Elektronska vezja

SENZOR TLAKA

Projektna naloga

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Kazalo

1. Uvod

Kot osnoven problem pri projektu sem si zadal merjenje tlaka na območju od 0 do 2,5bar. In sicer bom le tega meril z dvema različnima senzorjema, ki pokrivata dva področji tlaka. Za preciznejše meritve sem si izbral senzor MPX2102GP, medtem ko bom s senzorjem MPX4250GP meril celotno merilno območje(0-250kPa).

Tlak je tako kot temperatura, veličina stanja. S tlakom lahko izražamo tudi nekatere ostale fizikalne veličine, kot npr. gostoto plinov, gladino tekočine v posodi itd. Pri meritvah v tehniških sistemih nas zanimajo tri različne vrste tlaka. To so:

- absolutni tlak
- nadtlak
- diferencialni tlak

Pri absolutnem tlaku je kot primerjalna točka izbran prazen prostor, za nadtlak je to vsakokratna vrednost atmosferskega tlaka. Definicija nadtlaka je torej razlika absolutnega tlaka in atmosferskega tlaka. Za diferencialni tlak je lahko izbrana poljubna primerjalna točka in je definiran kot razlika absolutnih tlakov. V nalogi sem za merjenje tlaka izbral senzorja, ki merita nadtlak. Proizvodnja in konstrukcija senzorjev tlaka za merjenje nadtlakov je preprostejša in cenejša od proizvodnje senzorjev za merjenje absolutnih tlakov, zato se v tehniških sistemih pogosteje uporabljajo senzorji za merjenje nadtlakov.

Merilnike tlaka lahko razdelimo v dve večji skupini:

- mehanske
- električne

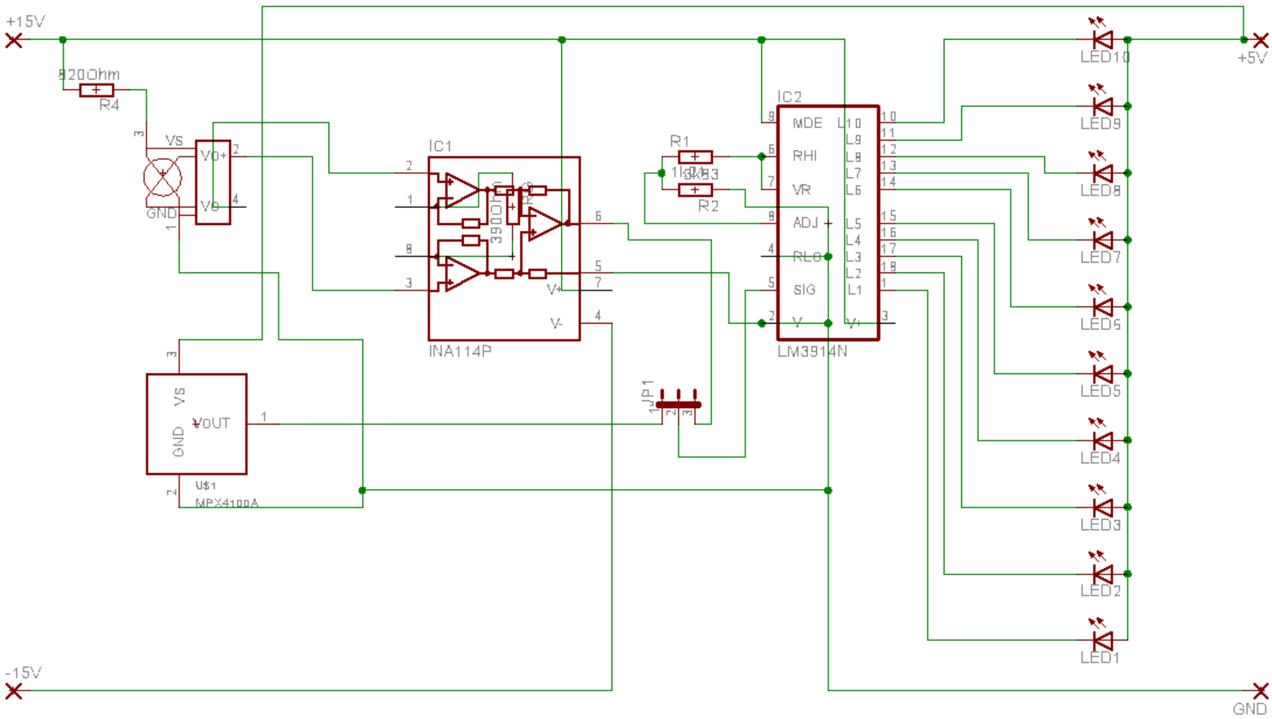
Mehanski se delijo na tekočinske in vzmetne merilnike tlaka. Veliko število izvedb pri pri električnih postopkih za merjenje tlaka po eni strani izhaja iz različnih fizikalnih principov, po drugi pa iz številnih konstrukcijskih rešitev. Uporabljeni so štirje principi merjenja:

- merjenje električne upornosti
- merjenje kapacitivnosti
- merjenje induktivnosti
- merjenje resonančne frekvence

Uporabljamo tudi piezoelektrični in optični princip. Sodobni senzorji tlaka pogosto uporabljajo princip merjenja električne upornosti zaradi spremembe raztezka merilnega elementa pod vplivom tlaka. V tem primeru je senzor kar upor, ki se mu zaradi spremembe merjenega parametra spremeni ohmska upornost. Za izdelavo senzorjev tlaka se uporabljajo različne tehnologije. Najbolj razširjena je polprevodniška, za nekatere uporabe pa je primerna debeloplastna tehnologija na keramičnem substratu.

Ena izmed bistvenih lastnosti vsakega proizvoda je tudi njegova cena. Senzorski element predstavlja v običajnem merilniku tlaka 10 – 20% proizvodne cene. Ostali stroški odpadejo na montažo, testiranje,kompenzacijo vplivnih veličin kot je temperatura, ohišje in elektroniko.

2. Shema merilnega vezja

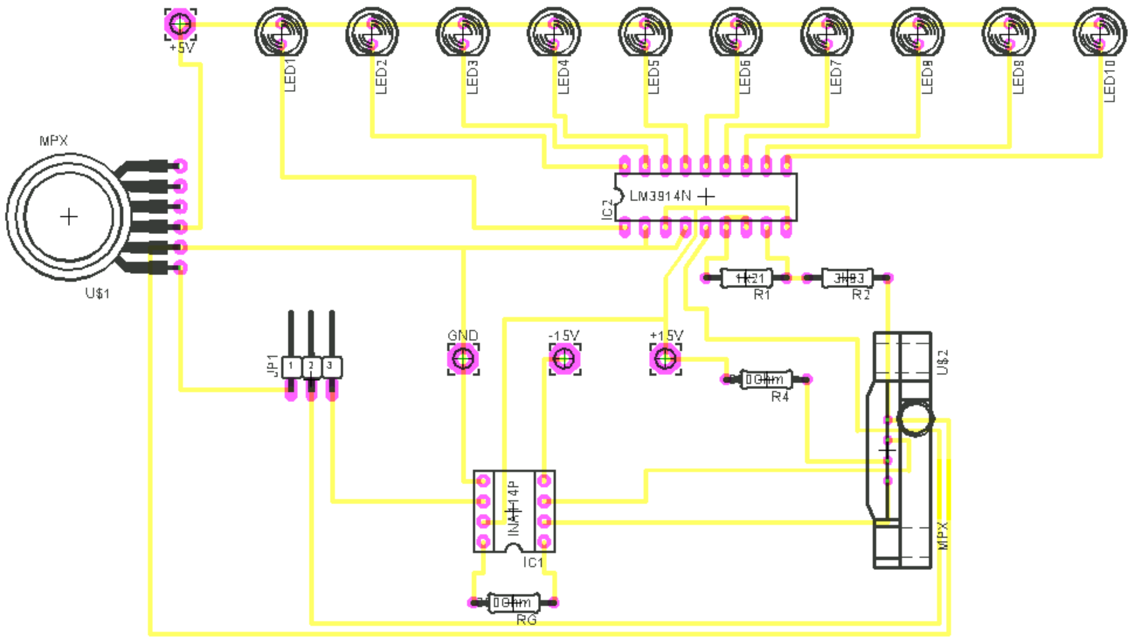


Slika 1

Kot prikazuje slika 1 sem pri realizaciji merilnega vezja uporabil dva senzorja MPX2102GP in MPX4250GP, instrumentacijski ojačevalnik INA114, Bar Display Driver LM3914, nekaj LED diod in ostalih 'enostavnih' elementov.

Shemo merilnega vezja sem izdelal s pomočjo programa Eagle 4.11, kateri mi je vzel kar nekaj časa, saj sem že takoj na začetku naletel na problem. V originalnih knjižnicah, ki so priložene programu namreč ni mojih senzorjev. Po nekajurnem internetnem brskanju sem našel približke, ki sicer niso enaki moji izbiri, a fizično ustrezajo. Tako da pri tiskanem vezju ne pričakujem težav zaradi tega.

3. Tiskano vezje merilnega vezja



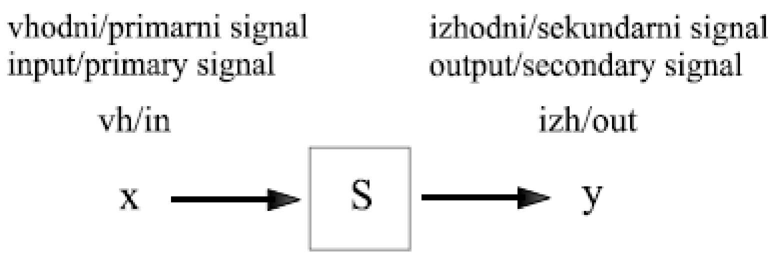
Slika 2

Tiskano vezje, ki ga prikazuje slika 2 sem prav tako izrisal s pomočjo programa Eagle 4.11. Povezave med elementi sem raje dokončal z ročnim vlečenjem miške, saj je avtomatska funkcija za vlečenje povezav precej nesposobna.

4. Senzor tlaka

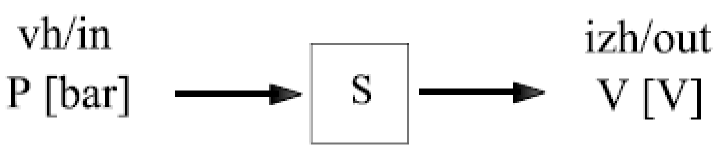
4.1 Osnovne značilnosti senzorjev

Splošna definicija: Senzor je element, ki proizvede na izhodu signal, ki enolično odgovarja vrednosti opazovane veličine na vhodu senzorja(slika 3).



Slika 3

V našem primeru, ko imamo senzor tlaka je na izhodu senzorja električni signal(napetost-U), ki je enolično odvisna od vrednosti tlaka-P na vhodu(slika 4).



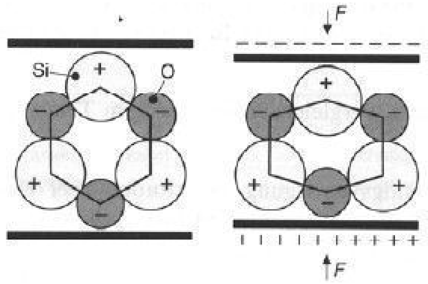
Slika 4

Senzor tlaka torej opravlja enolično pretvorbo vhodnega signala, tlaka-P v izhodni signal, napetost-U.

Pri delovanju senzorjev gre vedno za neko pretvorbo energije vhodnega signala v energijo izhodnega signala, ki naj bo v obliki, primerni za nadaljnjo uporabo. Take pretvorbe iz ene energije v drugo imenujemo običajno v naravoslovju in tehniki "efekt" ali "zakon".

4.2 Piezoeletrični senzor tlaka

Piezoelektrika je pojav, pri katerem se na mejnih ploskvah nekaterih kristalov pojavljata električna naboja z različnima predznakoma, če obremenimo kristal v določeni smeri s tlakom, z nategom ali torzijo. Pri tem piezoelektričnem pojavu se kristal električno polarizira, pri čemer je polarizacija vzporedna ali pravokotna na smer delujoče obemenitve.



Slika 5

Obratni pojav, ko se zaradi nanesenega električnega naboja na mejne ploskve kristala spremenijo njegove dimenzije imenujemo ***elektrostrikcija***.

Med mehanično obremenitvijo in električno polarizacijo(nabojem) je prema sorazmernost. Če se kristal zaradi zunanje obremenitve deformira, se ioni, ki sestavljajo kristalno mrežo, premaknejo in se tem se premakne tudi težišče nabojev. Na mejnih ploskvah kristala se tvori električni naboj. Kristali z izrazitimi piezoelektričnimi lastnostmi so kremen, turmalin in snovi kot Seignettova sol(kalijevo-natrijev tartrat) in barijev titanat.

