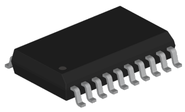
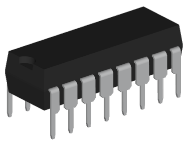
Precision Air-Core Tach/Speedo Driver with Return to Zero CS8190

FEATURES

- Direct Sensor Input
- High Output Torque
- Low Pointer Flutter
- High Input Impedance
- Over Voltage Protection
- Return to Zero



SOP-20



DIP-16

DESCRIPTION

The CS8190 is specially designed for use with air-core meter movements. The IC provides all the functions necessary for an analog tachometer or speedometer. The CS8190 takes a speed sensor input and generates sine and cosine related output signals to differentially drive an air-core meter.

The output utilizes differential drivers which eliminated the need for a Zener reference and offers more torque. The device withstands 60V transients which decreases the protection circuitry required.

ORDERING INFORMATION

Device	Package
CS8190D	SOP-20
CS8190N	DIP-16

ABSOLUTE MAXIMUM RATINGS (Note 1)

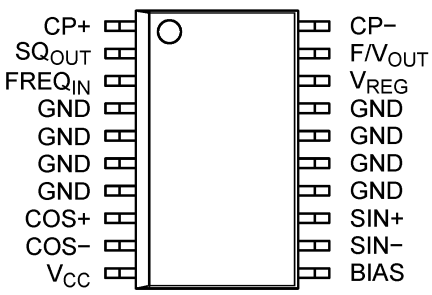
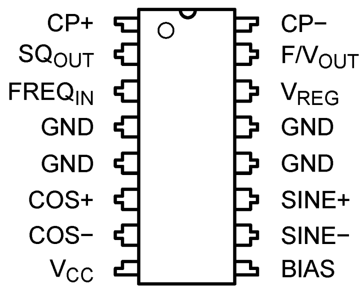
CHARACTERISTIC	SYMBOL	MIN	MAX	UNIT
Maximum Supply Voltage (< 100ms Pulse Transient)	V_{CC}	-	60	V
Maximum Supply Voltage (Continuous)	V_{CC}	-	24	V
ESD Rating, HBM	-	4	-	kV
Operating Ambient Temperature	T_A	−40	105	°C
Junction Temperature	T_J	−40	150	°C
Storage Temperature	T_{STG}	−60	165	°C

Note 1. Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

ORDERING INFORMATION

Package	Order No.	Description	Supplied As	Status
SOP-20	CS8190D	Air-Core Tach/Speedo Driver	Tape & Reel	Active
DIP-16	CS8190N	Air-Core Tach/Speedo Driver	Tube	Contact us

