Precision Air-Core Tach/Speedo Driver with Separate Function Generator Input

Description

The CS4101 is specifically designed for use with air-core meter movements. The IC provides all the functions necessary for an analog tachometer or speedometer. The CS4101 takes a speed sensor input and generates sine and cosine related output signals to differentially drive an air-core meter.

Many enhancements have been added over industry standard tachometer drivers such as the CS289 or LM1819. The output utilizes differential drivers which eliminates the need for a zener reference and offers more torque. The device withstands 60V transients which decreases the protection circuitry required. The device is also more precise than existing devices allowing for fewer trims and for use in a speedometer.

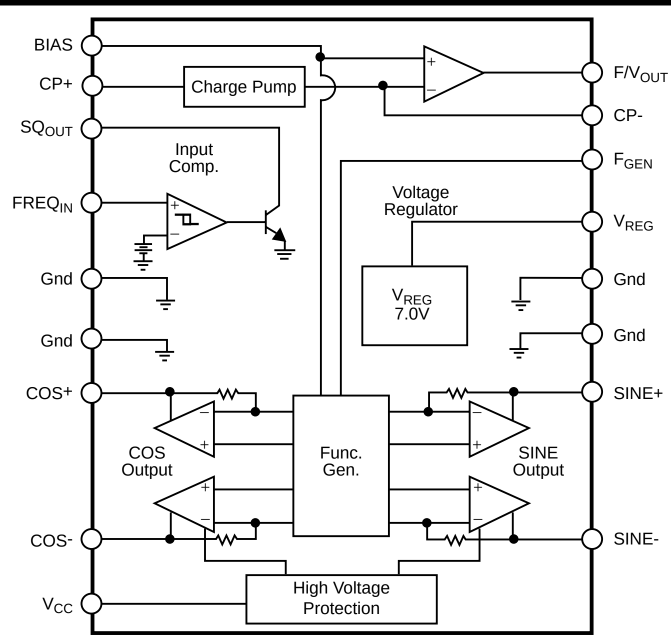
Features

- Direct Sensor Input
- High Output Torque
- Low Pointer Flutter
- High Input Impedance
- Overvoltage Protection

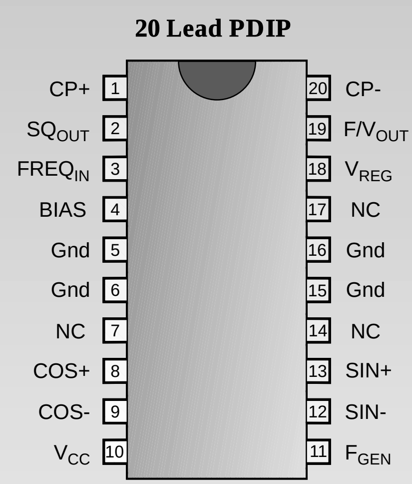
Absolute Maximum Ratings

Supply Voltage (<100ms pulse transient) .... V_{CC} = 60V
(continuous)... V_{CC} = 24V
Operating Temperature ....–40°C to +105°C
Storage Temperature...–40°C to +165°C
Junction Temperature ....–40°C to+150°C
ESD (Human Body Model) 4kV
Lead Temperature Soldering
Wave Solder(through hole styles only).............10 sec. max, 260°C peak

Block Diagram



Package Option



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Electrical Characteristics: -40°C ≤ T_A ≤ 85°C, 8.5V ≤ V_{CC} ≤ 15V unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ Supply Voltage Section					
I_{CC} Supply Current	V_{CC} = 16V, -40°C, No Load		50	125	mA
V_{CC} Normal Operation Range		8.5	13.1	16.0	V
■ Input Comparator Section					
Positive Input Threshold		2.4	3.4	4.4	V
Input Hysteresis		200	400		mV
Input Bias Current *	0V ≤ V_{IN} ≤ 8V		-10	-80	µA
Input Frequency Range		0		20	KHz
Input Voltage Range	in series with 1kΩ	-1		V_{CC}	V
Output V_{SAT}	I_{CC} = 10mA		0.15	0.40	V
Output Leakage	V_{CC} = 7V			10	µA
Low V_{CC} Disable Threshold		7.0	8.0	8.5	V
Logic 0 Input Voltage		2.4			V

*Note: Input is clamped by an internal 12V Zener.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ Voltage Regulator Section					
Output Voltage		6.25	7.00	7.50	V
Output Load Current				10	mA
Output Load Regulation	0 to 10 mA		10	50	mV
Output Line Regulation	8.5V ≤ V_{CC} ≤ 16V		20	150	mV
Power Supply Rejection	V_{CC} = 13.1V, 1Vp/p 1kHz	34	46		dB
■ Charge Pump Section					
Inverting Input Voltage		1.5	2.0	2.5	V
Input Bias Current			40	150	nA
V_{bias} Input Voltage		1.5	2.0	2.5	V
Non Invert. Input Voltage	I_{IN} = 1mA		0.7	1.1	V
Linearity*	@ 0, 87.5, 175, 262.5, + 350Hz	-0.10	0.28	+0.70	%
F/V_{OUT} Gain	@ 350Hz, C_T = 0.0033µF, R_T = 243kΩ	7	10	13	mV/Hz
Norton Gain, Positive	I_{IN} = 15µA	0.9	1.0	1.1	I/I
Norton Gain, Negative	I_{IN} = 15µA	0.9	1.0	1.1	I/I

*Note: Applies to % of full scale (270°).