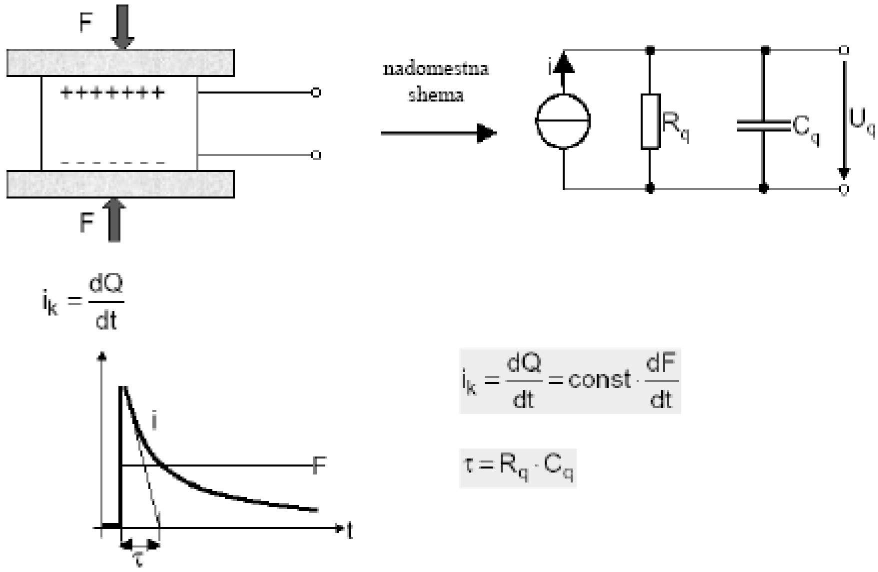
Piezoelektrični senzorji tlaka imajo glede na ostale več prednosti:

- enostavna zgradba, ki zahteva zelo malo dodatnih komponent(zgolj kovinska folija za odvzem električnega naboja)
- imajo majhno temperaturno odvisnost
- ne potrebujejo zunanjega vira napetosti(vendar potrebuje občutljivo merilno pripravo za zajem električnega naboja – precizijski ojačevalnik s kompenzacijo offset napetosti)
- energijski izkoristek pri pretvorbi mehanične v električno energijo je pravtako zelo velik
- kristal generira električni naboj proporcionalno s silo, ki deluje nanj
- kristal združuje lastnosti vzmeti in električnega pretvornika
- merjena sila generira signal neposredno
- izhodni signal piezo kristala je linearen in brez histereze

- piezo senzorji so kompaktni, robustni in visoko občutljivi
- piezo senzorji so zelo togi, zato so deformacije v rangu mikrometrov
- ponujajo široko merilno območje
- piezo kristali imajo visoke lastne frekvence in so zato primerni za meritve procesov pri visokih frekvencah
- generirajo električni naboj, ki ga je težje procesirati

Slabosti:

- namenjeni so le merjenju sprememb sile ne pa njenemu statičnemu iznosu. Razlog temu je, da se pri spremembi mehanične obremenitve na majhnih ploskvah pojavi električni naboj, ki pa zaradi končno velike upornosti merilne priprave odteče z obeh mejnih ploskev



Slika 6

4.3 Teoretični opis delovanja senzorja tlaka

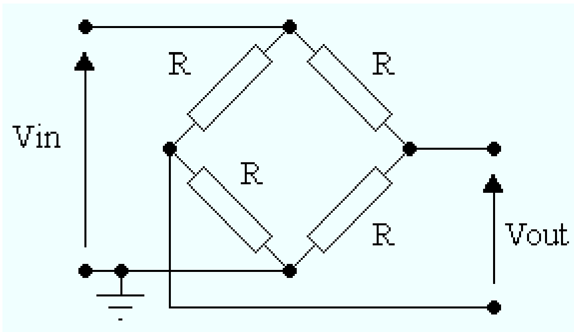
Za razumevanje delovanja senzorja tlaka je pomembno,da si ogledamo mehaniko upogiba senzorjeve membrane in piezorezistivni efekt, kot posledico mehanskih napetosti, ki se pojavijo v deformirani membrani. Membrana ima nalogo da spremeni pritisk tekočina ali plina, ki nanjo deluje v mehanske napetosti in te prenese na piezo upore. Membrana je projektirana tako, da omogoči najbolj linearno odvisnost mehanskih napetosti od pritiska. Pri tem pa mora doseči dovolj velike mehanske napetosti za dober izhodni odziv kot posledico spremembe upornosti. To sta nasprotni zahtevi in je zato končna rešitev kompromis med nelinearnostmi napetosti in njihovo intenzivnostjo.

Piezouporovni efekt oziroma piezoupornost je lastnost materiala, da spremeni svoje električne lastnosti(v našem primeru upornosti), kadar ga izpostavimo mehanski obremenitvi. Ta sprememba upornosti je delno posledica deformacije, to je sprememba dimenzij, delno pa posledica spremembe specifične upornosti zaradi sprememb v mikrostrukturi materiala. V omenjenem primeru je deformacija relativni skrček ali podaljšek pod vplivom mehanske napetosti.

4.4 Ničelna napetost

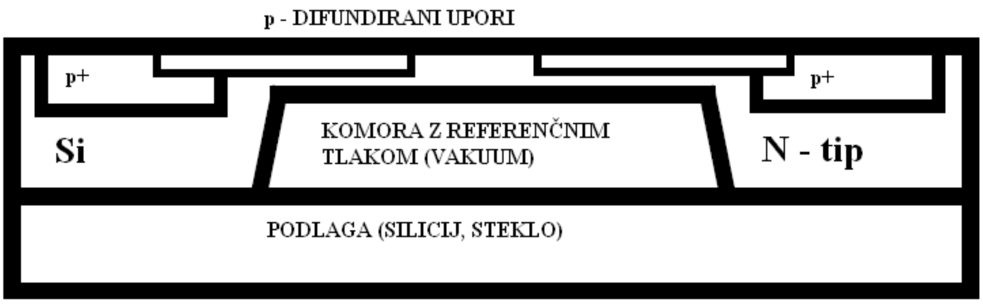
V mostiču senzorja tlaka se nahajajo štirje difundirani upori. Nemogoče je izvesti tako enakomerno difuzijo, da bi bili vsi upori popolnoma enaki med seboj. Zato se ob priključenem napajanju pojavi določena izhodna napetosti tudi v primeru, ko na senzor tlak ne deluje. To napetost imenujemo ničelna napetost, njena velikost pa je enaka:

$$\Delta V_{nič} = V_{\text{in}} * \frac{R_2 * R_3 - R_1 * R_4}{(R_1 + R_3)(R_2 + R_4)}$$



Slika 7

Senzorji delujejo na podlagi piezouporovnega efekta v siliciju, to je spremembe upornosti zaradi deformacij oziroma mehanskih napetosti, ki se pojavijo v tlačno obremenjenem materialu. Štirje upori so v vsakem senzorju vezani v Wheatstoneov mostič, tako da imamo zadosti visok izhodni signal in manj težav s temperaturnim driftom.



Slika 8

Poleg različnih uporov lahko ugotovimo še nekaj vzrokov za nastanek ničelne napetosti. Razdelimo jih na:

- take, ki v membrani ustvarijo mehanske napetosti ter preko piezorezistivnosti tudi določeno napetost(v glavnem so to termični efekti)
- ostale, kamor lahko prištevamo tudi vpliv neenakih uporov, poleg tega pa še vpliv zapornega toka

Vsi ti vzroki imajo na velikost ničelne napetosti, v primerjavi z neenakimi upori, zanemarljivo vlogo.

4.5 Tlačna občutljivost

Tlačne občutljivosti senzorjev se lahko spreminjajo zaradi:

- različne debeline membrane
- kot posledica netočnega jedkanja
- zaradi slabe naravnanosti uporov glede na robove membrane
- zaradi velikosti uporov
- neenakomerne debeline membrane.

4.6 Senzor MPX2102GP; 0 – 100kPa (1bar)

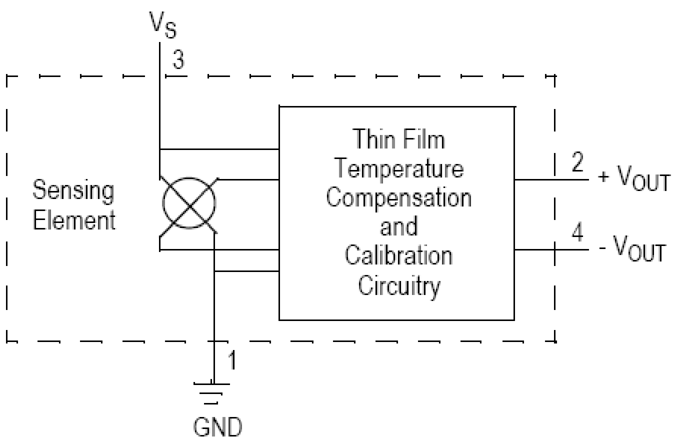
Freescale Semiconductor MPX2102 je silicijev piezorezistivni senzor tlaka. Zasnovan je tako, da podaja celotno in točno informacijo tlaka, poleg tega ima linearen napetostni izhod proporcionalen merjenemu tlaku. Senzor je sestavljen iz silicijeve diafragme na kateri je s tankim filmom nanesena mreža integriranih uporov. Vezje je lasersko doravnano(trimano) za precizen razpon merilnega območja, offsetno napetostno kalibrirano in temperaturno kompenzirano.

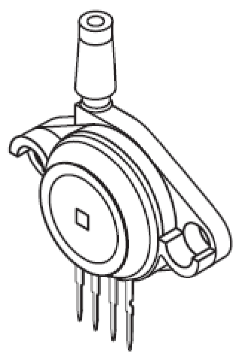
Lastnosti:

- temperaturno kompenziran med 0°C in 85°C
- oblika ohišja enostavna za uporabo
- dostopen v izvedbi za merjenje diference tlakov,absolutnih tlakov in nadtlakov
- izhodna napetosti odvisna od vhodne napetosti
- maksimalni tlak s katerim lahko senzor obremenimo je 400kPa

Primeri uporabe:

- kontrola pritiska olja v motorjih
- robotika
- medicina
- senzorji nivoja tekočin
- barometri
- altimetri;višinometri





MPX2102AP/GP
CASE 344B-01

Slika 9

Characteristic		Symbol	Min	Typ	Max	Units
Differential Pressure Range[1]		P_{OP}	0	—	100	kPa
Supply Voltage[2]		V_S	—	10	16	V_{DC}
Supply Current		I_O	—	6.0	—	mAdc
Full Scale Span[3]		V_{FSS}	38.5	40	41.5	mV
Offset[4]	MPX2102D Series MPX2102A Series	V_{OFF}	-1.0 -2.0	— —	1.0 2.0	mV
Sensitivity		ΔV/ΔP	—	0.4	—	mV/kPa

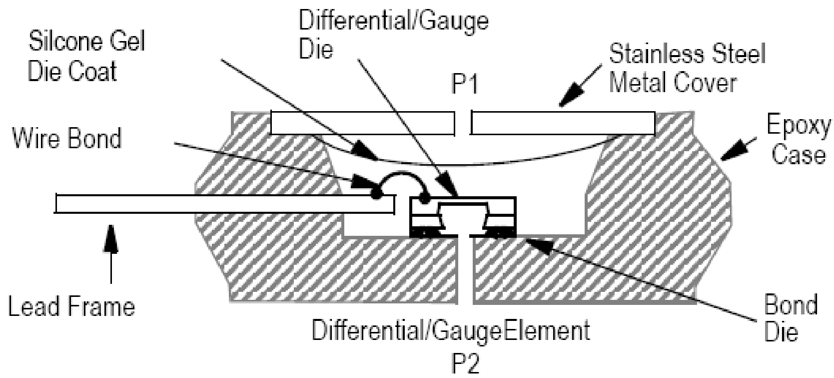
Senzor daje na izhod linearno napetost pri pritisku med 0 in 100kPa. Ta izhodna napetost se prav tako linearno spreminja z napetostjo na vhodu. Na primer če bi senzor napajali z 5V in ne z 10V, kot je nazivna napajalna napetost bi dobili izhodni razpon napetosti namesto 40mV nazivnega razpona 20mV. To je mogoče tudi izračunati po spodnji enačbi:

$$\frac{(V_{s\ actual})}{V_{s\ spec}} * V_{OUT\ \ full\,scale\,spec} = V_{OUT\ \ full\,scale}$$

$$(\frac{5.0\text{V}}{10.0\text{V}}) * 40\text{mV} = 20\text{mV}$$

Idealno ***linearen*** senzor bi v tem primeru sledil spodnji enačbi, a seveda prihaja da nekaj procentnih odstopanj:

$$V_{OUT} = V_{OFF} + sensitivity * P\ ;\ P -> preasure$$



Slika 10

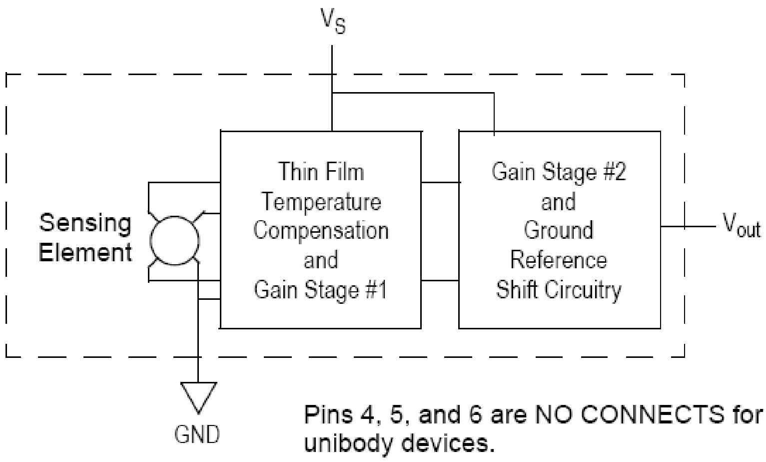
Na sliki 10 je prikazan prerez senzorja tlaka, s katerim merimo nadtlak. Na strani P2 je odprtina za zajem atmosferskega tlaka, na P1 pa pripeljemo tlak, ki ga želimo meriti.