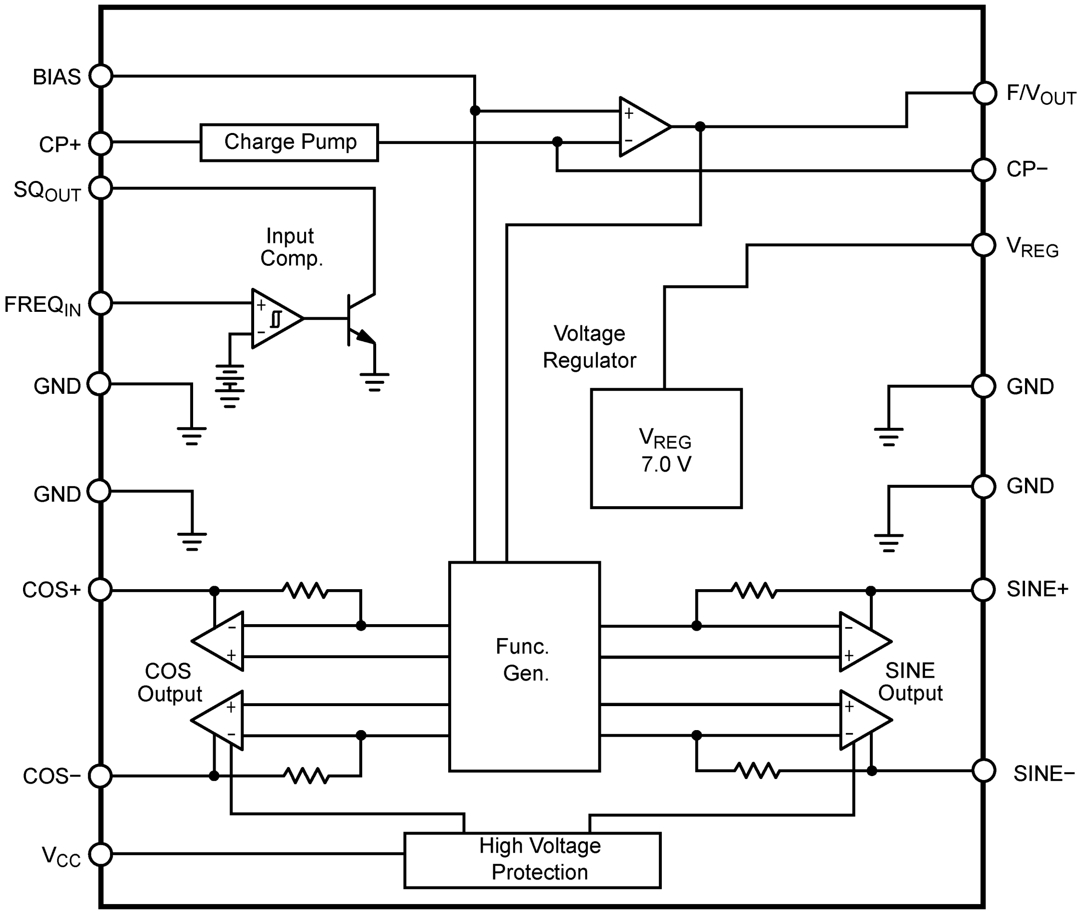
PIN CONFIGURATION

SOP-20	DIP-16
	

PIN DESCRIPTION

Pin No.		Pin Name	Pin Function
SOP-20	DIP-16		
1	1	CP+	Positive Input to Charge Pump
2	2	SQ_{OUT}	Buffered Square Wave Output Signal
3	3	$FREQ_{IN}$	Speed or RPM Input Signal
4-7, 14-17	4, 5, 12, 13	GND	Ground
8	6	COS+	Positive Cosine Output Signal
9	7	COS−	Negative Cosine Output
10	8	VCC	Ignition or Battery Supply Voltage
11	9	BIAS	Test Point or Zero Adjustment
12	10	SIN−	Negative Sine Output Signal
13	11	SIN+	Positive Sine Output Signal
18	14	VREG	Voltage Regulator Output
19	15	F/V_{OUT}	Output Voltage Proportional to Input Signal Frequency
20	16	CP−	Negative Input to Charge Pump

BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

$-40°C \le T_A \le 85°C$, $8.5V \le V_{CC} \le 16V$, unless otherwise noted.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
SUPPLY VOLTAGE SECTION						
Supply Current	I_{CC}	V_{CC} = 16V, −40°C, No Load	-	66	125	mA
Normal Operation Range	V_{CC}		8.5	13.1	16	V
INPUT COMPARATOR SECTION						
Positive Input Threshold	V_{TH}		1.0	2.1	3.0	V
Input Hysteresis	V_{HYS}		200	470	-	mV
Input Bias Current (Note 3)	I_{IB1}	$0V \le V_{IN} \le 8.0V$	-	±4	±80	µA
Input Frequency Range	F_{IN}		0	-	20	kHz
Input Voltage Range	V_{IN}	In series with 1.0kΩ	−1.0	-	V_{CC}	V
Output Saturation Voltage	V_{SAT}	I_O = 10mA	-	0.1	0.4	V
Output Leakage Current	IL	V_O = 7.0V	-	0.02	10	µA
Low V_{CC} Disable Threshold	V_{CC_TH}		7.0	8.0	8.5	V
Logic Zero Input Voltage	V_{IL}		1.0	1.6	-	V
VOLTAGE REGULATOR SECTION						
Output Voltage	V_{REF}		6.25	7.00	7.50	V
Output Load Current	I_O		-	-	10	mA
Output Load Regulation	LDR	0 to 10mA	-	4.0	50	mV
Output Line Regulation	LNR	$8.5V \le V_{CC} \le 16V$	-	30	150	mV
Power Supply Rejection	PSRR	V_{CC} = 13.1V, 1.0V_{PP} , 1.0kHz	34	46	-	dB
CHARGE PUMP SECTION						
Inverting Input Voltage	V_{IN_INV}		1.5	2.1	2.5	V
Input Bias Current	I_{IB2}		-	35	150	nA
VBIAS Input Voltage	V_{BIAS}		1.5	2.1	2.5	V
Non Inverting Input Voltage	V_{IN_NINV}	I_{IN} = 1.0mA	-	0.6	1.1	V
Linearity (Note 4)	L_K	@ 0, 87.5, 175, 262.5, 350Hz	−0.10	0.28	0.70	%
F/V_{OUT} Gain	K	@ 350Hz, C_{CP} = 0.0033µF, R_T = 243kΩ	7.0	10.5	13	mV/Hz
Norton Gain, Positive	G_{INP}	I_{IN} = 15µA	0.9	1.0	1.1	I/I
Norton Gain, Negative	G_{INN}	I_{IN} = 15µA	0.9	1.0	1.1	I/I

Note 3. Input is clamped by and internal 12V Zener.
Note 4. Applies to % of full scale (270°).

ELECTRICAL CHARACTERISTICS (continued)

$-40°C \le T_A \le 85°C$, $V_{CC} = 13.1V$, unless otherwise noted.

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
FUNCTION GENERATOR SECTION						
Return to Zero Threshold	V_{CC_TH}	$T_A = 25°C$	5.2	6.0	7.0	V
Differential Drive Voltage ($V_{COS+} - V_{COS-}$)		$8.5V \le V_{CC} \le 16V$, $\theta = 0°$	5.5	6.5	7.5	V
Differential Drive Voltage ($V_{SIN+} - V_{SIN-}$)		$8.5V \le V_{CC} \le 16V$, $\theta = 90°$	5.5	6.5	7.5	V
Differential Drive Voltage ($V_{COS+} - V_{COS-}$)		$8.5V \le V_{CC} \le 16V$, $\theta = 180°$	−7.5	−6.5	−5.5	V
Differential Drive Voltage ($V_{SIN+} - V_{SIN-}$)		$8.5V \le V_{CC} \le 16V$, $\theta = 270°$	−7.5	−6.5	−5.5	V
Differential Drive Current	I_{OUT}	$8.5V \le V_{CC} \le 16V$	-	33	42	mA
Zero Hertz Output Angle	θ		−1.5	0	1.5	deg
Function Generator Error (Note 5)		$V_{CC} = 13.1V$, $\theta = 0°$ to $305°$	−2.0	0	2.0	deg
Function Generator Error		$13.1V \le V_{CC} \le 16V$	−2.5	0	2.5	deg
Function Generator Error		$13.1V \le V_{CC} \le 11V$	−1.0	0	1.0	deg
Function Generator Error		$13.1V \le V_{CC} \le 9.0V$	−3.0	0	3.0	deg
Function Generator Error		$25°C \le T_A \le 80°C$	−3.0	0	3.0	deg
Function Generator Error		$25°C \le T_A \le 105°C$	−5.5	0	5.5	deg
Function Generator Error		$-40°C \le T_A \le 25°C$	−3.0	0	3.0	deg
Function Generator Gain		$T_A = 25°C$, θ vs F/V_{OUT}	60	77	95	°/V

Note 5. Deviation from nominal per Table 1 after calibration at 0° and 270°. Reference Figures 1, 2, 3, 4.