■ Function Generator Section: -40° ≤ T_A ≤ 85°C, V_{CC} = 13.1V unless otherwise noted.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Differential Drive Voltage (V_{COS}+ - V_{COS}-)	8.5V ≤ V_{CC} ≤ 16V Θ = 0°	5.5	6.5	7.5	V
Differential Drive Voltage (V_{SIN}+ - V_{SIN}-)	8.5V ≤ V_{CC} ≤ 16V Θ = 90°	5.5	6.5	7.5	V
Differential Drive Voltage (V_{COS}+ - V_{COS}-)	8.5V ≤ V_{CC} ≤ 16V Θ = 180°	-7.5	-6.5	-5.5	V
Differential Drive Voltage (V_{SIN}+ - V_{SIN}-)	8.5V ≤ V_{CC} ≤ 16V Θ = 270°	-7.5	-6.5	-5.5	V
Differential Drive Current	8.5V ≤ V_{CC} ≤ 16V		33	42	mA
Zero Hertz Output Angle		-1.5	0.0	1.5	deg
Function Generator Error * Reference Figures 1,2,3,4	V_{CC} = 13.1V Θ = 0° to 305°	-2	0	+2	deg

* Note: Deviation from nominal per Table 1 after calibration at 0 and 270°.

Electrical Characteristics: -40°C ≤ T_A ≤ 85°C, 8.5V ≤ V_{CC} ≤ 15V unless otherwise specified.

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
■ Function Generator Section: continued					
Function Generator Error	13.1V ≤ V_{CC} ≤ 16V	-2.5	0	+2.5	deg
Function Generator Error	13.1V ≤ V_{CC} ≤ 11V	-1	0	+1	deg
Function Generator Error	13.1V ≤ V_{CC} ≤ 9V	-3	0	+3	deg
Function Generator Error	25°C ≤ T_A ≤ 80°C	-3	0	+3	deg
Function Generator Error	25°C ≤ T_A ≤ 105°C	-5.5	0	+5.5	deg
Function Generator Error	–40°C ≤ T_A ≤ 25°C	-3	0	+3	deg
Function Generator Gain	T_A = 25°C Θ vs F / V_{OUT}	60	77	95	° / V

Package Lead Description

PACKAGE LEAD #	LEAD SYMBOL	FUNCTION
20L		
1	CP+	Positive input to charge pump.
2	SQ_{OUT}	Buffered square wave output signal.
3	$FREQ_{IN}$	Speed or rpm input signal.
4	BIAS	Test point or Zero adjustment.
5, 6, 15, 16	Gnd	Ground Connections.
7, 14, 17	NC	No Connection.
8	COS+	Positive cosine output signal.
9	COS-	Negative cosine output signal.
10	V_{CC}	Ignition or battery supply voltage.
11	F_{GEN}	Function generator input signal.
12	SIN-	Negative sine output signal.
13	SIN+	Positive sine output signal.
18	V_{REG}	Voltage regulator output.
19	F / V_{OUT}	Output voltage proportional to input signal frequency.
20	CP-	Negative input to charge pump.

Typical Performance Characteristics

Figure 1: Function Generator Output Voltage vs Degrees of Deflection

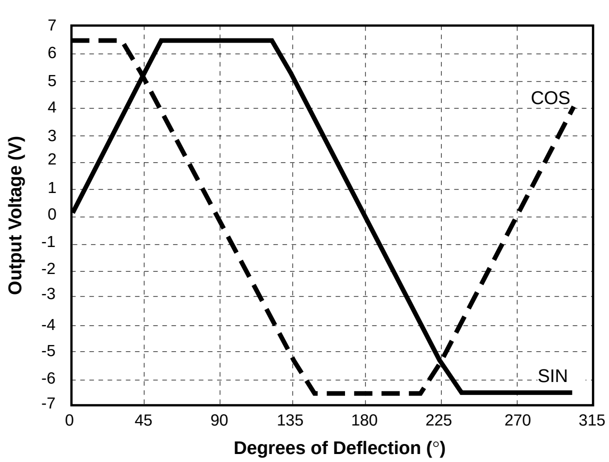
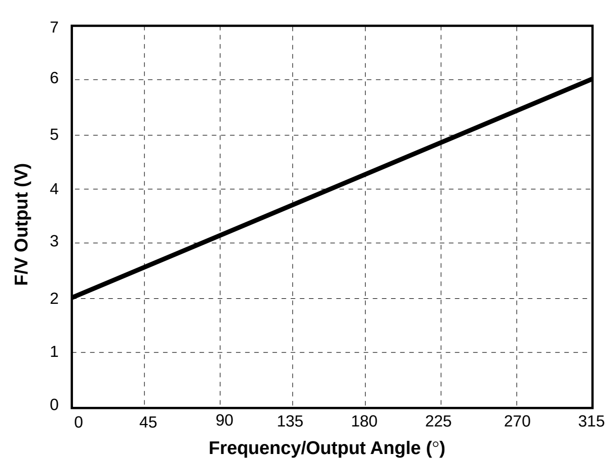


