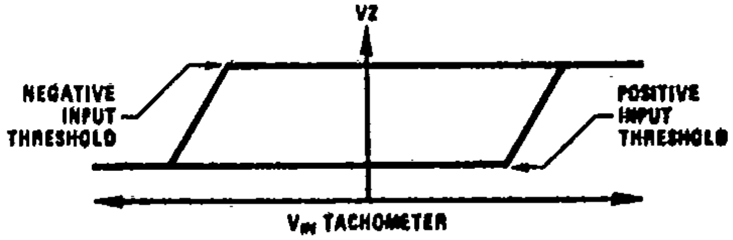
***Note 1:** For operation in ambient temperatures above 25°C, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 175°C/W junction to ambient.

Test Circuit



Waveform

Tachometer Input Threshold Measurement



Electrical Characteristics (V_{cc} = 12 V_{DC}, T_A = 25°C, see test circuit)

Parameter	Conditions	Min	Typ	Max	Unit
Tachometer					
Input Thresholds	V_{IN} = 250 $mV_{p\text{-}p}$ @ 1 kHz (Note 2)	±10	±15	±40	mV
Hysteresis	V_{IN} = 250 $mV_{p\text{-}p}$ @ 1 kHz (Note 2)		30		mV
Offset Voltage	V_{IN} = 250 $mV_{p\text{-}p}$ @ 1 kHz (Note 2)		3.5	10	mV
Input Bias Current	V_{IN} = ±50 mV_{DC}		0.1	1	μA
V_{OH}, Pin 2	V_{IN} = +125 mV_{DC} (Note 3)		8.3		V
V_{OL}, Pin 2	V_{IN} = −125 mV_{DC} (Note 3)		2.3		V
Output Current; I_2, I_3	V2 = V3 = 6.0 V (Note 4)	140	180	240	μA
Leakage Current; I_3	12 = 0, V3 = 0			0.1	μA
Gain Constant, K	(Note 3)	0.9	1.0	1.1	
Linearity	f_{IN} = 1 kHz, 5 kHz, 10 kHz (Note 5)	−1.0	0.3	+1.0	%
Op/Amp Comparator					
V_{OS}	V_{IN} = 6.0 V		3	10	mV
I_{BIAS}	V_{IN} = 6.0 V		50	500	nA
Input Common-Mode Voltage		0		V_{cc} −1.5V	V
Voltage Gain			200		V/mV
Output Sink Current	V_c = 1.0	40	50		mA
Output Source Current	V_E = V_{cc} − 2.0		10		mA
Saturation Voltage	I_{SINK} = 5 mA		0.1	0.5	V
	I_{SINK} = 20 mA			1.0	V
	I_{SINK} = 50 mA		1.0	1.5	V
Zener Regulation					
Regulator Voltage	R_{DROP} = 470 Ω		7.56		V
Series Resistance			10.5	15	Ω
Temperature Stability			+1		mV/°C
Total Supply Current			3.8	6	mA

Note 2: Hysteresis is the sume $+V_{TH} - (-V_{TH})$, offset voltage is their difference. See test circuit.

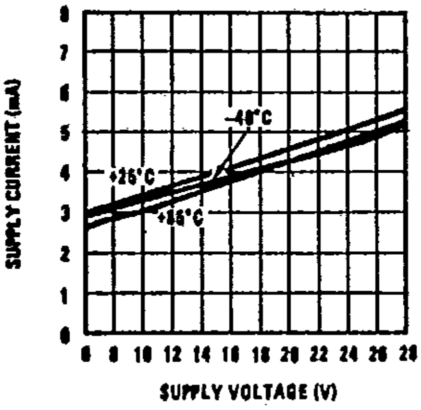
Note 3: V_{OH} is equal to 3/4 x V_{cc} − 1 V_{BE}, V_{OL} is equal to 1/4 x V_{cc} − 1 V_{BE} therefore $V_{OH} - V_{OL} = V_{cc}/2$. The difference, $V_{OH} - V_{OL}$, and the mirror gain, I_2/I_3, are the two factors that cause the tachometer gain constant to vary from 1.0.

Note 4: Be sure when choosing the time constant R1 x C1 that R1 is such that the maximum anticipated output voltage at pin 3 can be reached with I_3 x R1. The maximum value for R1 is limited by the output resistance of pin 3 which is greater than 10 MΩ typically.