TYPICAL OPERATING CHARACTERISTICS

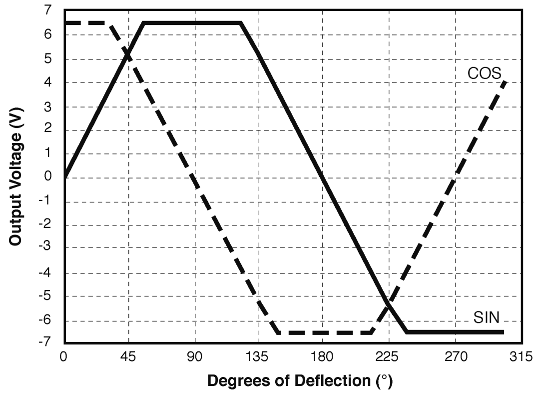


Figure 1. Function Generator Output Voltage vs. Degrees of Deflection

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

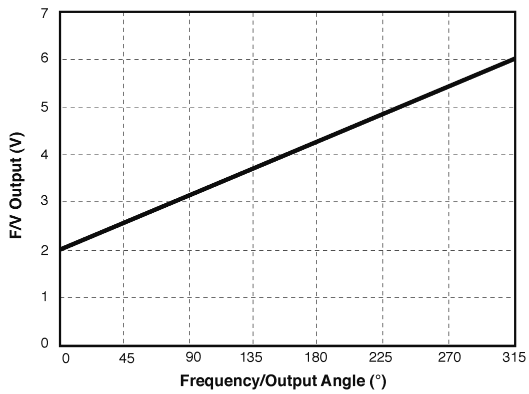


Figure 2. Charge Pump Output Voltage vs. Output Angle

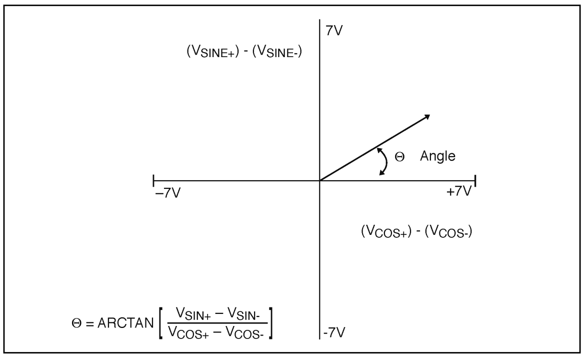


Figure 3. Output Angle in Polar Form

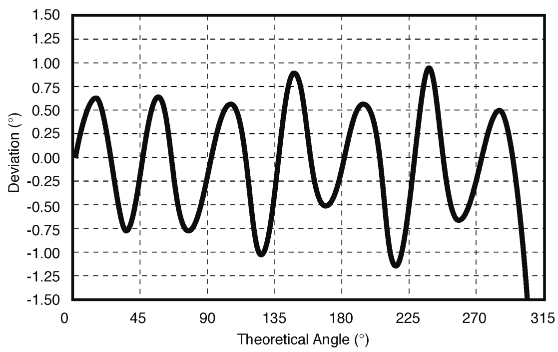
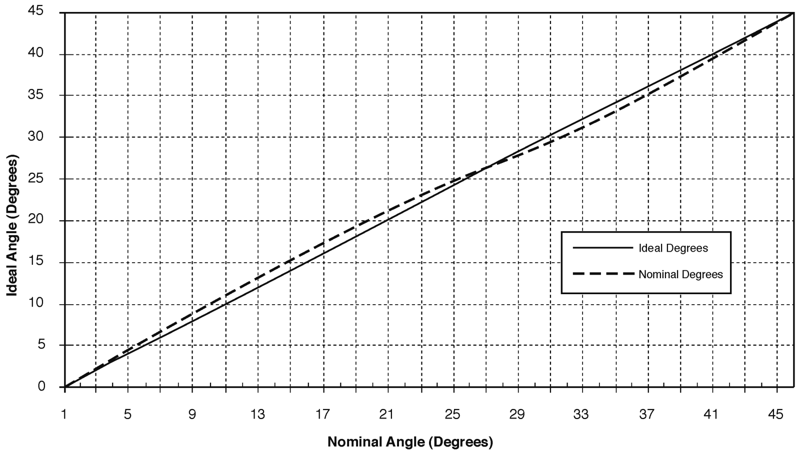


Figure 4. Nominal Output Deviation



Note: Temperature, voltage, and nonlinearity not included.