Figure 2: Charge Pump Output Voltage vs Output Angle

F / V_{OUT} = 2.0V + 2 FREQ × C_T × R_T × (V_{REG} - 0.7)



Typical Performance Characteristics continued

Figure 3: Output Angle in Polar Form

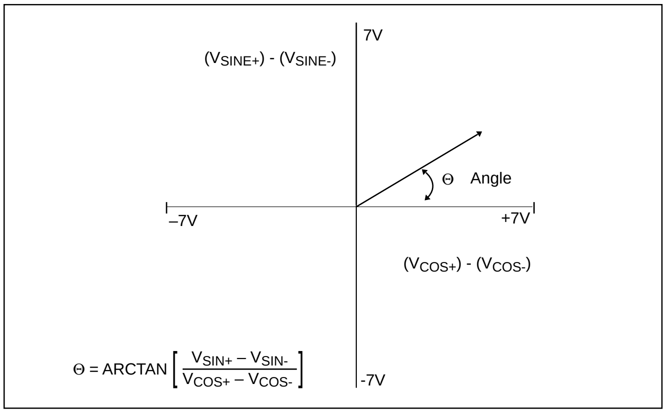
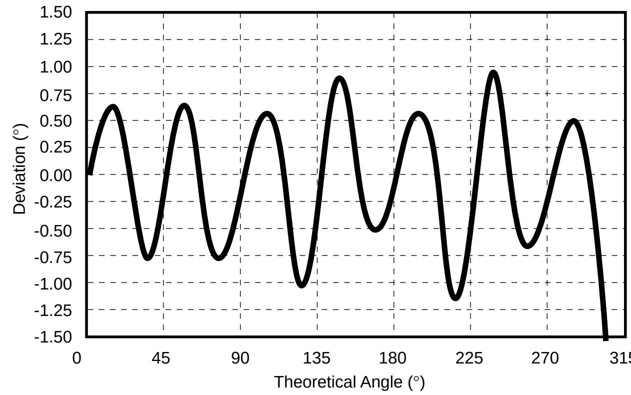


Figure 4: Nominal Output Deviation



Nominal Angle vs. Ideal Angle (After calibrating at 180°)

Note: Temperature, voltage and nonlinearity not included.

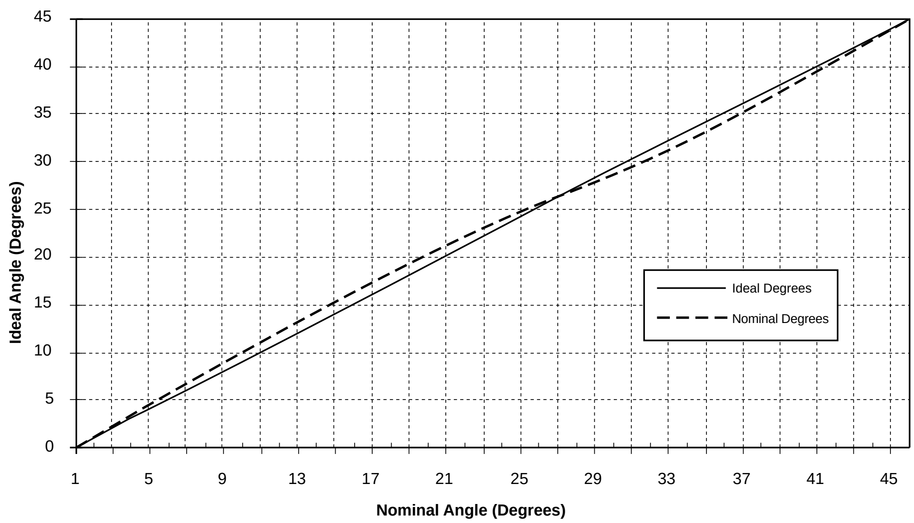


Table 1: Function Generator Output Nominal Angle vs. Ideal Angle (After calibrating at 270°)