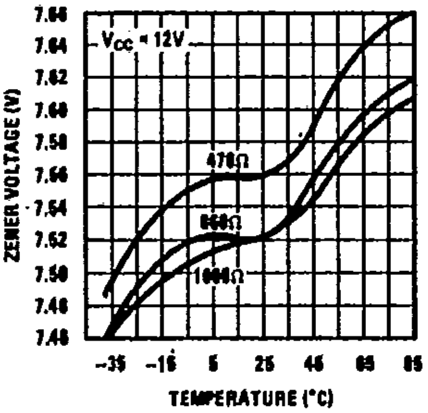
Note 5: Nonlinearity is defined as the deviation of V_{out} (@ pin 3) for f_{IN} = 5 kHz from a straight line defined by the V_{out} @ 1 kHz and V_{out} @ 10 kHz, C1 = 1000 pF, R1 = 68k and C2 = 0.22 mFd.

Typical Performance Characteristics

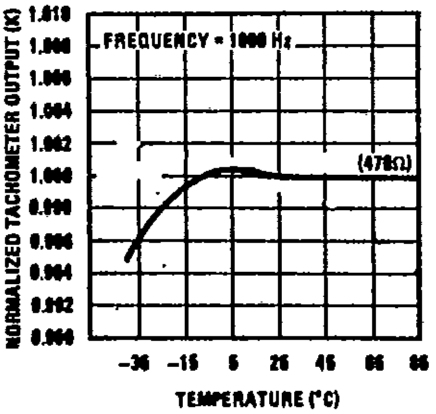
Total Supply Current



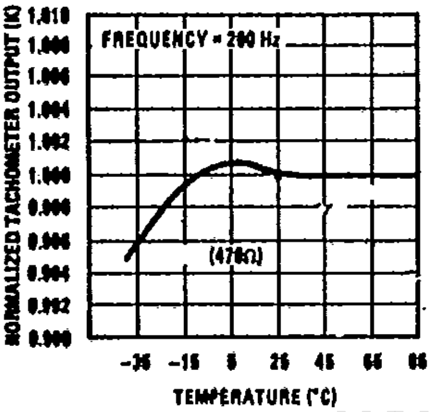
Zener Voltage vs Temperature



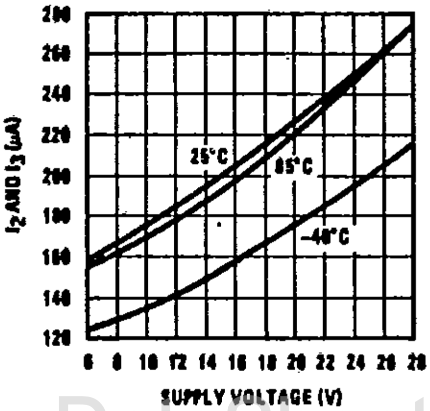
Normalized Tachometer Output vs Temperature



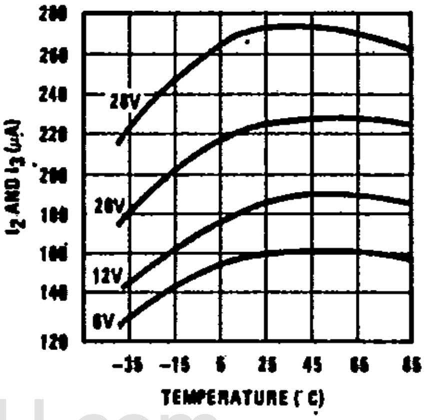
Normalized Tachometer Output vs Temperature



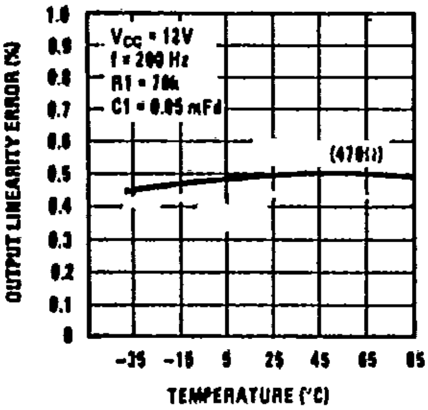
Tachometer Currents I_2 and I_3 vs Supply Voltage