Figure 5. Nominal Angle vs. ideal Angle (After Calibrating at 180°)

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.

CIRCUIT DESCRIPTION AND APPLICATION NOTES

The CS8190 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 for stable operation, and a function generator with sine and cosine amplifiers to differentially drive the meter coils.

From the partial schematic of Figure 6, 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 2.0V and typical hysteresis of 0.5V. The output of the comparator, SQ_{OUT}, is applied to the charge pump input CP+ through an external capacitor C_{CP}. When the input signal changes state, C_{CP} is charged or discharged through R3 and R4. The charge accumulated on C_{CP} is mirrored to C4 by the Norton Amplifier circuit comprising of Q1, Q2 and Q3. The charge pump output voltage, F/V_{OUT}, ranges from 2.0V to 6.3V depending on the input signal frequency and the gain of the charge pump according to the formula:

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

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 which generates the sine and cosine output voltages. 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 drive, 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;

$$\theta = A_{FG} \times 2.0 \times FREQ \times C_{CP} \times R_T \times (V_{REG} - 0.7V)$$

or,

$$\theta = 970 \times FREQ \times C_{CP} \times R_T$$

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

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

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.

The CS8190 has an under-voltage detect circuit that disables the input comparator when VCC falls below 8.0V (typical). With no input signal the F/V output voltage decreases and the needle moves towards zero. A second under-voltage detect circuit at 6.0V (typical) causes the function generator to generate a differential SIN drive voltage of zero volts and the differential COS drive voltage to go as high as possible. This combination of voltages (Figure 1) across the meter coil moves the needle to the 0° position. Connecting a large capacitor (> 2,000 µF) to the V_{CC} lead (C2 in the Figure 8) increases the time between these under-voltage points since the capacitor discharges slowly and ensures that the needle moves towards 0° as opposed to 360°. The exact value of the capacitor depends on the response time of the system, the maximum meter deflection and the current consumption of the circuit. It should be selected by bread-boarding the design in the lab.