Ideal Θ Degrees	Nominal Θ Degrees	Ideal Θ Degrees	Nominal Θ Degrees	Ideal Θ Degrees	Nominal Θ Degrees	Ideal Θ Degrees	Nominal Θ Degrees	Ideal Θ Degrees	Nominal Θ Degrees	Ideal Θ Degrees	Nominal Θ Degrees
0	0	17	17.98	34	33.04	75	74.00	160	159.14	245	244.63
1	1.09	18	18.96	35	34.00	80	79.16	165	164.00	250	249.14
2	2.19	19	19.92	36	35.00	85	84.53	170	169.16	255	254.00
3	3.29	20	20.86	37	36.04	90	90.00	175	174.33	260	259.16
4	4.38	21	21.79	38	37.11	95	95.47	180	180.00	265	264.53
5	5.47	22	22.71	39	38.21	100	100.84	185	185.47	270	270.00
6	6.56	23	23.61	40	39.32	105	106.00	190	190.84	275	275.47
7	7.64	24	24.50	41	40.45	110	110.86	195	196.00	280	280.84
8	8.72	25	25.37	42	41.59	115	115.37	200	200.86	285	286.00
9	9.78	26	26.23	43	42.73	120	119.56	205	205.37	290	290.86
10	10.84	27	27.07	44	43.88	125	124.00	210	209.56	295	295.37
11	11.90	28	27.79	45	45.00	130	129.32	215	214.00	300	299.21
12	12.94	29	28.73	50	50.68	135	135.00	220	219.32	305	303.02
13	13.97	30	29.56	55	56.00	140	140.68	225	225.00		
14	14.99	31	30.39	60	60.44	145	146.00	230	230.58		
15	16.00	32	31.24	65	64.63	150	150.44	235	236.00		
16	17.00	33	32.12	70	69.14	155	154.63	240	240.44		

Note: Temperature, voltage and nonlinearity not included.

The CS4101 is specifically designed for use with air-core meter movements. It includes an input comparator for sensing an input signal from an ignition pulse or speed sensor, a charge pump for frequency to voltage conversion, a bandgap voltage regulator for stable operation, and a function generator with sine and cosine amplifiers to differentially drive the motor coils.

From the simplified block diagram of Figure 5A, the input signal is applied to the $FREQ_{IN}$ lead, this is the input to a high impedance comparator with a typical positive input threshold of 3.4V and typical hysteresis of 0.4V. The output of the comparator, SQ_{OUT}, is applied to the charge pump input CP+ through an external capacitor C_T. When the input signal changes state, C_T is charged or discharged through R3 and R4. The charge accumulated on C_T is mirrored to C_4 by the Norton Amplifier circuit comprising Q1, Q2 and Q3. The charge pump output voltage, F/V_{OUT}, ranges from 2V to 6.3V depending on the input signal frequency and the gain of the charge pump according to the formula:

$$F/V_{OUT} = 2.0V + 2 \times FREQ \times C_T \times R_T \times (V_{REG} - 0.7V)$$

R_T is a potentiometer used to adjust the gain of the F/V output stage and give the correct meter deflection. The F/V output voltage is applied to the function generator input lead, F_{GEN}. An additional filter circuit can be added between F/V_{OUT} and F_{GEN} to reduce needle flutter. The output voltage of the sine and cosine amplifiers are derived from the on-chip amplifier and function generator circuitry. The various trip points for the circuit (i.e., 0°, 90°, 180°, 270°) are determined by an internal resistor divider, and the bandgap voltage reference. The coils are differentially driven, allowing bidirectional current flow in the outputs, thus providing up to 305° range of meter deflection. Driving the coils differentially offers faster response time, higher current capability, higher output voltage swings, and reduced external component count. The key advantage is a higher torque output for the pointer.

The output angle, Θ, is equal to the F/V gain multiplied by the function generator gain:

$$\Theta = A_{F/V} \times A_{FG},$$

where:

$$A_{FG} = 77°/V \text{ (typ)}$$

The relationship between input frequency and output angle is:

$$\Theta = A_{FG} \times 2 \times FREQ \times C_T \times R_T \times (V_{REG} - 0.7V)$$

or, $$\Theta = 970 \times FREQ \times C_T \times R_T$$

The ripple voltage at the F/V converter's output is determined by the ratio of C_T and C4 in the formula:

$$\Delta V = \frac{C_T(V_{REG} - 0.7V)}{C4}$$

Ripple voltage on the F/V output causes pointer or needle flutter especially at low input frequencies.

The response time of the F/V is determined by the time constant formed by R_T and C4. Increasing the value of C4 will reduce the ripple on the F/V output but will also increase the response time. An increase in response time causes a very slow meter movement and may be unacceptable for many applications.