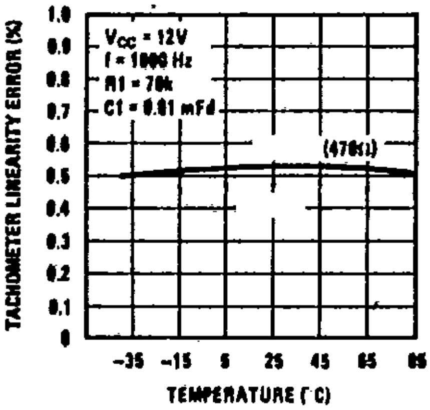
Tachometer Currents I_2 and I_3 vs Temperature



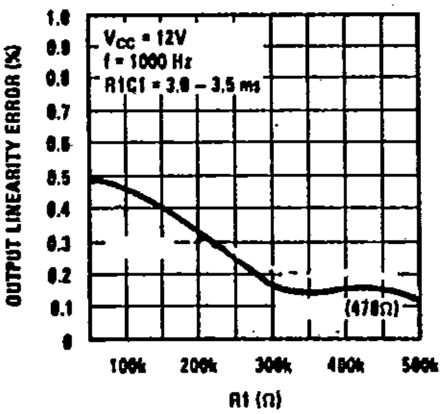
Tachometer Linearity vs Temperature



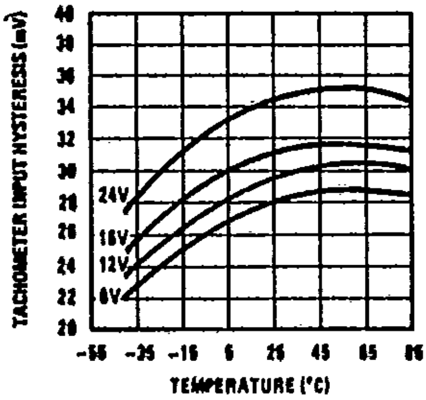
Tachometer Linearity vs Temperature



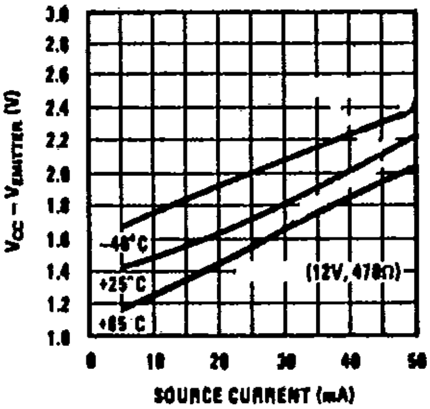
Tachometer Linearity vs R1



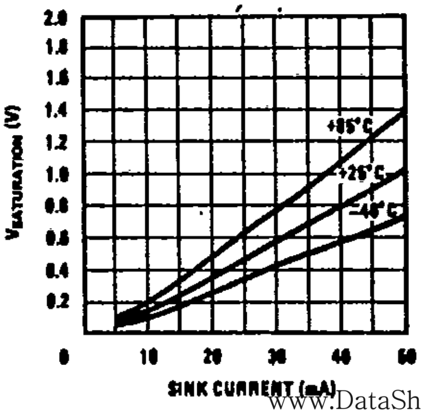
Tachometer Input Hysteresis vs Temperature



Op Amp Output Transistor Characteristics



Op Amp Output Transistor Characteristics



Applications Information

The ECG995 tachometer circuit is designed for minimum external part count applications and maximum versatility. In order to fully exploit its features and advantages let's examine its theory of operation. The first stage of operation is a differential amplifier driving a positive feedback flip-flop circuit. The input threshold voltage is the amount of differential input voltage at which the output of this stage changes state.

The differential input of ECG995 gives the user the option of setting his own input switching level and still have the hysteresis around that level for excellent noise rejection in any application. Of course in order to allow the inputs to attain common-mode voltages above ground, input protection is removed and neither input should be taken outside the limits of the supply voltage being used. It is very important that an input not go below ground without some resistance in its lead to limit the current that will then flow in the epi-substrate diode.