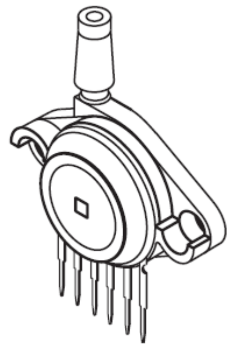
UNIBODY PACKAGE PIN NUMBERS			
1	GND[1]	3	V_S
2	$+V_{OUT}$	4	$-V_{OUT}$

4.7 Senzor MPX4250GP; 0 – 250kPa (2.5bar)

Lastnosti:

- dostopen v izvedbi za merjenje nadtlaka in diferencialnega tlaka
- 1.4% maksimalna napaka med 0°C in 85°C
- temperaturno kompenziran med - 40°C in + 125°C
- maksimalni tlak s katerim lahko senzor obremenimo je 1000kPa
- temperaturno delovno območje je med -40°C in + 125°C





Slika 11

Slika 11 prikazuje integrirano vezje, ki je že v senzorju tlaka.

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range(1)		P_{OP}	0	—	250	kPa
Supply Voltage(2)		V_S	4.85	5.1	5.35	Vdc
Supply Current		I_o	—	7.0	10	mAdc
Minimum Pressure Offset @ V_S = 5.1 Volts(3)	(0 to 85°C)	V_{off}	0.139	0.204	0.269	Vdc
Full Scale Output @ V_S = 5.1 Volts(4)	(0 to 85°C)	V_{FSO}	4.844	4.909	4.974	Vdc
Full Scale Span @ V_S = 5.1 Volts(5)	(0 to 85°C)	V_{FSS}	—	4.705	—	Vdc
Accuracy(6)	(0 to 85°C)	—	—	—	±1.4	$\%V_{FSS}$
Sensitivity		ΔV/ΔP	—	18.8	—-	mV/kPa

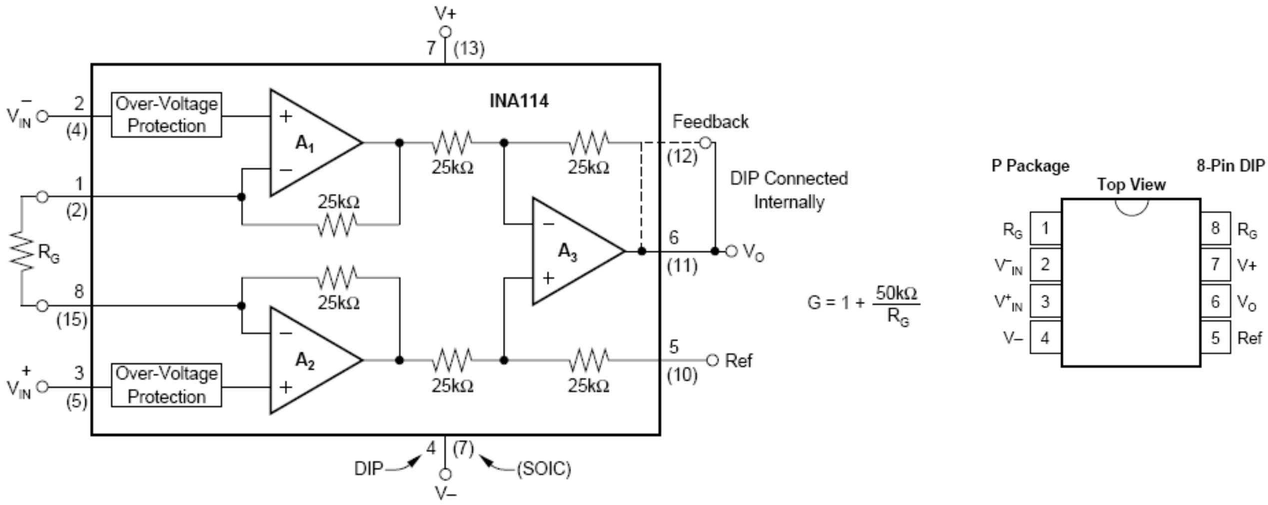
PIN NUMBERS(1)			
1	V_{out}	4	N/C
2	GND	5	N/C
3	V_S	6	N/C

5. Instrumentacijski ojačevalnik INA114

Lastnosti:

- nizka offsetna napetost: *max.* $50\,\mu V$
- vhodna prenapetostna zaščita: $\pm 40\mathrm{V}$
- razpon območja napajanja: $\pm 2.25\mathrm{V}$ *do* $\pm 18\mathrm{V}$
- neaktivni tok je maksimalno 3mA
- proizvaja zelo nizek nivo šuma
- vhodna impedanca je zelo visoka; cca. $10^{10}\,\Omega$;vhodni tok je zato zelo majhen, manjši kot $\pm 1\mathrm{nA}$

INA114 je cenen osnovni instrumentasijski ojačevalnik, ki ponuja odlične in točne informacije. Njegova večnamenska, s tremi operacijskimi ojačevalniki, fizično majhna izvedba ga naredi uporabnega za zelo široko območje uporabe. En sam zunanji upor lahko nastavi poljubno ojačanje med 1 in 10 000.

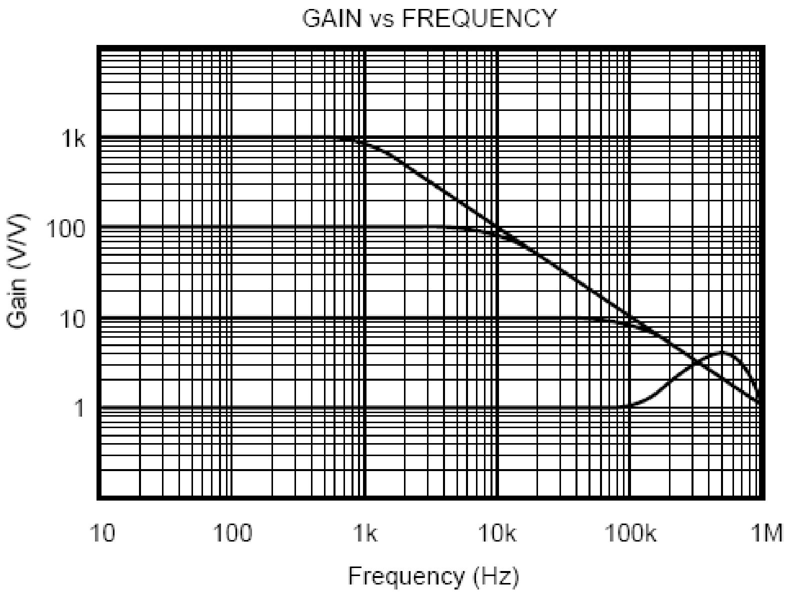


Slika 12

Na sliki 12 lahko vidimo shematski prikaz integriranega vezja v instrumentacijskem ojačevalniku. Za računanje oz. nastavitev želenega ojačanja uporabimo formulo:

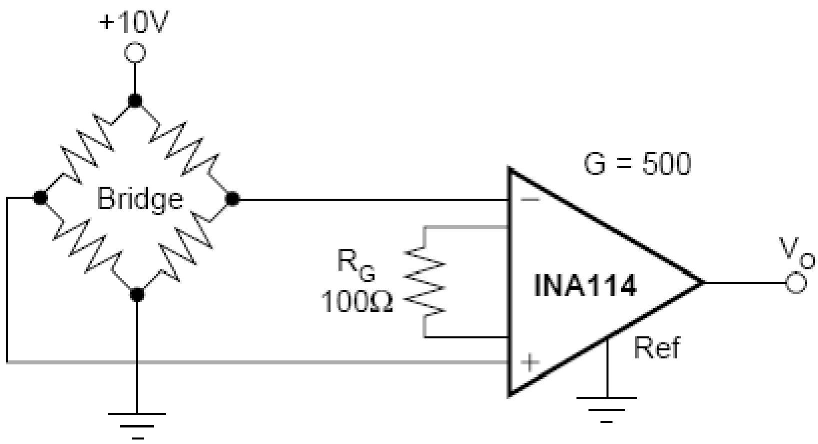
$$G = 1 + \frac{50\mathrm{k}\,\Omega}{R_G}$$

Bodejev diagram:



INA114 je lasersko doravnan, tako da ima zelo nizko offsetno napetost. Za večino aplikacij v katerih uporabljamo ta instrumentacijski ojačevalnik zunanje doravnavanje offsetne napetosti ni potrebno.

V našem primeru je instrumentacijski ojačevalnik uporabljen, kot prikazuje spodnja slika 13.



Slika 13

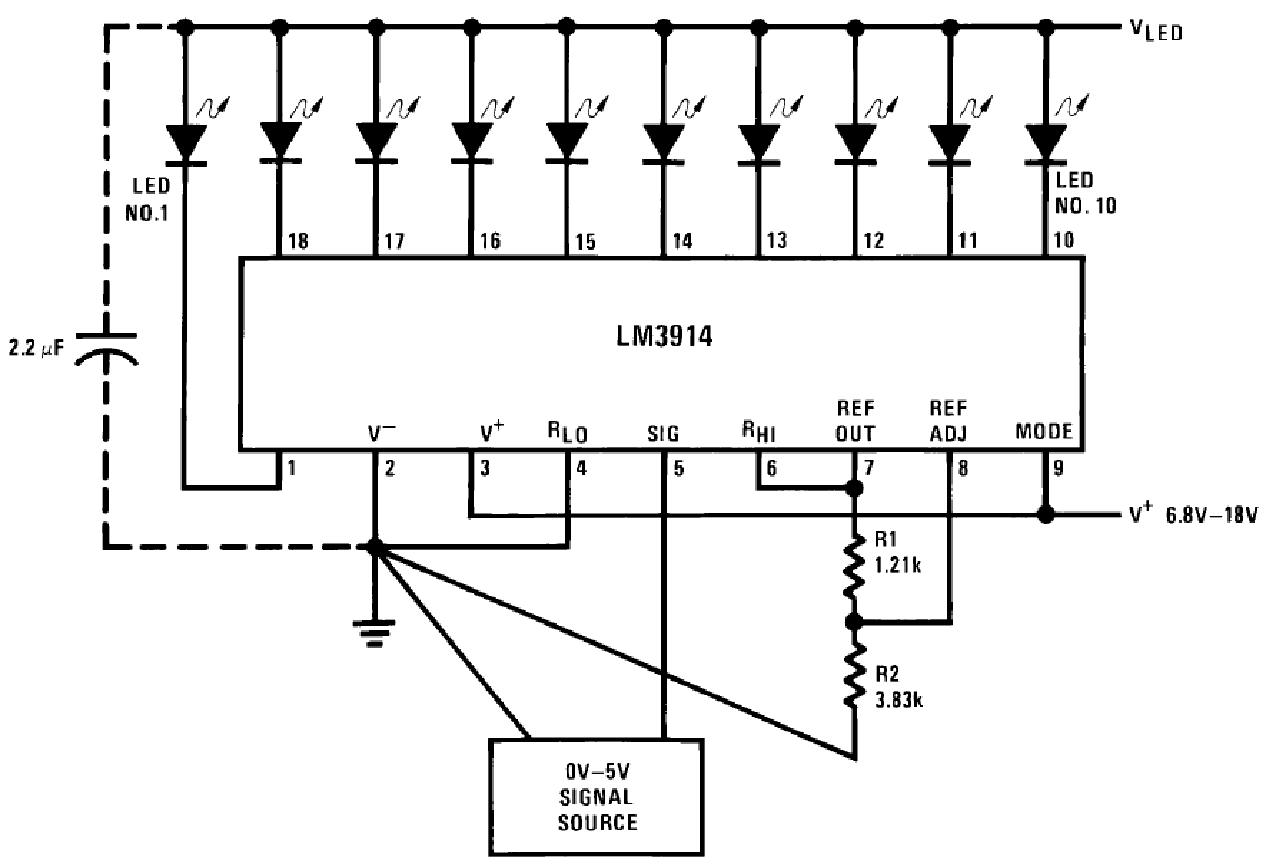
6. Dot/Bar Display Driver LM3914

LM3914 je monolitni integrirano vezje, katero zaznava analogne napetostne stopnje in glede na to upravlja z LED diodami, tako da tvori linearen analogni prikazovalnik. Z enim samim konektorjem (pin) lahko spreminjamo ali bomo na prikazovalniku prikazali samo eno delujočo diodo (dot display) ali celo vrsto do najvišje (bar display). LM3914 lahko upravlja z LED diodami vseh barv, in lahko se jih poveže več skupaj tako da dosežemo prikazovalnike z več ko 10, pa tja do 100 LED diod. Vezje je bilo zasnovano za normalno delovanje na temperaturnem območju med 0°C in 70°C.