Design Example

Maximum meter Deflection = 270°

Maximum Input Frequency = 350Hz

1. Select R_T and C_T

$$\Theta = A_{GEN} \times \Delta_{F/V}$$

$$\Delta_{F/V} = 2 \times FREQ \times C_T \times R_T \times (V_{REG} - 0.7V)$$

$$\Theta = 970 \times FREQ \times C_T \times R_T$$

Let C_T = 0.0033µF, Find R_T

$$R_T = \frac{270°}{970 \times 350Hz \times 0.0033\mu F}$$

$$R_T = 243k\Omega$$

R_T should be a 250kΩ potentiometer to trim out any inaccuracies due to IC tolerances or meter movement pointer placement.

2. Select R3 and R4

Resistor R3 sets the output current from the voltage regulator. The maximum output current from the voltage regulator is 10mA R_3 must ensure that the current does not exceed this limit.

Choose R3 = 3.3kΩ

The charge current for C_T is:

$$\frac{V_{REG} - 0.7V}{3.3k\Omega} = 1.90mA$$

C_1 must charge and discharge fully during each cycle of the input signal. Time for one cycle at maximum frequency is 2.85ms. To ensure that C_T is discharged, assume that the (R3 + R4) C_T time constant is less than 10% of the minimum input frequency pulse width.

$$T = 285\mu s$$

Choose R4 = 1kΩ.

Charge time: $T = R3 \times C_T = 3.3k\Omega \times 0.0033\mu F = 10.9\mu s$

Discharge time: $T = (R3 + R4)C_T = 4.3k\Omega \times 0.0033\mu F = 14.2\mu s$

3. Determine C4

C4 is selected to satisfy both the maximum allowable ripple voltage and response time of the meter movement.

$$C4 = \frac{C_T(V_{REG} - 0.7V)}{V_{RIPPLE(MAX)}}$$

With C4 = 0.47µF, the F/V ripple voltage is 44mV.

Figure 7 shows how the CS4101 and the CS-8441 are used to produce a speedometer and odometer circuit.