Following the input stage is the charge pump where the input frequency is converted to a dc voltage. To do this requires one timing capacitor, one output resistor, and an integrating or filter capacitor. When the input stage changes state (due to a suitable zero crossing or differential voltage on the input) the timing capacitor is either charged or discharged linearly between two voltages whose difference is $V_{CC}/2$. Then in one half cycle of the input frequency or a time equal to 1/2 f_{IN} the change in charge on the timing capacitor is equal to $V_{CC}/2 \times C1$. The average amount of current pumped into or out of the capacitor then is:

$$\frac{\Delta Q}{T} = I_{C(AVG)} = C1 \times \frac{V_{CC}}{2} \times (2f_{IN}) = V_{CC} \times f_{IN} \times C1$$

The output circuit mirrors this current very accurately into the load resistor R1, connected to ground, such that if the pulses of current are integrated with a filter capacitor, then $V_O = I_C \times R1$, and the total conversion equation becomes:

$$V_O = V_{CC} \times f_{IN} \times C1 \times R1 \times K$$

Where K is the gain constant—typically 1.0.

The size of C2 is dependent only on the amount of ripple voltage allowable and the required response time.

Crossing R1 and C1

There are some limitations on choosing R1 and C1 which should be considered for optimum performance. The timing capacitor also provides internal compensation for the charge pump and should be kept larger than 100 pF for very accurate operation. Smaller values can cause an error current on R1, especially at low temperatures. Several considerations must be met when choosing R1. The output current at pin 3 is internally fixed and therefore $V_O/R1$ must e less than or equal to this value. If R1 is too large, it can become a significant fraction of the output impedance at pin 3 which degrades linearity. Also output ripple voltage must be considered and the size of C2 is affected by R1. An expression that describes the ripple content on pin 3 for a single R1C2 combination is:

$$V_{RIPPLE} = \frac{V_{CC}}{2} \times \frac{C1}{C2} \times \quad 1 - \frac{V_{CC} \times f_{IN} \times C1}{I_2} \quad \text{pk}-\text{pk}$$

It appears R1 can be chosen independent of ripple, however response time, or the time it takes V_{OUT} to stabilize at a new voltage increases as the size of C2 increases so a compromise between ripple, response time, and linearity must be chosen carefully.

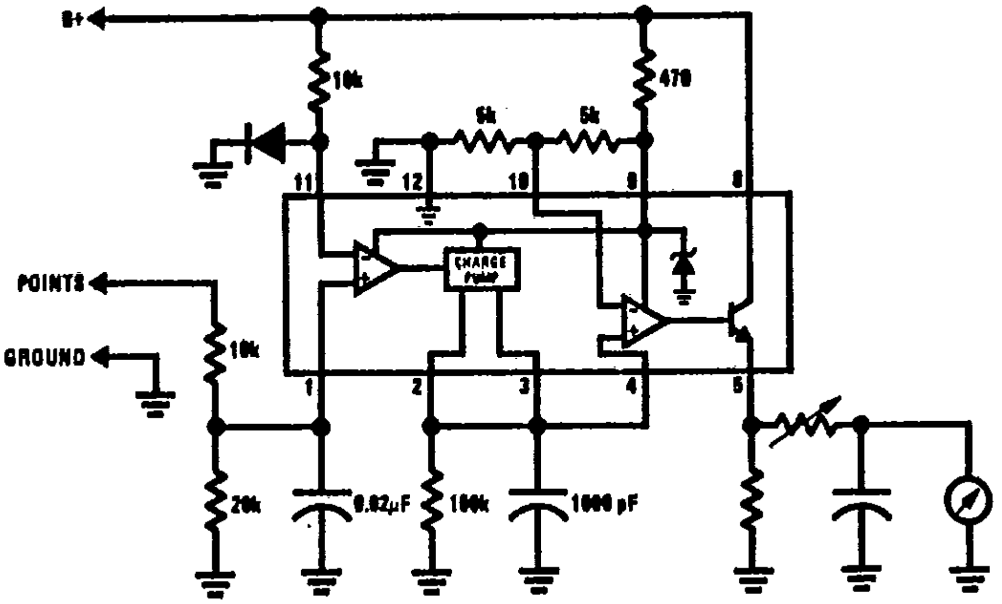
As a final consideration, the maximum attainable input frequency is determined by V_{CC}, C1 and I_2:

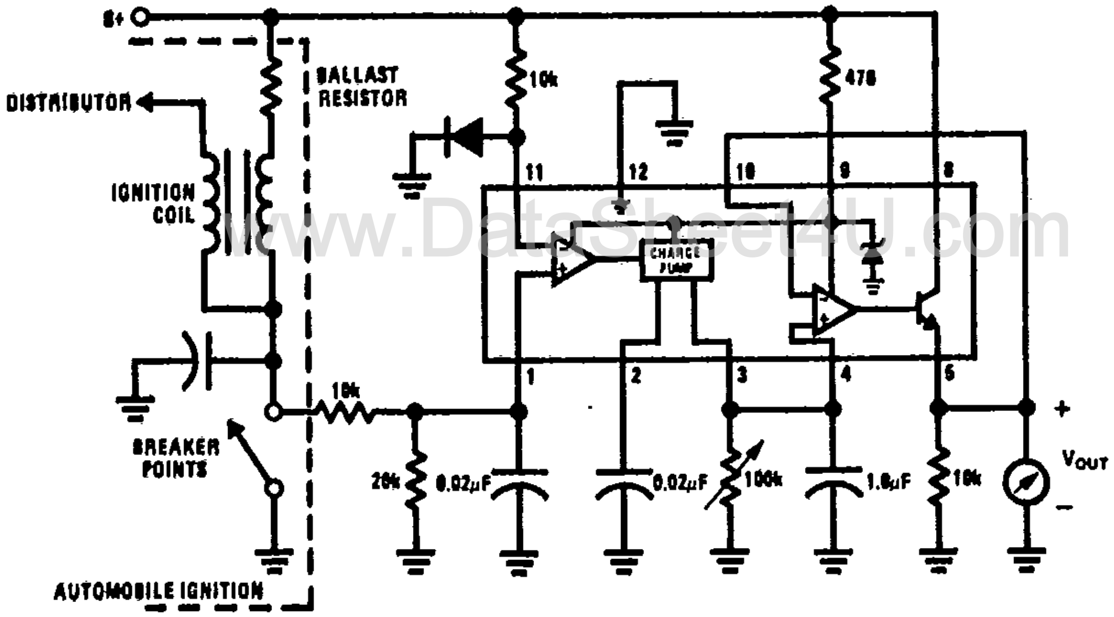
$$f_{MAX} = \frac{I_2}{C1 \times V_{CC}}$$

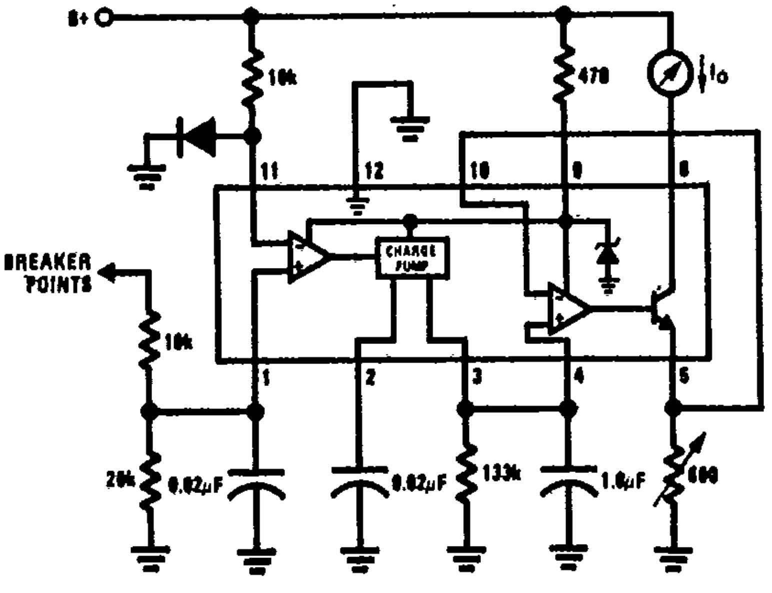
Using Zener Regulated Options

ECG995 is for applications where an output voltage or current must be obtained independent of supply voltage variations. The most important consideration in choosing a dropping resistor from the unregulated supply to the device is that the taachometer and op amp circuitry alone require about 3 mA at the voltage level provided by the zener. At low supply voltages there must be some current flowing in the resistor above the 3 mA circuit current to operate the regulator. As an example, it the raw supply varies from 9 to 16 V, a resistance of 470 Ω will minimize the zener voltage variation to 160 mV. If the resistance goes under 400 Ω or over 600 Ω the zener variation quickly rises above 200 mV for the same input variation.