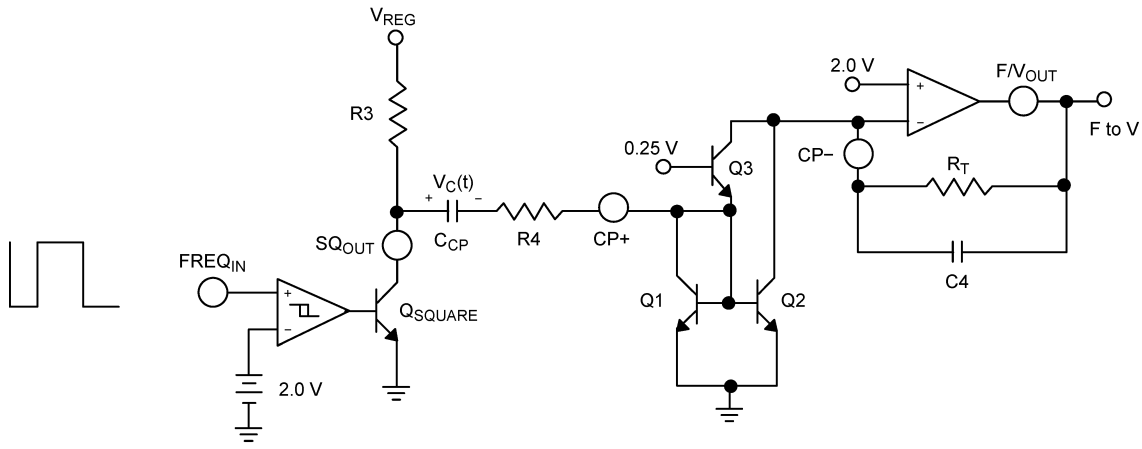


Figure 6. Partial Schematic of Input and Charge Pump

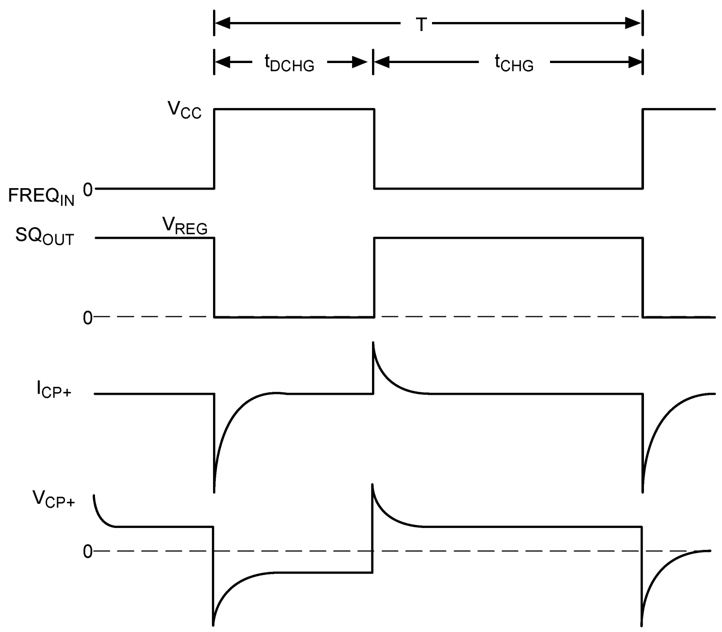
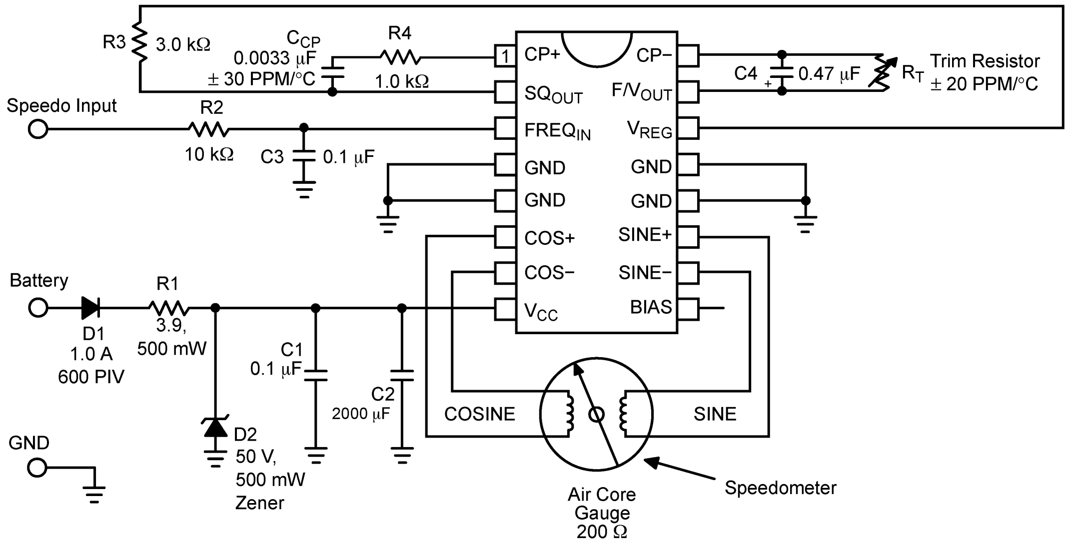


Figure 7. Timing Diagram of $FREQ_{IN}$ and I_{CP}



Notes:
1. C2 (> 2,000 µF) is needed if return to zero function is required.
2. The product of C_{CP} and R_T have a direct effect on the transfer function (f to V conversion) and therefore directly affect temperature compensation.
3. C_{CP} Range: 20 pF to 0.2 µF
4. R_T Range: 100 kΩ to 500 kΩ.
5. The IC must be protected from transients above 60V and reverse battery conditions.
6. Additional filtering on the $FREQ_{IN}$ lead may be required.
7. Gauge coil connections to the IC must be kept as short as possible (≤ 3.0 inch) for best pointer stability.