Lastnosti:

- upravlja z LED diodami, LCD prikazovalniki ali vakuumskimi svetilkami(vacuum fluorescents)
- *bar* ali *dot* prikazovanje lahko zelo enostavno nastavi uporabnik
- razširljiv na prikazovalnike s 100 koraki
- lahko deluje že pri zelo nizki napajalni napetosti 3V
- izhodni tok je mogoče nastavljati od 2mA do 30mA
- na vhod lahko pripeljemo napetosti tja do $\pm 35V$ brez da bi pri tem poškodovali čip ali povzročili napake na izhodu
- izhodi so združljivi z TTL in CMOS tehnilogijami

0V to 5V Bar Graph Meter



Slika 14

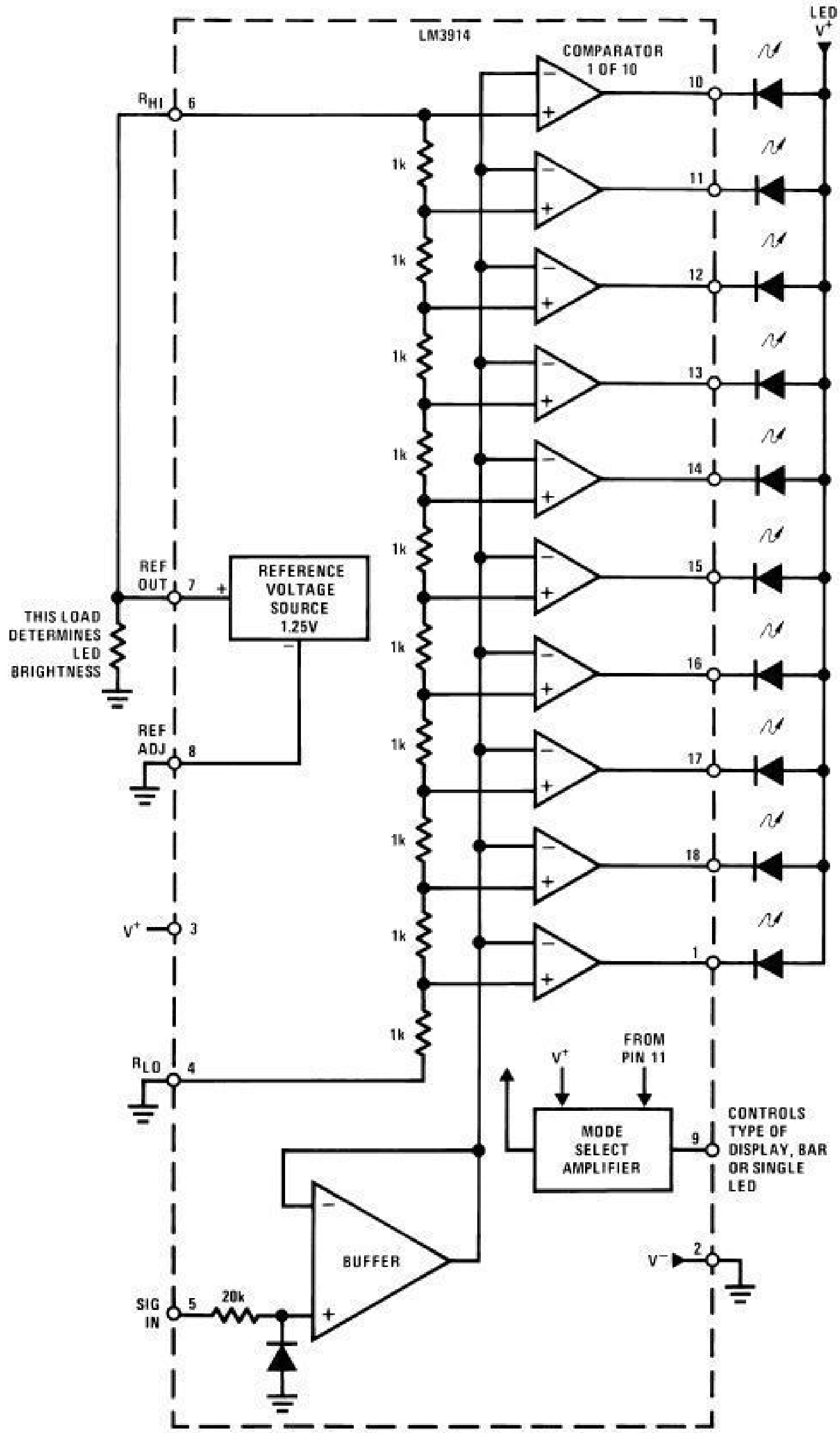
Na sliki 14 vidimo tipično vezavo LM3914, katero sem tudi sam uporabil. Referenčno izhodno napetost uravnavamo po formuli:

$$Ref\ Out\ V = 1.25*(1+\frac{R_2}{R_1})$$

Medtem ko za uravnavanje toka LED diod in s tem svetlosti diod uporabljamo formulo:

$$I_{LED} \simeq \frac{12.5}{R_1}$$

Blok diagram vezja LM3914:



Slika 15

Način prikazovanja z LED diodami lahko uravnavamo na 9. priključku(pinu), kjer izberemo ali bomo uporabljali dot ali bar prikazovalnik:

- *bar* prikazovalnik: priključek 9(Mode pin) vežemo direktno na priključek 3($V_+ \ pin$)
- *dot* prikazovalnik: priključek 9(Mode pin) pustimo nepriključenega

7. Zaključek

Že iz samega opisa posameznih uporabljenih elementov bi se dalo sklepati, kako celotna stvar deluje.

Za izvedbo projekta sem si izbral dva senzorja, ki delujeta na različnih merilnih območjih, a delujeta po enakem principu. MPX2102GP daje na izhod diferencialno napetost, ki je $\Delta V = 40\text{mV}$, katero je potrebno še ojačat. To sem z INA114 realiziral s pomočjo upora $390\,\Omega$, kar pomeni, da sem uporabil ojačanje:

$$G = 1 + \frac{50\text{k}\,\Omega}{R_G} = 1 + \frac{50\text{k}\,\Omega}{390\,\Omega} = 129.21$$

To je na vmesni stopnji dalo maksimalno $\Delta V = 5.17\text{V}$, kar sem nato uporabil kot vhod v LM3914, kateri je nato prižgal ustrezno število LED diod. V našem zgoraj izračunanem modelu bi to bilo vseh 10 LED diod.

Z senzorjem tlaka MPX4250GP je popolnoma enako, razlika je le v tem da je ojačitvena stopnja z INA114 izpuščena.

8. Priloge

Prilagam podatkovne liste(datasheet)

- MPX2102
- MPX4250
- INA114
- LM3914

9. Viri in literatura

- http://lms.fe.uni-lj.si/amon/literatura/SA/1OsnZnac.pdf
- http://lrt2.fe.uni-lj.si/lrtme/meri_pret/PREDAVANJE_X_Senzorji%20tlaka_2006.pdf
- http://www.freescale.com/files/sensors/doc/app_note/AN1979.pdf
- http://www.depeca.uah.es/docencia/BIOING/fb/ina114.pdf
- http://www.freescale.com/files/sensors/doc/data_sheet/MPX2102.pdf
- http://www.freescale.com/files/sensors/doc/data_sheet/MPX4250D.pdf
- http://cache.national.com/ds/LM/LM3914.pdf
- Bernik, Gorazd: Silicijev senzor tlaka, 1991. (diplomsko delo)
- Janc, Gregor: Keramični piezouporovni senzor tlaka, 2004. (diplomsko delo)

Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated

The MPX4250D series piezoresistive transducer is a state-of-the-art monolithic silicon pressure sensor designed for a wide range of applications, particularly those employing a microcontroller or microprocessor with A/D inputs. This transducer combines advanced micromachining techniques, thin-film metallization, and bipolar processing to provide an accurate, high-level analog output signal that is proportional to the applied pressure. The small form factor and high reliability of on-chip integration make the Freescale sensor a logical and economical choice for the automotive system engineer.

Features

- Differential and Gauge Applications Available
- 1.4% Maximum Error Over 0° to 85°C
- Patented Silicon Shear Stress Strain Gauge
- Temperature Compensated Over –40° to +125°C
- Offers Reduction in Weight and Volume Compared to Existing Hybrid Modules
- Durable Epoxy Unibody Element

Typical Applications

- Ideally Suited for Microprocessor or Microcontroller-Based Systems

ORDERING INFORMATION[(1)]

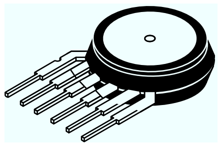
Device Type	Case No.	MPX Series Order No.	Device Marking
UNIBODY PACKAGE (MPX4250D SERIES)			
Basic Element	867	MPX4250D	MPX4250D
Gauge Ported Element	867B	MPX4250GP	MPX4250GP
Dual Ported Element	867C	MPX4250DP	MPX4250DP

1. The MPX4250D series silicon pressure sensors are available in the basic element package or with pressure port fittings that provide mounting ease and barbed hose connections.

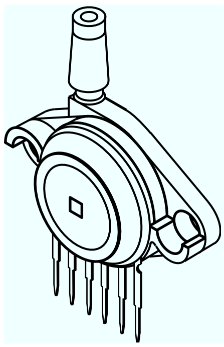
MPX4250D SERIES

INTEGRATED PRESSURE SENSOR
0 TO 250 kPA (0 TO 36.3 psi)
0.2 TO 4.9 V OUTPUT

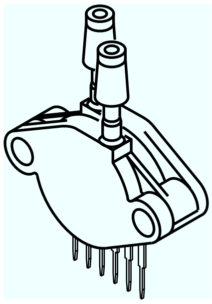
UNIBODY PACKAGES



BASIC CHIP CARRIER ELEMENT
CASE 867-08
STYLE 1



GAUGE PORT OPTION
CASE 867B-04
STYLE 1



DUAL PORT OPTION
CASE 867C-05
STYLE 1

PIN NUMBERS[(1)]

1	V_{out}	4	N/C
2	GND	5	N/C
3	V_S	6	N/C

1. Pins 4, 5, and 6 are internal device connections. Do not connect to external circuitry or ground. Pin 1 is noted by the notch in the lead.

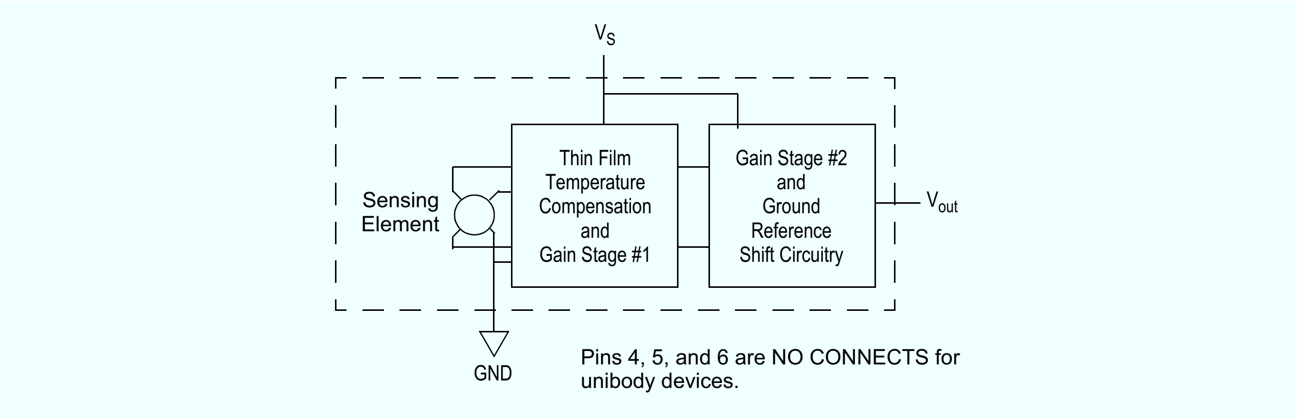


Figure 1. Fully Integrated Pressure Sensor Schematic

Table 1. Maximum Ratings(1)

Rating	Symbol	Value	Unit
Maximum Pressure (P1 > P2)	P_{MAX}	1000	kPa
Storage Temperature	T_{STG}	–40 to +125	°C
Operating Temperature	T_A	–40 to +125	°C

1. Exposure beyond the specified limits may cause permanent damage or degradation to the device.

Table 2. Operating Characteristics (V_S = 5.1 Vdc, T_A = 25°C unless otherwise noted, P1 > P2. Decoupling circuit shown in Figure 3 required to meet electrical specifications.)