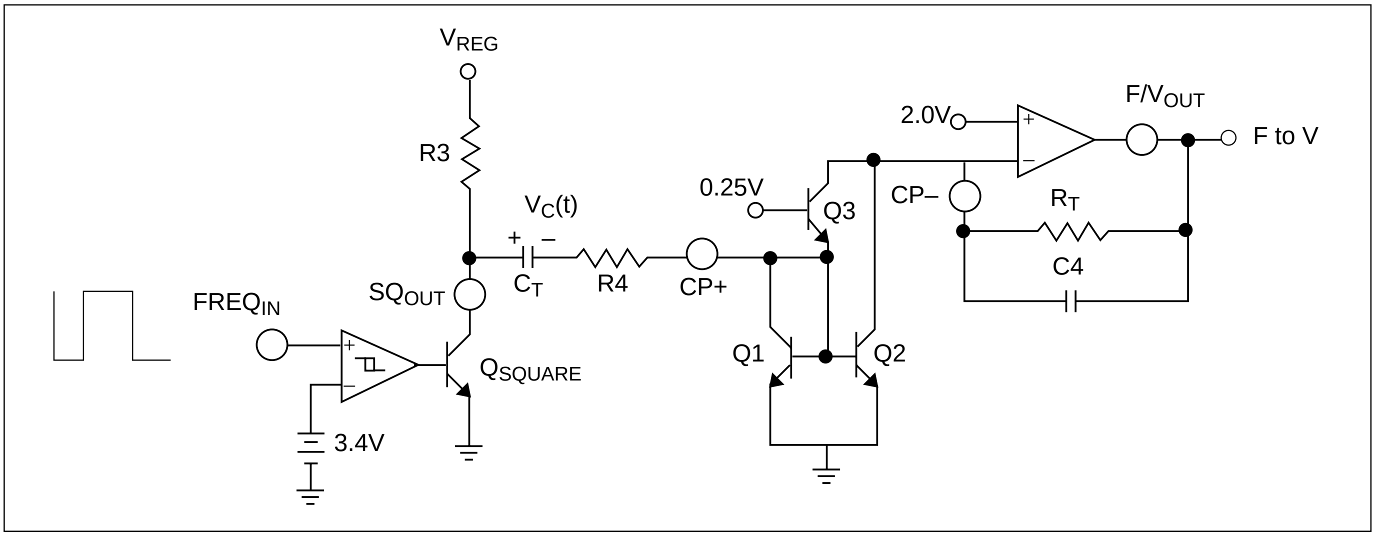


Figure 5A: Partial Schematic of Input and Charge Pump

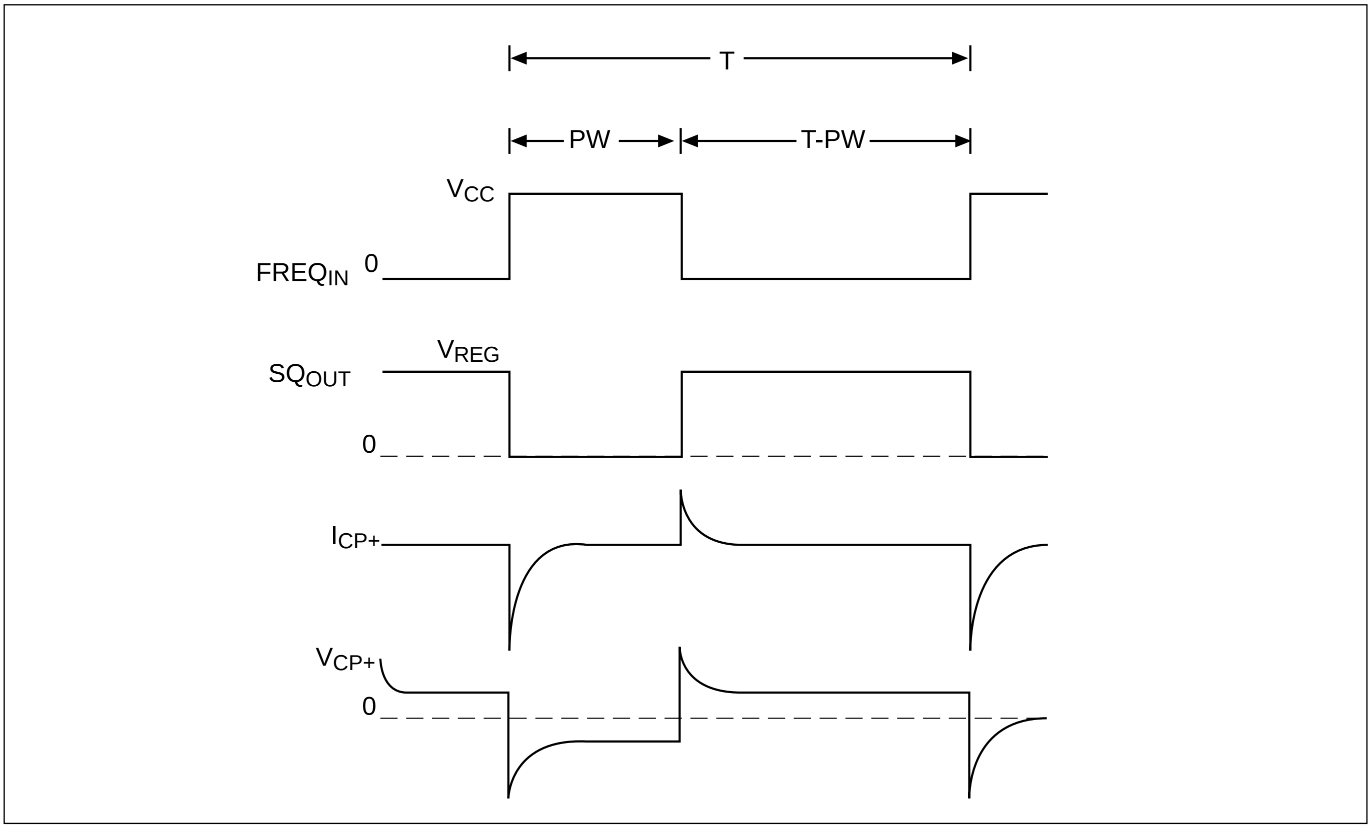


Figure 5B: Timing Diagram of $FREQ_{IN}$ and I_{CP}

Speedometer/Odometer or Tachometer Application

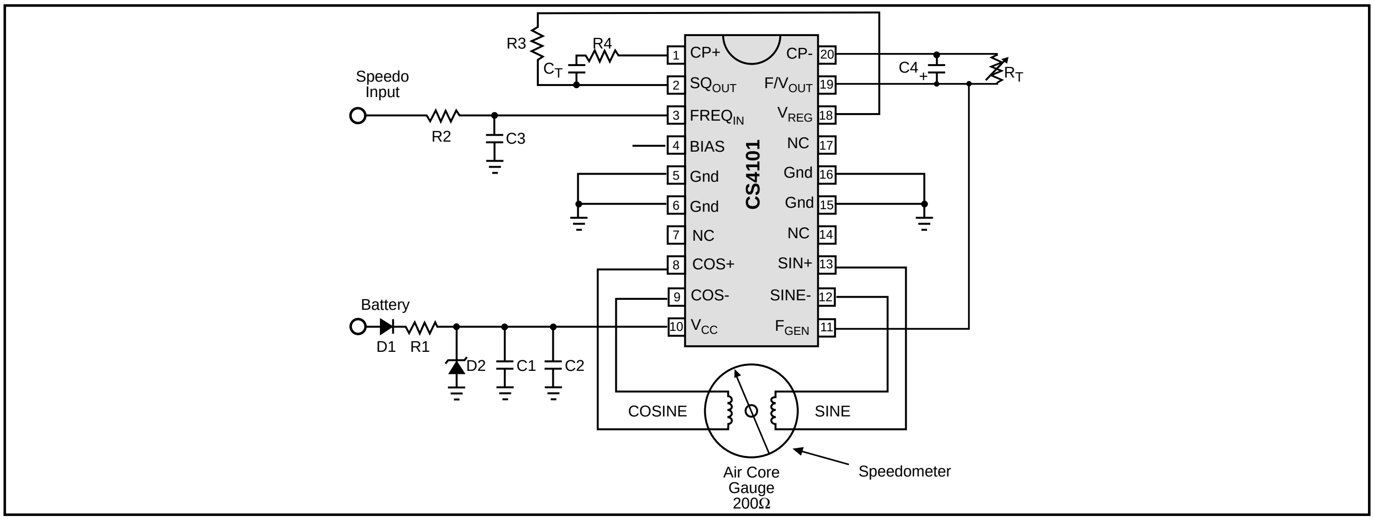


Figure 6

R1 - 3.9, 500mW
R2 - 10kΩ
R3 - 3kΩ
R4 - 1kΩ
R_T - Trim Resistor + / - 20 PPM / DEG. C
C1 - 0.1µF
C2 - 1. Stand alone Speedo or Tach "0" µF
2. Stand alone Speedo or Tach with return to Zero, 2000µF
3. With CS-8441 application, 10µF
C3 - 0.1µF

C4 - 0.47µF
C_T - 0.0033µF, + / - 30 PPM / °C
D1 - 1A, 600 PIV
D2 - 50V, 500mW Zener
Note 1: For 58% Speed Input $T_{MAX} \leq 5 / f_{MAX}$ where
$T_{MAX} = C_T(R3+R4)$
f_{MAX} = maximum speed input frequency