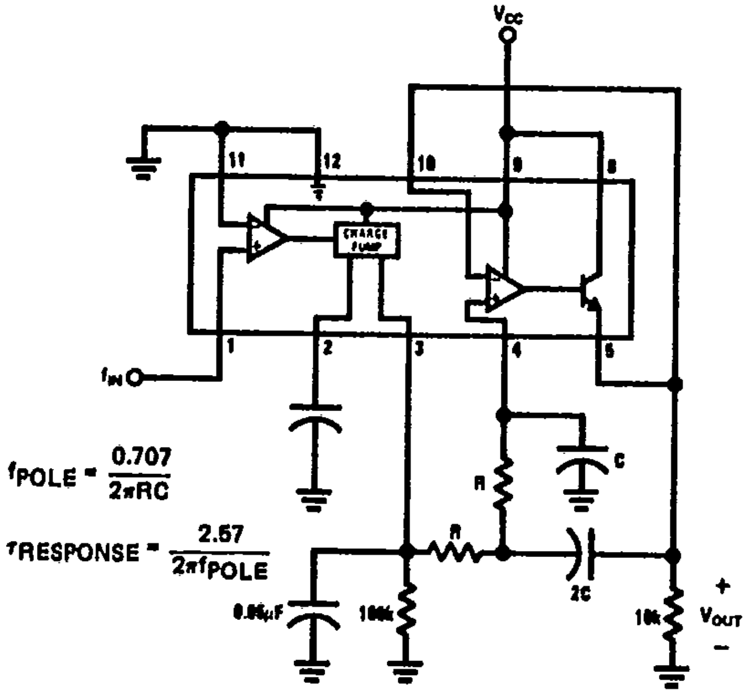
Typical Applications


Breaker Point Dwell Meter


Voltage Driven Meter Indicating Engine RPM
$V_O = 6$ V @ 400 Hz or 6000 ERPM (8 Cylinder Engine)


Curent Driven Meter Indicating Engine RPM
$I_O = 10$ mA @ 300 Hz or 6000 ERPM (6 Cylinder Engine)

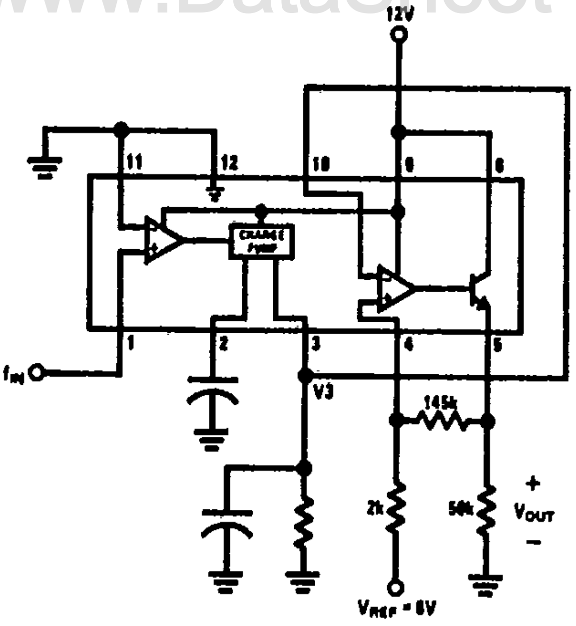
Frequency to Voltage Converter with 2 Pole Butterworth Filter to Reduce Ripple

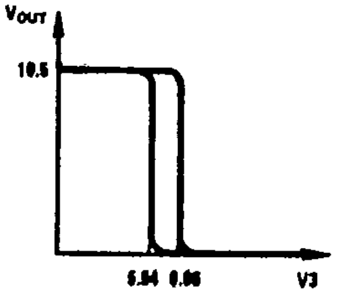


$$f_{POLE} = \frac{0.707}{2\pi RC}$$

$$\tau_{RESPONSE} = \frac{2.57}{2\pi f_{POLE}}$$

Hysteresis in the Comparator Function for Frequency Switch Applications





Schematic Diagram