Characteristic		Symbol	Min	Typ	Max	Unit
Pressure Range[1]		P_{OP}	0	—	250	kPa
Supply Voltage[2]		V_S	4.85	5.1	5.35	Vdc
Supply Current		I_o	—	7.0	10	mAdc
Minimum Pressure Offset @ V_S = 5.1 Volts[3]	(0 to 85°C)	V_{off}	0.139	0.204	0.269	Vdc
Full Scale Output @ V_S = 5.1 Volts[4]	(0 to 85°C)	V_{FSO}	4.844	4.909	4.974	Vdc
Full Scale Span @ V_S = 5.1 Volts[5]	(0 to 85°C)	V_{FSS}	—	4.705	—	Vdc
Accuracy[6]	(0 to 85°C)	—	—	—	±1.4	$\%V_{FSS}$
Sensitivity		$\Delta V/\Delta P$	—	18.8	—	mV/kPa
Response Time[7]		t_R	—	1.0	—	ms
Output Source Current at Full Scale Output		I_{o+}	—	0.1	—	mAdc
Warm-Up Time[8]		—	—	20	—	ms
Offset Stability[9]		—	—	±0.5	—	$\%V_{FSS}$

1. 1.0 kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range.
3. Offset (V_{off}) is defined as the output voltage at the minimum rated pressure.
4. Full Scale Output (V_{FSO}) is defined as the output voltage at the maximum or full rated pressure.
5. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum rated pressure.
6. Accuracy (error budget) consists of the following:
   - Linearity: Output deviation from a straight line relationship with pressure over the specified pressure range.
   - Temperature Hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure Hysteresis: Output deviation at any pressure within the specified range, when this pressure is cycled to and from the minimum or maximum rated pressure, at 25°C.
   - TcSpan: Output deviation over the temperature range of 0 to 85°C, relative to 25°C.
   - TcOffset: Output deviation with minimum rated pressure applied, over the temperature range of 0 to 85°C, relative to 25°C.
   - Variation from Nominal: The variation from nominal values, for Offset or Full Scale Span, as a percent of V_{FSS}, at 25°C.
7. Response Time is defined as the time for the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
8. Warm-up Time is defined as the time required for the product to meet the specified output voltage after the Pressure has been stabilized.
9. Offset Stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

Table 3. Mechanical Characteristics

Characteristics	Typ	Unit
Weight, Basic Element (Case 867)	4.0	grams

ON-CHIP TEMPERATURE COMPENSATION AND CALIBRATION

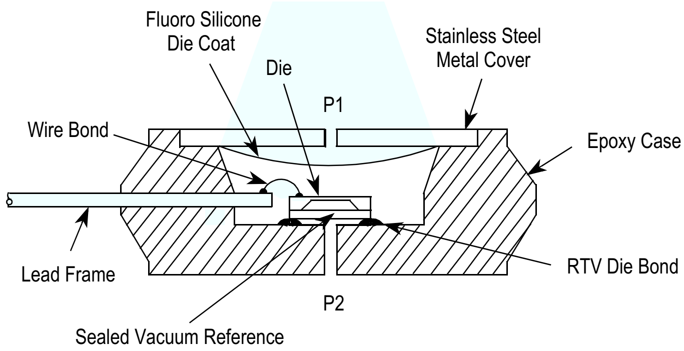


Figure 2. Cross Sectional Diagram (not to scale)

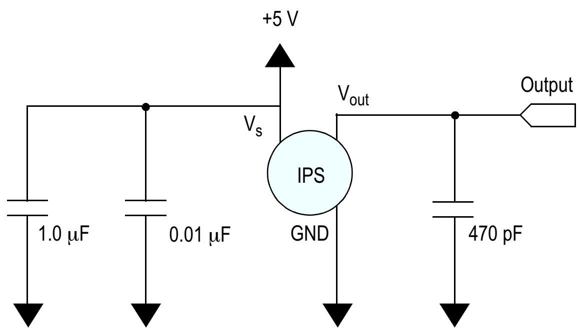


Figure 3. Recommended Power Supply Decoupling and Output Filtering

(For additional output filtering, please refer to Application Note AN1535)

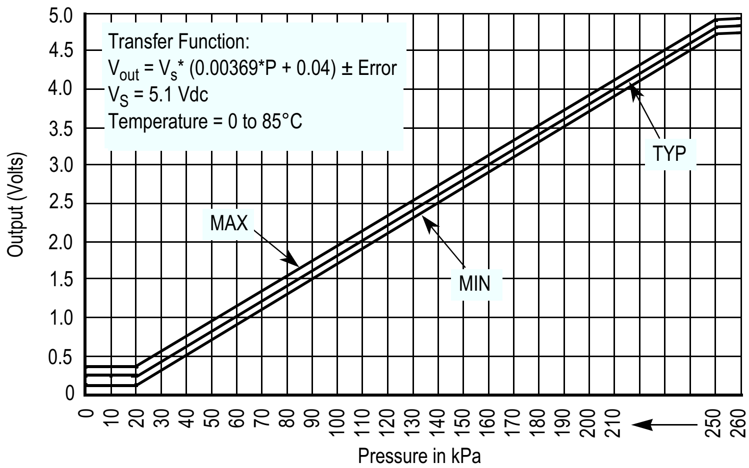


Figure 4. Output versus Absolute Pressure

Figure 2 illustrates the differential/gauge pressure sensing chip in the basic chip carrier (Case 867). A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the sensor diaphragm.

The MPX4250D series pressure sensor operating characteristics and internal reliability and qualification tests are based on use of dry air as the pressure media. Media, other than dry air, may have adverse effects on sensor performance and long-term reliability. Contact the factory for information regarding media compatibility in your application.

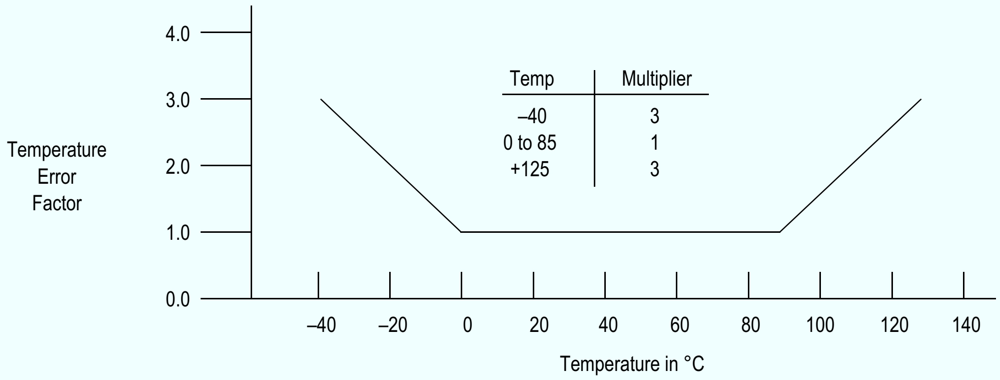
Figure 3 shows the recommended decoupling circuit for interfacing the output of the integrated sensor to the A/D input of a microprocessor or microcontroller.

Figure 4 shows the sensor output signal relative to pressure input. Typical, minimum, and maximum output curves are shown for operation over a temperature range of 0° to 85°C using the decoupling circuit shown in Figure 3. The output will saturate outside of the specified pressure range.

Transfer Function (MPX4250D)

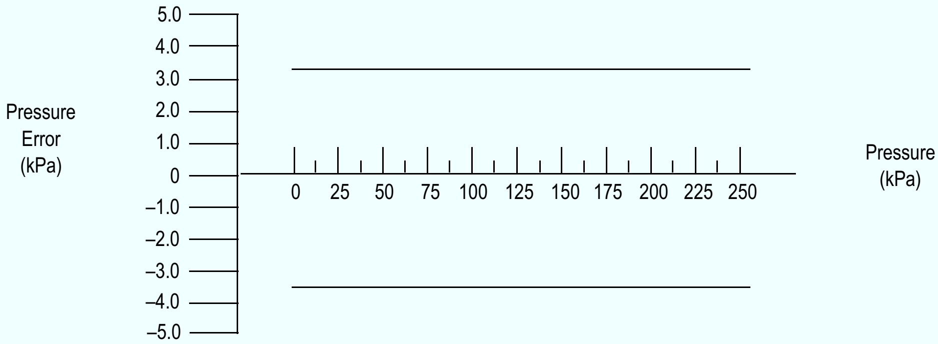
Nominal Transfer Value: $V_{out} = V_S \times (0.00369 \times P + 0.04)$
$\pm$ (Pressure Error x Temp. Factor x $0.00369 \times V_S$)
$V_S = 5.1 \pm 0.25$ Vdc

Temperature Error Band



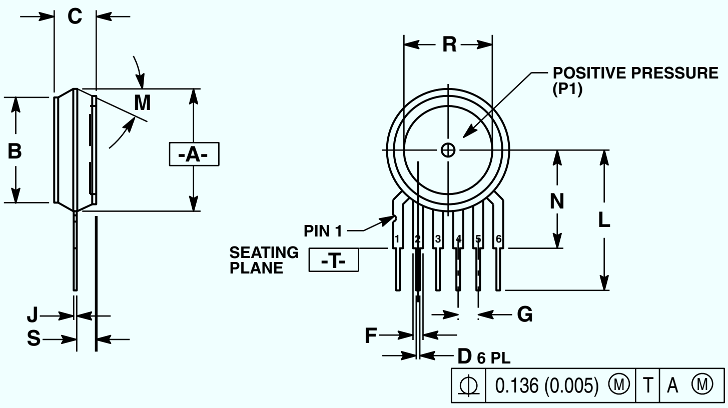
NOTE: The Temperature Multiplier is a linear response from 0°C to –40°C and from 85°C to 125°C.

Pressure Error Band



Pressure	Error (Max)
0 to 250 kPa	±3.45 kPa

PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION -A- IS INCLUSIVE OF THE MOLD STOP RING. MOLD STOP RING NOT TO EXCEED 16.00 (0.630).

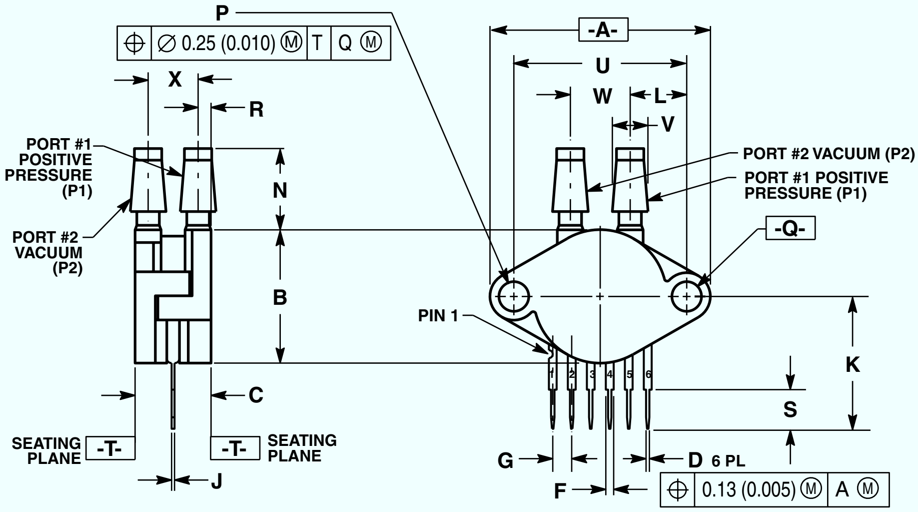
	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	0.595	0.630	15.11	16.00
B	0.514	0.534	13.06	13.56
C	0.200	0.220	5.08	5.59
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.40
L	0.695	0.725	17.65	18.42
M	30° NOM		30° NOM	
N	0.475	0.495	12.07	12.57
R	0.430	0.450	10.92	11.43
S	0.090	0.105	2.29	2.66

STYLE 1:
PIN 1. VOUT
2. GROUND
3. VCC
4. V1
5. V2
6. VEX

STYLE 2:
PIN 1. OPEN
2. GROUND
3. -VOUT
4. VSUPPLY
5. +VOUT
6. OPEN

STYLE 3:
PIN 1. OPEN
2. GROUND
3. +VOUT
4. +VSUPPLY
5. -VOUT
6. OPEN

BASIC ELEMENT (D)
CASE 867-08
ISSUE N



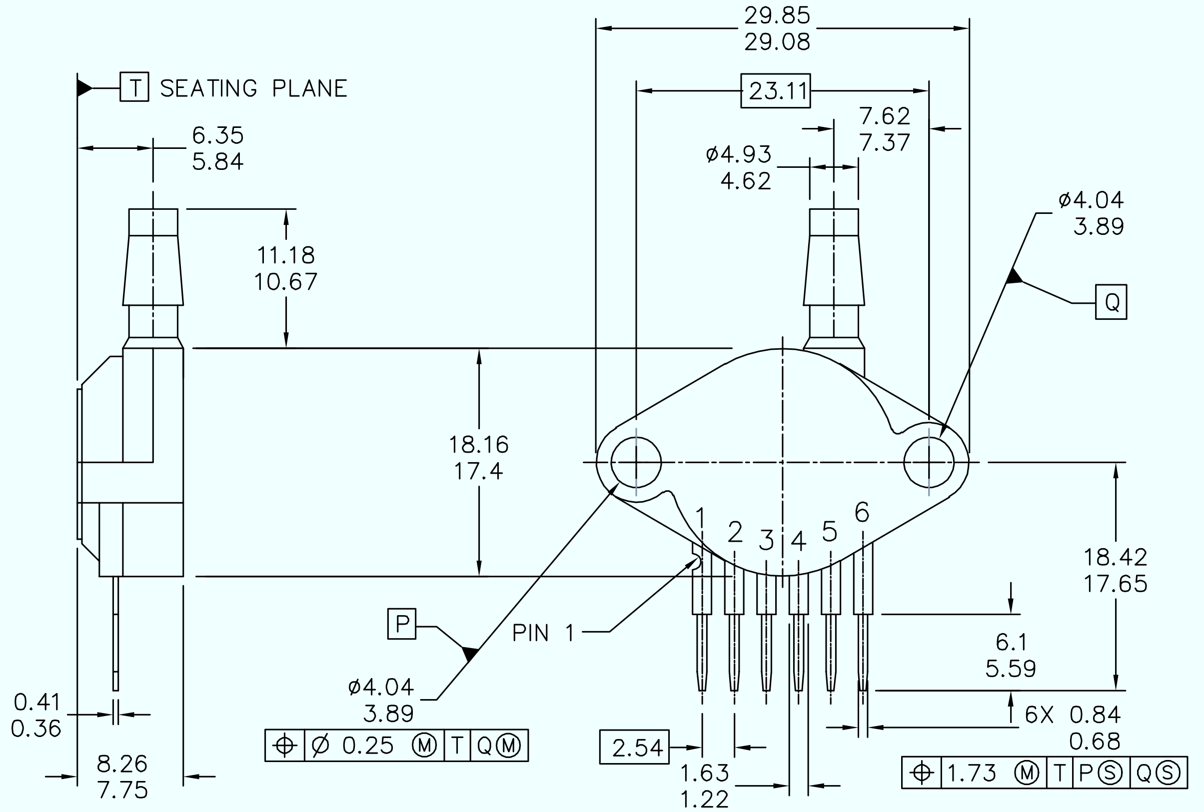
NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.405	0.435	10.29	11.05
D	0.027	0.033	0.68	0.84
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.159	3.89	4.04
R	0.063	0.083	1.60	2.11
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	
V	0.182	0.194	4.62	4.93
W	0.310	0.330	7.87	8.38
X	0.248	0.278	6.30	7.06