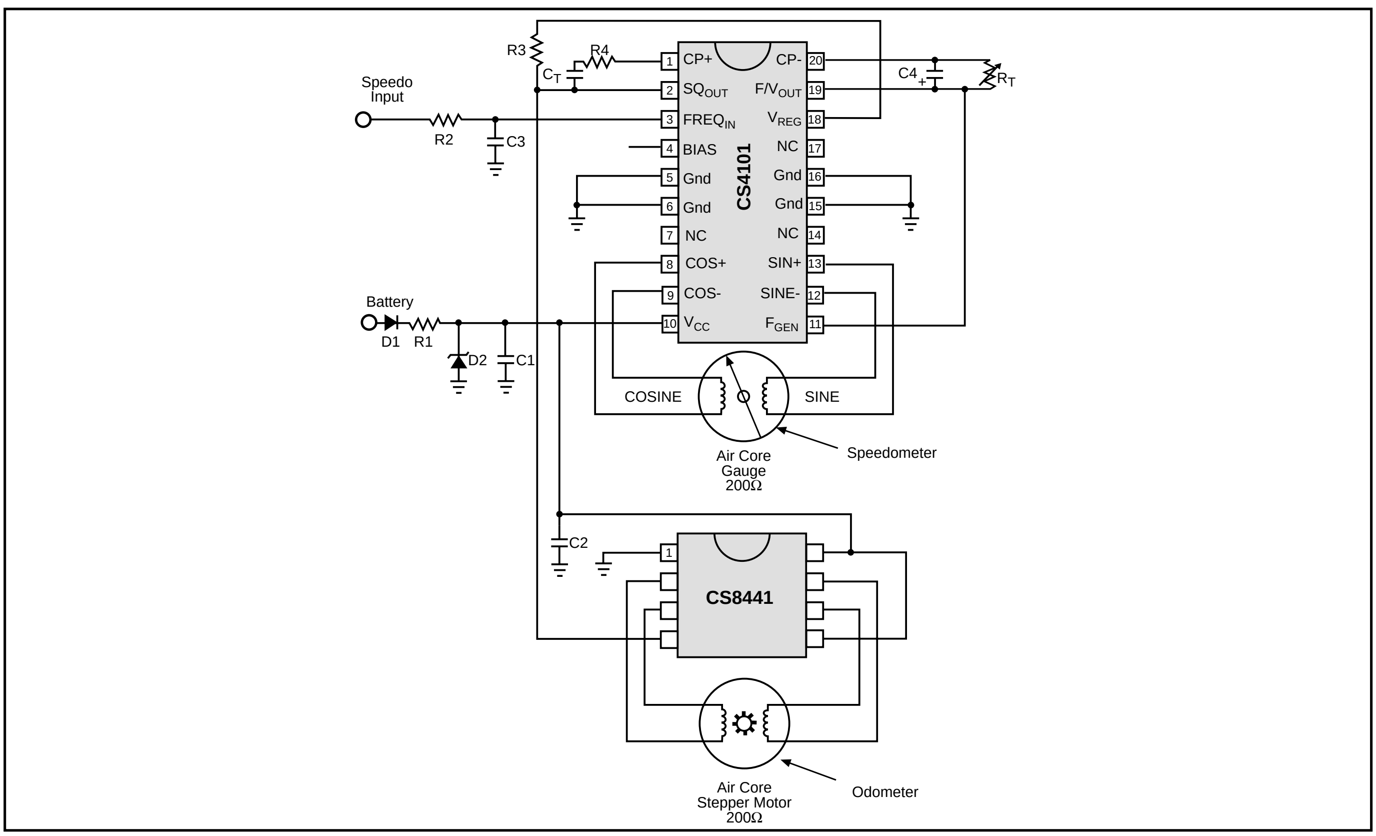


Figure 7

Note 1: The product of C_T and R_T have a direct effect on gain and therefore directly effect temperature compensation
Note 2: C4 Range; 20pF to .2µF
Note 3: R4 Range; 100kΩ to 500kΩ
Note 4: The IC must be protected from transients above 60V and reverse battery conditions
Note 5: Additional filtering on the $FREQ_{IN}$ lead may be required

Package Specification

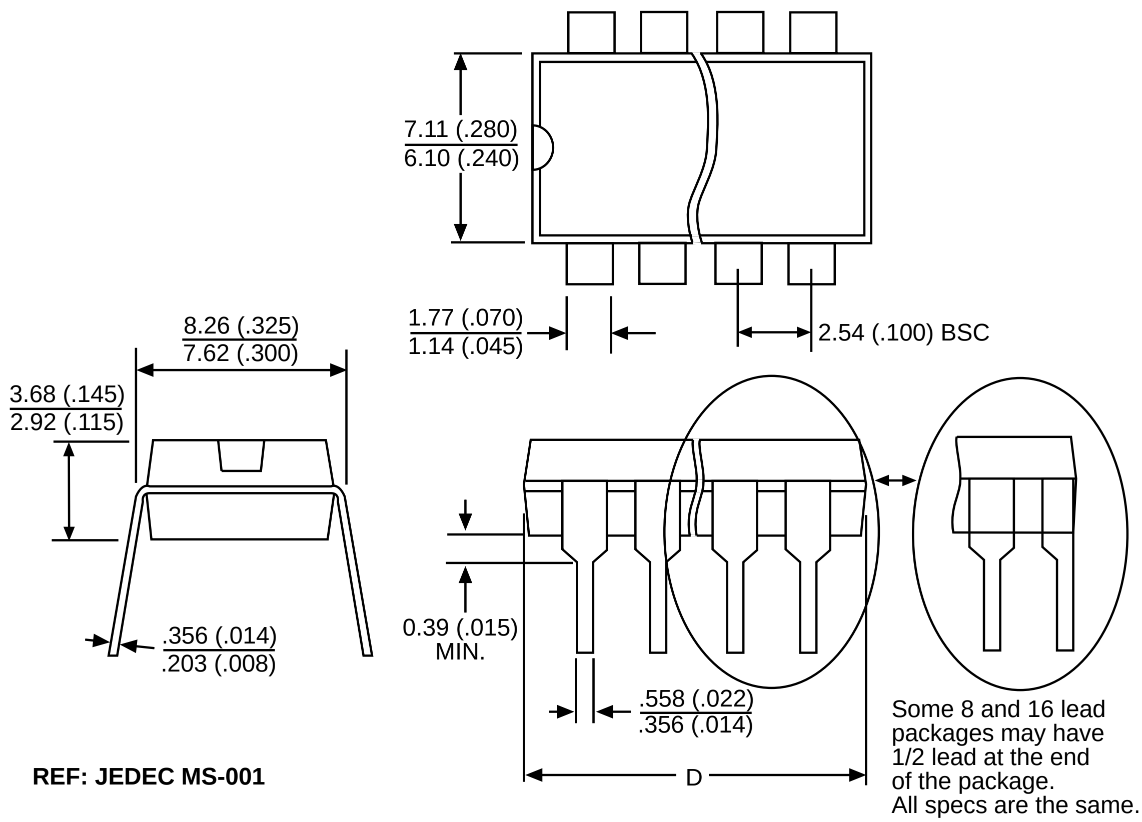
PACKAGE DIMENSIONS IN mm (INCHES)

Lead Count	D			
	Metric		English	
	Max	Min	Max	Min
20 Lead PDIP	26.92	24.89	1.060	.980

PACKAGE THERMAL DATA

Thermal Data		20L PDIP	
$R_{\Theta JC}$	typ	25	°C / W
$R_{\Theta JA}$	typ	65	°C / W

Plastic DIP (N); 300 mil wide



Ordering Information

Part Number	Description
CS4101EN20	20L PDIP

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