Figure 8. Speedometer or Tachometer Application

DESIGN EXMAPLE

Maximum Meter Deflection = 270°
Maximum Input Frequency = 350 Hz

1. Select R_T and C_{CP}

$$\Theta = 970 \times FREQ \times C_{CP} \times R_T = 270°$$

Let C_{CP} = 0.0033 µF, find R_T

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

$$R_T = 243\ \text{k}\Omega$$

R_T should be a 250 kΩ 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. R3 must ensure that the current does not exceed this limit.
Choose R3 = 3.3 kΩ.

The charge current for C_{CP} is

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

C_{CP} 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_{CP} is charged, assume that the (R3+R4) C_{CP} time constant is less than 10% of the minimum input period.

$$T = 10\% \times \frac{1}{350\ Hz} = 285\ \mu S$$

Choose R4 = 1.0 kΩ.
Discharge time: $t_{DCHG} = R3 \times C_{CP} = 3.3\ k\Omega \times 0.0033\ \mu F = 10.9\ \mu s$
Charge time: $t_{CHG} = (R3 + R4)\ C_{CP} = 4.3\ k\Omega \times 0.0033\ \mu F = 14.2\ \mu S$

3. Determine C4

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

$$C4 = \frac{C_{CP}\ (V_{REG} - 0.7V)}{\Delta V_{MAX}}$$

With C4 = 0.47 µF, the F/V ripple voltage is 44 mV.
The last component to be selected is the return to zero capacitor C2. This is selected by increasing the input signal frequency to its maximum so the pointer is at its maximum deflection, then removing the power from the circuit. C2 should be large enough to ensure that the pointer always returns to the 0° position rather than 360° under all operating conditions.

In some cases a designer may wish to use the CS8190 only as a driver for an air-core meter having performed the F/V conversion elsewhere in the circuit.
Figure 9 shows how to drive the CS8190 with a DC voltage ranging from 2.0V to 6.0V this is accomplished by forcing a voltage on the F/V_{OUT} lead. The alternative scheme shown in Figure 10 uses an external op amp as a buffer and operates over in input voltage range of 0V to 4.0V.

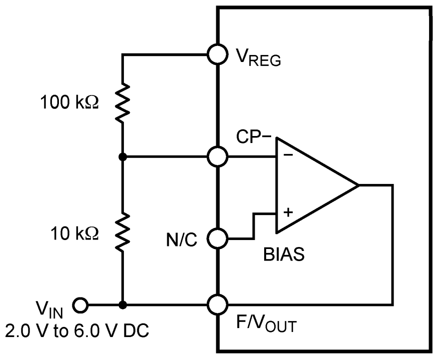


Figure 9. Driving the CS8190 from an External DC Voltage

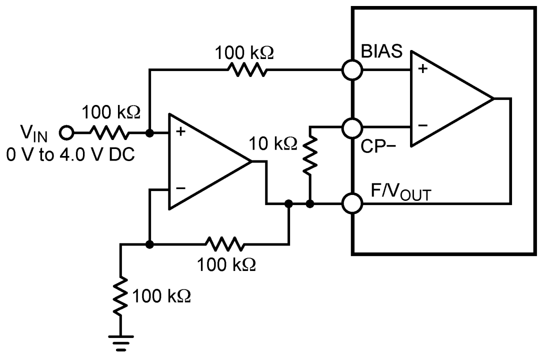


Figure 10. Driving the CS8190 from an External DC Voltage Using an Op Amp Buffer

Figures 9 and 10 are not temperature compensated.

REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.