STYLE 1:
PIN 1. V_{OUT}
2. GROUND
3. V_{CC}
4. V1
5. V2
6. V_{EX}

PRESSURE AND VACUUM SIDE DUAL PORTED (DP)
CASE 867C-05
ISSUE F

PACKAGE DIMENSIONS



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TITLE: SENSOR, 6 LEAD UNIBODY CELL, AP & GP 01ASB09087B	DOCUMENT NO: 98ASB42796B	REV: G
	CASE NUMBER: 867B-04	28 JUL 2005
	STANDARD: NON-JEDEC	

PAGE 1 OF 2

PRESSURE SIDE PORTED (GP)
CASE 867B-04
ISSUE G

PACKAGE DIMENSIONS

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M−1994.
3. 867B−01 THRU −3 OBSOLETE, NEW STANDARD 867B−04.

STYLE 1:

PIN 1: V OUT
2: GROUND
3: VCC
4: V1
5: V2
6: V EX

	MECHANICAL OUTLINE		PRINT VERSION NOT TO SCALE
TITLE: SENSOR, 6 LEAD UNIBODY CELL, AP & GP 01ASB09087B	DOCUMENT NO: 98ASB42796B		REV: G
	CASE NUMBER: 867B−04		28 JUL 2005
	STANDARD: NON−JEDEC		

PAGE 2 OF 2

PRESSURE SIDE PORTED (GP)
CASE 867B-04
ISSUE G

NOTES

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freescale™ semiconductor

MPX4250D
Rev. 5
12/2006

100 kPa On-Chip Temperature Compensated & Calibrated Silicon Pressure Sensors

MPX2102
MPXV2102G
SERIES

The MPX2102/MPXV2102G series device is a silicon piezoresistive pressure sensor providing a highly accurate and linear voltage output directly proportional to the applied pressure. The sensor is a single, monolithic silicon diaphragm with the strain gauge and a thin-film resistor network integrated on-chip. The chip is laser trimmed for precise span and offset calibration and temperature compensation.

0 TO 100 kPA (0 TO 14.5 psi)
40 mV FULL SCALE SPAN
(TYPICAL)

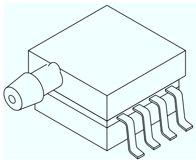
Features

- Temperature Compensated Over 0°C to +85°C
- Easy-to-Use Chip Carrier Package Options
- Available in Absolute, Differential and Gauge Configurations
- Ratiometric to Supply Voltage

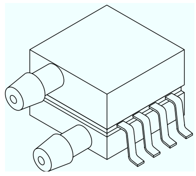
Application Examples

- Pump/Motor Controllers
- Robotics
- Level Indicators
- Medical Diagnostics
- Pressure Switching
- Barometers
- Altimeters

SMALL OUTLINE PACKAGES



MPX2102GP
CASE 1369-01



MPXV2102DP
CASE 1351-01

ORDERING INFORMATION

Device Type	Options	Case No.	MPX Series Order No.	Packing Options	Device Marking
SMALL OUTLINE PACKAGE (MPXV2102G SERIES)					
Ported Elements	Gauge, Side Port, SMT	1369	MPXV2102GP	Trays	MPXV2102G
	Differential, Dual Port, SMT	1351	MPXV2102DP	Trays	MPXV2102G
UNIBODY PACKAGE (MPX2102 SERIES)					
Basic Element	Absolute, Differential	344	MPX2102A MPX2102D	—	MPX2102A MPX2102D
Ported Elements	Differential, Dual Port	344C	MPX2102DP	—	MPX2102DP
	Absolute, Gauge	344B	MPX2102AP MPX2102GP	—	MPX2102AP MPX2102GP
	Absolute, Gauge Axial	344F	MPX2102ASX MPX2102GSX	—	MPX2102A MPX2102D
	Gauge, Vacuum	344D	MPX2102GVP	—	MPX2102GVP

SMALL OUTLINE PACKAGE PIN NUMBERS

1	GND(1)	5	N/C
2	$+V_{OUT}$	6	N/C
3	V_S	7	N/C
4	$-V_{OUT}$	8	N/C

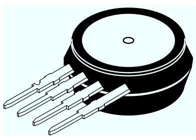
1. Pin 1 in noted by the notch in the lead.

UNIBODY PACKAGE PIN NUMBERS

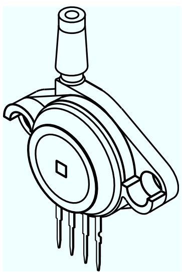
1	GND(1)	3	V_S
2	$+V_{OUT}$	4	$-V_{OUT}$

1. Pin 1 in noted by the notch in the lead.

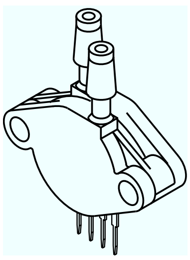
UNIBODY PACKAGES



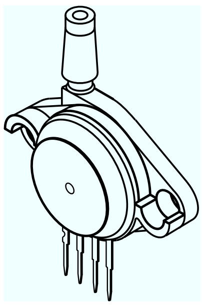
MPX2102A/D
CASE 344-15



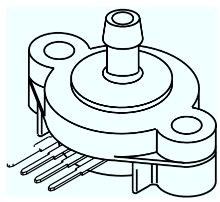
MPX2102AP/GP
CASE 344B-01



MPX2102DP
CASE 344C-01



MPX2102GVP
CASE 344D-01



MPX2102ASX/GSX
CASE 344F-01

freescale semiconductor

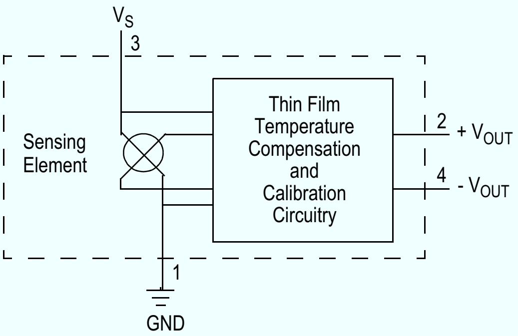


Figure 1. Temperature Compensated Pressure Sensor Schematic

VOLTAGE OUTPUT VS. APPLIED DIFFERENTIAL PRESSURE

The differential voltage output of the sensor is directly proportional to the differential pressure applied.

The absolute sensor has a built-in reference vacuum. The output voltage will decrease as vacuum, relative to ambient, is drawn on the pressure (P1) side.

The output voltage of the differential or gauge sensor increases with increasing pressure applied to the pressure (P1) side relative to the vacuum (P2) side. Similarly, output voltage increases as increasing vacuum is applied to the vacuum (P2) side relative to the pressure (P1) side.

Figure 1 illustrates a block diagram of the internal circuitry on the stand-alone pressure sensor chip.

Table 1. Maximum Ratings(1)

Rating	Symbol	Value	Unit
Maximum Pressure (P1 > P2)	P_{MAX}	400	kPa
Storage Temperature	T_{STG}	-40 to +125	°C
Operating Temperature	T_A	-40 to +125	°C

1. Exposure beyond the specified limits may cause permanent damage or degradation to the device.

Table 2. Operating Characteristics (V_S = 10 V_{DC}, T_A = 25°C unless otherwise noted, P1 > P2)

Characteristic		Symbol	Min	Typ	Max	Units
Differential Pressure Range(1)		P_{OP}	0	—	100	kPa
Supply Voltage(2)		V_S	—	10	16	V_{DC}
Supply Current		I_O	—	6.0	—	mAdc
Full Scale Span(3)		V_{FSS}	38.5	40	41.5	mV
Offset(4)	MPX2102D Series MPX2102A Series	V_{OFF}	-1.0 -2.0	— —	1.0 2.0	mV
Sensitivity		$\Delta V/\Delta P$	—	0.4	—	mV/kPa
Linearity(5)	MPX2102D Series MPX2102A Series	— —	-0.6 -1.0	— —	0.4 1.0	$\%V_{FSS}$
Pressure Hysteresis(5) (0 to 100 kPa)		—	—	±0.1	—	$\%V_{FSS}$
Temperature Hysteresis(5)(- 40°C to +125°C)		—	—	±0.5	—	$\%V_{FSS}$
Temperature Coefficient of Full Scale Span(5)		TCV_{FSS}	-2.0	—	2.0	$\%V_{FSS}$
Temperature Coefficient of Offset(5)		TCV_{OFF}	-1.0	—	1.0	mV
Input Impedance		Z_{IN}	1000	—	2500	W
Output Impedance		Z_{OUT}	1400	—	3000	W
Response Time(6) (10% to 90%)		t_R	—	1.0	—	ms
Warm-Up Time		—	—	20	—	ms
Offset Stability(7)		—	—	±0.5	—	$\%V_{FSS}$

1. 1.0 kPa (kiloPascal) equals 0.145 psi.
2. Device is ratiometric within this specified excitation range. Operating the device above the specified excitation range may induce additional error due to device self-heating.
3. Full Scale Span (V_{FSS}) is defined as the algebraic difference between the output voltage at full rated pressure and the output voltage at the minimum related pressure.
4. Offset (V_{OFF}) is defined as the output voltage at the minimum rated pressure.
5. Accuracy (error budget) consists of the following:
   - Linearity: Output deviation from a straight line relationship with pressure, using end point method, over the specified pressure range.
   - Temperature Hysteresis: Output deviation at any temperature within the operating temperature range, after the temperature is cycled to and from the minimum or maximum operating temperature points, with zero differential pressure applied.
   - Pressure Hysteresis: Output deviation at any pressure with the specified range, when this pressure is cycled to and from the minimum or maximum rated pressure at 25°C.
   - TcSpan: Output deviation at full rated pressure over the temperature range of 0 to 85°C, relative to 25°C.
   - TcOffset: Output deviation with minimum rated pressure applied, over the temperature range of 0 to 85°C, relative to 25°C.
6. Response Time is defined as the time form the incremental change in the output to go from 10% to 90% of its final value when subjected to a specified step change in pressure.
7. Offset stability is the product's output deviation when subjected to 1000 hours of Pulsed Pressure, Temperature Cycling with Bias Test.

LINEARITY

Linearity refers to how well a transducer's output follows the equation: $V_{OUT} = V_{OFF}$ + sensitivity x P over the operating pressure range. There are two basic methods for calculating nonlinearity: (1) end point straight line fit (see Figure 2) or (2) a least squares best line fit. While a least squares fit gives the "best case" linearity error (lower numerical value), the calculations required are burdensome.

Conversely, an end point fit will give the "worst case" error (often more desirable in error budget calculations) and the calculations are more straightforward for the user. Freescale's specified pressure sensor linearities are based on the end point straight line method measured at the midrange pressure.

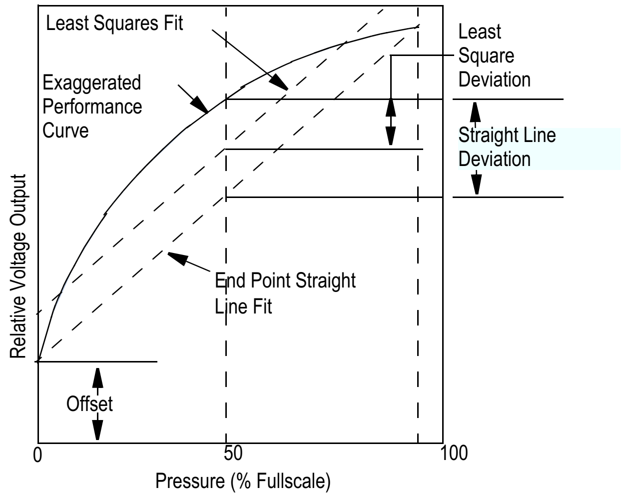


Figure 2. Linearity Specification Comparison

ON-CHIP TEMPERATURE COMPENSATION AND CALIBRATION

Figure 3 shows the output characteristics of the MPX2102/MPXV2102G series at 25°C. The output is directly proportional to the differential pressure and is essentially a straight line.

The effects of temperature on Full Scale Span and Offset are very small and are shown under Operating Characteristics.

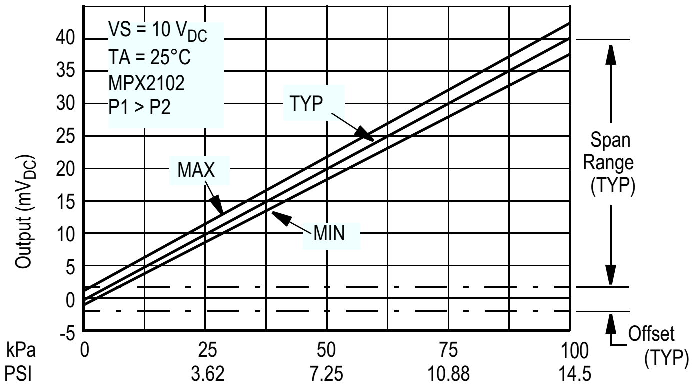


Figure 3. Output vs. Pressure Differential

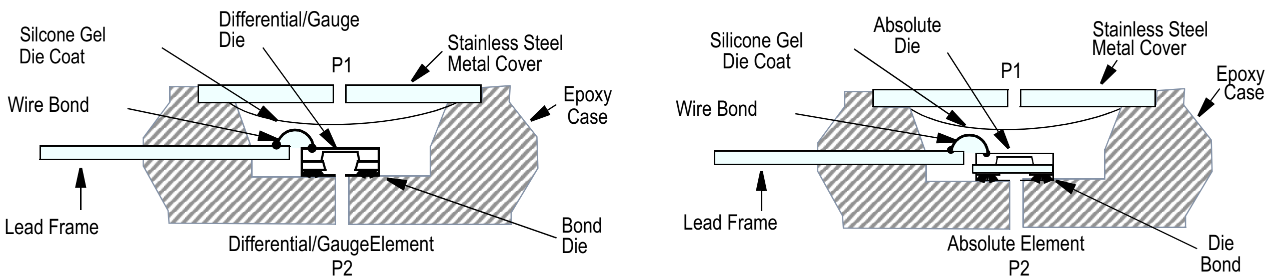


Figure 4. Cross Sectional Diagrams (Not to Scale)

Figure 4 illustrates the absolute sensing configuration (right) and the differential or gauge configuration in the basic chip carrier (Case 344). A silicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the silicon diaphragm.

The MPX2102/MPXV2102G series pressure sensor operating characteristics and internal reliability and qualification tests are based on use of dry air as the pressure media. Media other than dry air may have adverse effects on sensor performance and long term reliability. Contact the factory for information regarding media compatibility in your application.

PRESSURE (P1)/VACUUM (P2) SIDE IDENTIFICATION TABLE

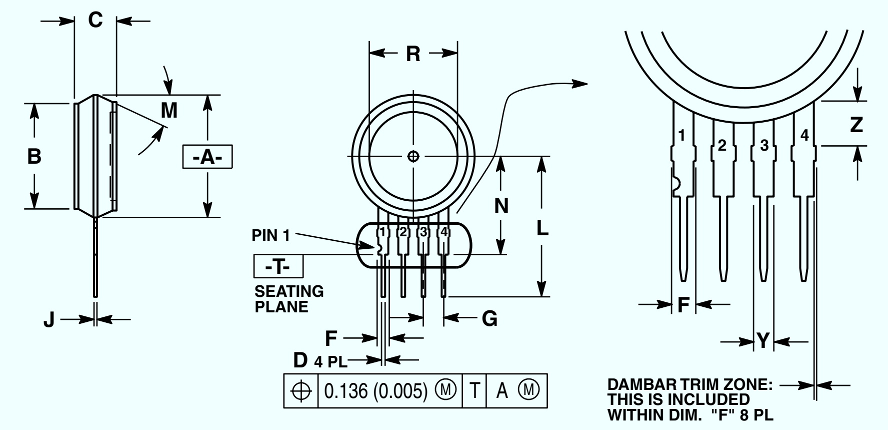
Freescale designates the two sides of the pressure sensor as the Pressure (P1) side and the Vacuum (P2) side. The Pressure (P1) side is the side containing the silicone gel which isolates the die. The differential or gauge sensor is designed to operate with positive differential pressure applied, P1 > P2. The absolute sensor is designed for vacuum applied to P1 side.

The Pressure (P1) side may be identified by using Table 3.

Table 3. Pressure (P1) Side Delineation

Part Number		Case Type	Pressure (P1) Side Identifier
MPX2102A	MPX2102D	344	Stainless Steep Cap
MPX2102DP		344C	Side with Part Marking
MPX2102AP	MPX2102GP	344B	Side with Port Attached
MPX2102GVP		344D	Stainless Steep Cap
MPX2102ASX	MPX2102GSX	344F	Side with Port Marking
MPX2102GP		1369	Side with Port Attached
MPX2102DP		1351	Side with Part Marking

PACKAGE DIMENSIONS



NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION -A- IS INCLUSIVE OF THE MOLD STOP RING. MOLD STOP RING NOT TO EXCEED 16.00 (0.630).

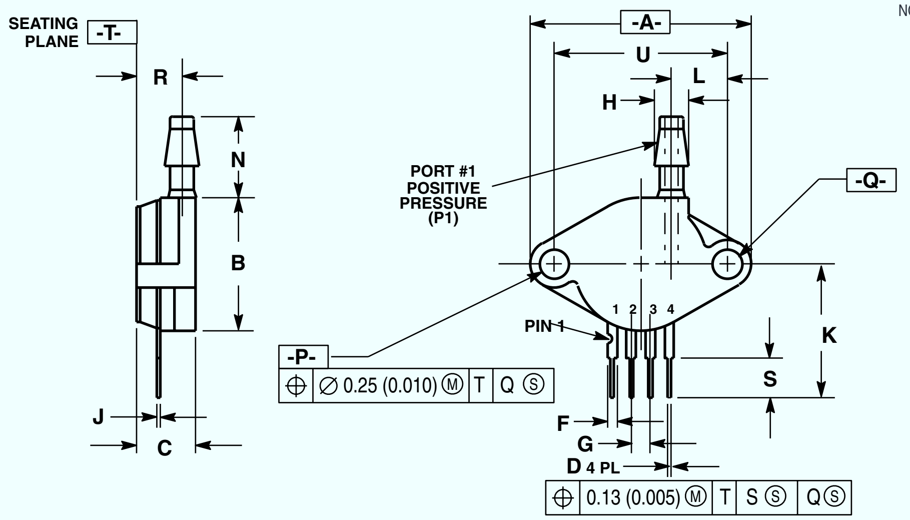
DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.595	0.630	15.11	16.00
B	0.514	0.534	13.06	13.56
C	0.200	0.220	5.08	5.59
D	0.016	0.020	0.41	0.51
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.40
L	0.695	0.725	17.65	18.42
M	30˚ NOM		30˚ NOM	
N	0.475	0.495	12.07	12.57
R	0.430	0.450	10.92	11.43
Y	0.048	0.052	1.22	1.32
Z	0.106	0.118	2.68	3.00

STYLE 1:
PIN 1. GROUND
2. + OUTPUT
3. + SUPPLY
4. - OUTPUT

STYLE 2:
PIN 1. V_{CC}
2. - SUPPLY
3. + SUPPLY
4. GROUND

STYLE 3:
PIN 1. GND
2. -VOUT
3. VS
4. +VOUT

CASE 344-15
ISSUE AA
UNIBODY PACKAGE



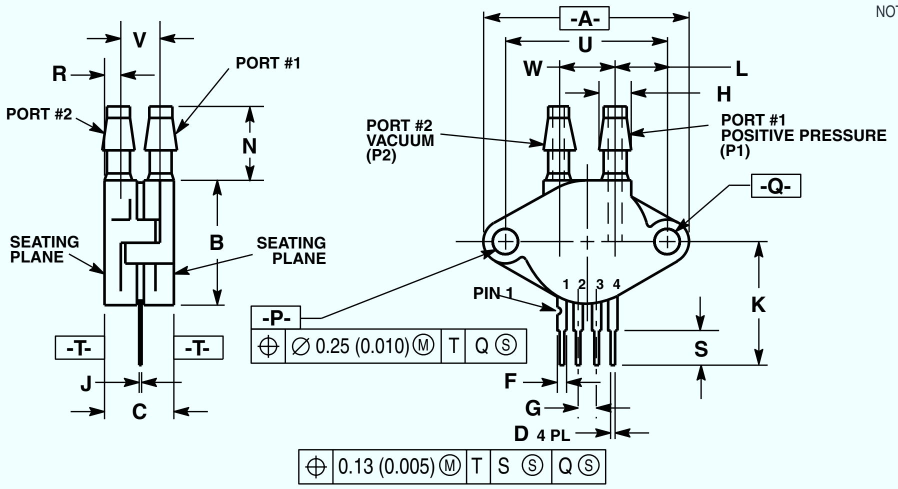
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.305	0.325	7.75	8.26
D	0.016	0.020	0.41	0.51
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
H	0.182	0.194	4.62	4.93
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.159	3.89	4.04
R	0.230	0.250	5.84	6.35
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	

STYLE 1:
PIN 1. GROUND
2. + OUTPUT
3. + SUPPLY
4. - OUTPUT

CASE 344B-01
ISSUE B
UNIBODY PACKAGE

PACKAGE DIMENSIONS



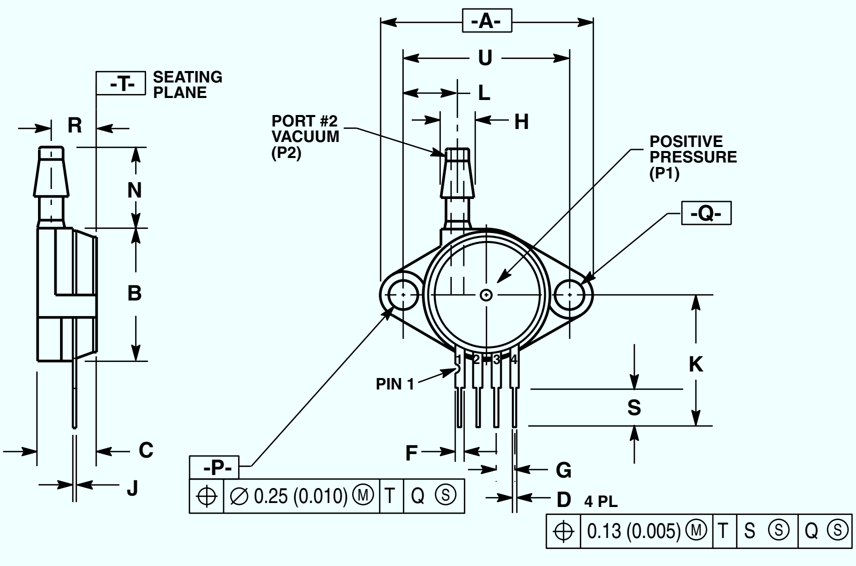
NOTES:

1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.405	0.435	10.29	11.05
D	0.016	0.020	0.41	0.51
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
H	0.182	0.194	4.62	4.93
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.159	3.89	4.04
R	0.063	0.083	1.60	2.11
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	
V	0.248	0.278	6.30	7.06
W	0.310	0.330	7.87	8.38

STYLE 1:
PIN 1. GROUND
2. + OUTPUT
3. + SUPPLY
4. - OUTPUT

CASE 344C-01
ISSUE B
UNIBODY PACKAGE



NOTES:

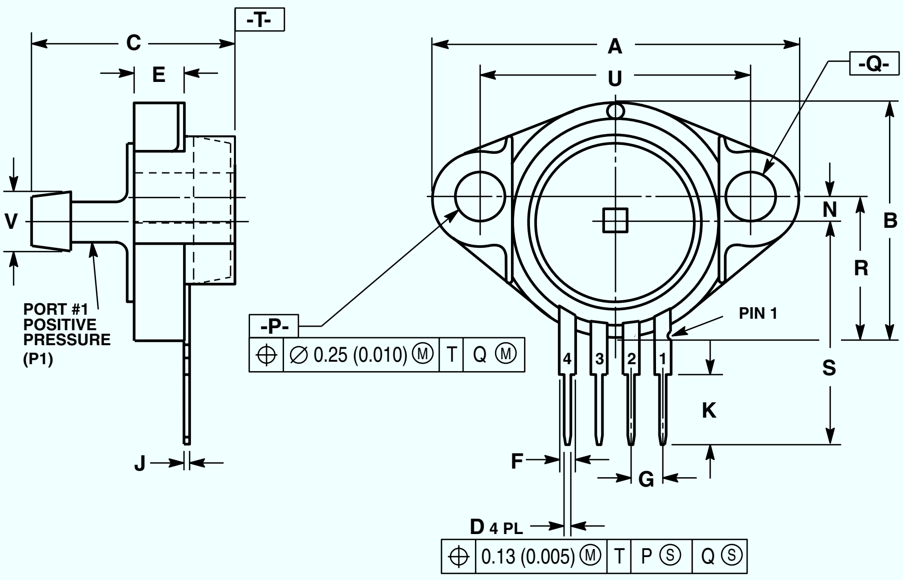
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCH.

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	1.145	1.175	29.08	29.85
B	0.685	0.715	17.40	18.16
C	0.305	0.325	7.75	8.26
D	0.016	0.020	0.41	0.51
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
H	0.182	0.194	4.62	4.93
J	0.014	0.016	0.36	0.41
K	0.695	0.725	17.65	18.42
L	0.290	0.300	7.37	7.62
N	0.420	0.440	10.67	11.18
P	0.153	0.159	3.89	4.04
Q	0.153	0.158	3.89	4.04
R	0.230	0.250	5.84	6.35
S	0.220	0.240	5.59	6.10
U	0.910 BSC		23.11 BSC	

STYLE 1:
PIN 1. GROUND
2. + OUTPUT
3. + SUPPLY
4. - OUTPUT

CASE 344D-01
ISSUE B
UNIBODY PACKAGE

PACKAGE DIMENSIONS

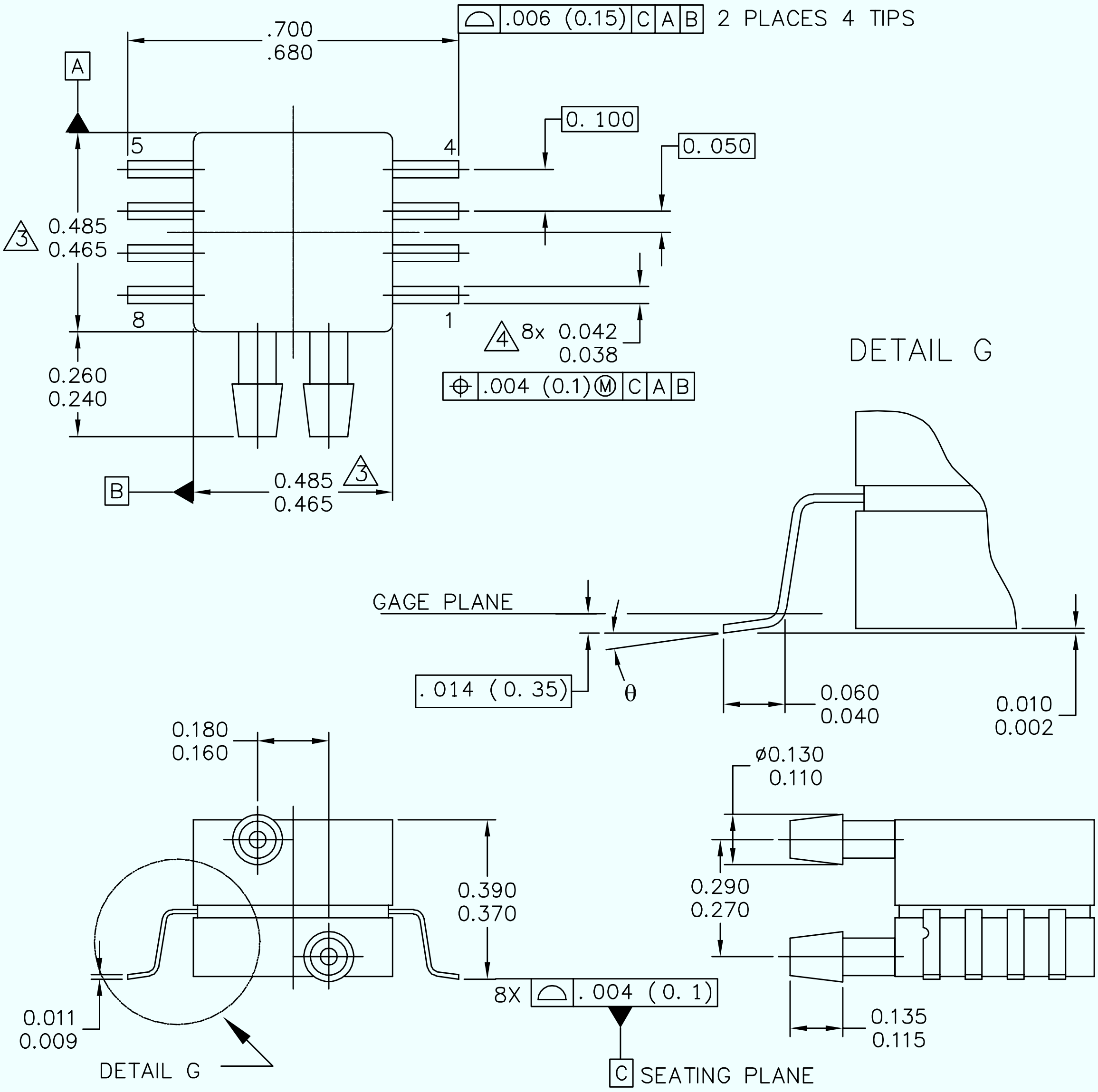


NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	1.080	1.120	27.43	28.45
B	0.740	0.760	18.80	19.30
C	0.630	0.650	16.00	16.51
D	0.016	0.020	0.41	0.51
E	0.160	0.180	4.06	4.57
F	0.048	0.064	1.22	1.63
G	0.100 BSC		2.54 BSC	
J	0.014	0.016	0.36	0.41
K	0.220	0.240	5.59	6.10
N	0.070	0.080	1.78	2.03
P	0.150	0.160	3.81	4.06
Q	0.150	0.160	3.81	4.06
R	0.440	0.460	11.18	11.68
S	0.695	0.725	17.65	18.42
U	0.840	0.860	21.34	21.84
V	0.182	0.194	4.62	4.92

STYLE 1:
PIN 1. GROUND
2. V (+) OUT
3. V SUPPLY
4. V (-) OUT

CASE 344F-01
ISSUE B
UNIBODY PACKAGE



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	CASE NUMBER: 1351-01	27 JUL 2005
	STANDARD: NON-JEDEC	

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CASE 1351-01
ISSUE A
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PACKAGE DIMENSIONS

NOTES:

1. CONTROLLING DIMENSION: INCH
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M–1994.
3. DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PPROTRUSIONS. MOLD FLASH AND PROTRUSIONS SHALL NOT EXCEED .006 PER SIDE.
4. DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .008 MAXIMUM.

STYLE 1:		STYLE 2:	
PIN 1:	GND	PIN 1:	N/C
PIN 2:	+Vout	PIN 2:	Vs
PIN 3:	Vs	PIN 3:	GND
PIN 4:	–Vout	PIN 4:	Vout
PIN 5:	N/C	PIN 5:	N/C
PIN 6:	N/C	PIN 6:	N/C
PIN 7:	N/C	PIN 7:	N/C
PIN 8:	N/C	PIN 8:	N/C

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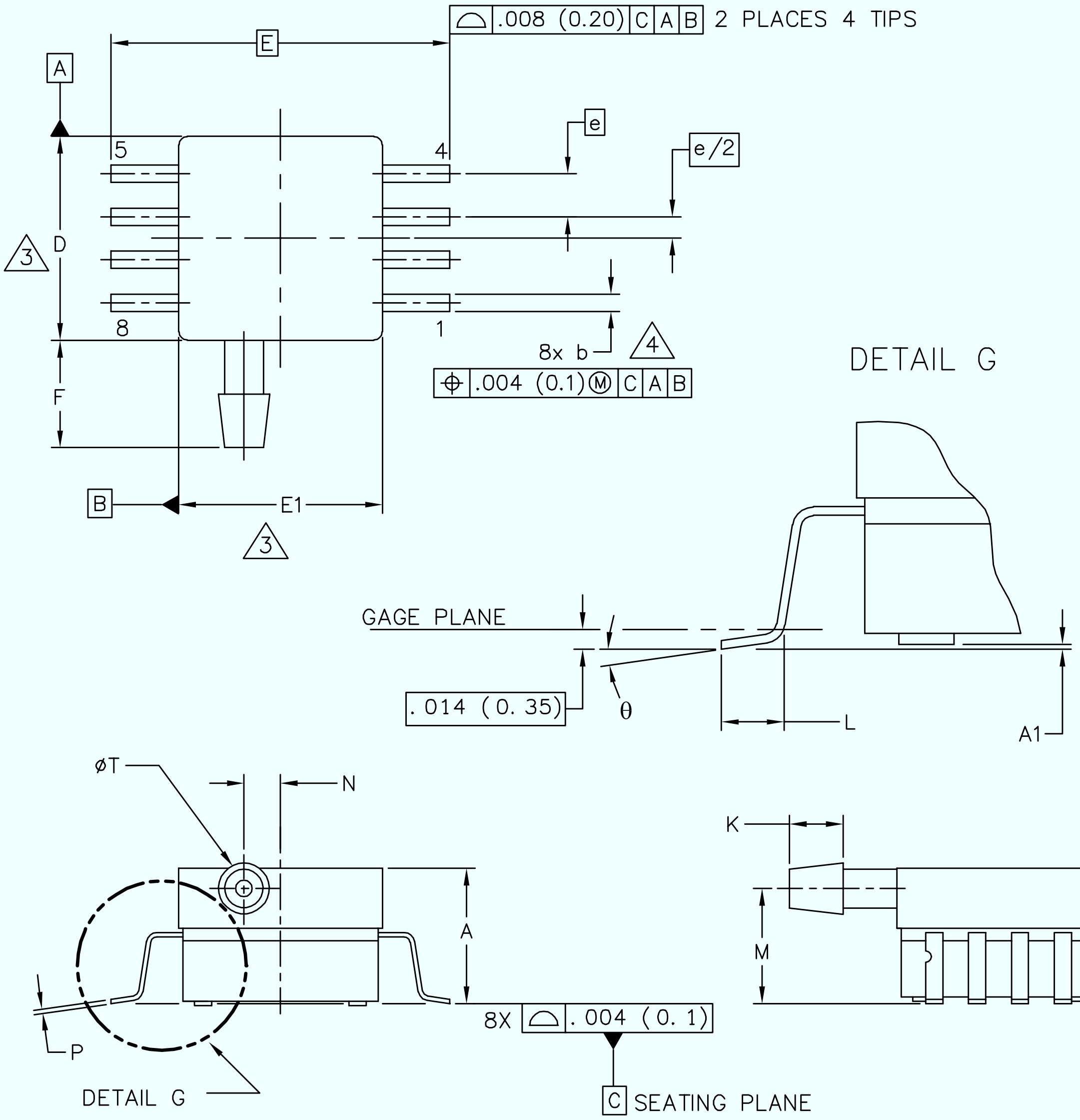
CASE 1351-01
ISSUE A
SMALL OUTLINE PACKAGE



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	CASE NUMBER: 1369-01		24 MAY 2005
	STANDARD: NON-JEDEC		

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CASE 1369-01
ISSUE B
SMALL OUTLINE PACKAGE

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NOTES:
1. CONTROLLING DIMENSION: INCH
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M—1994.
3. DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PPROTRUSIONS. MOLD FLASH AND PROTRUSIONS SHALL NOT EXCEED .006 (0.152) PER SIDE.
4. DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE .008 (0.203) MAXIMUM.

DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX	DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	.300	.330	7.11	7.62	θ	0°	7°	0°	7°
A1	.002	.010	0.05	0.25	–	---	---	---	---
b	.038	.042	0.96	1.07	–	---	---	---	---
D	.465	.485	11.81	12.32	–	---	---	---	---
E	.717 BSC		18.21 BSC		–	---	---	---	---
E1	.465	.485	11.81	12.32	–	---	---	---	---
e	.100 BSC		2.54 BSC		–	---	---	---	---
F	.245	.255	6.22	6.47	–	---	---	---	---
K	.120	.130	3.05	3.30	–	---	---	---	---
L	.061	.071	1.55	1.80	–	---	---	---	---
M	.270	.290	6.86	7.36	–	---	---	---	---
N	.080	.090	2.03	2.28	–	---	---	---	---
P	.009	.011	0.23	0.28	–	---	---	---	---
T	.115	.125	2.92	3.17	–	---	---	---	---

MECHANICAL OUTLINE	PRINT VERSION NOT TO SCALE	
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	CASE NUMBER: 1369–01	24 MAY 2005
	STANDARD: NON–JEDEC	

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CASE 1369-01
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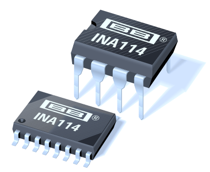


INA114

Precision INSTRUMENTATION AMPLIFIER

FEATURES

- LOW OFFSET VOLTAGE: 50µV max
- LOW DRIFT: 0.25µV/°C max
- LOW INPUT BIAS CURRENT: 2nA max
- HIGH COMMON-MODE REJECTION: 115dB min
- INPUT OVER-VOLTAGE PROTECTION: ±40V
- WIDE SUPPLY RANGE: ±2.25 to ±18V
- LOW QUIESCENT CURRENT: 3mA max
- 8-PIN PLASTIC AND SOL-16

APPLICATIONS

- BRIDGE AMPLIFIER
- THERMOCOUPLE AMPLIFIER
- RTD SENSOR AMPLIFIER
- MEDICAL INSTRUMENTATION
- DATA ACQUISITION

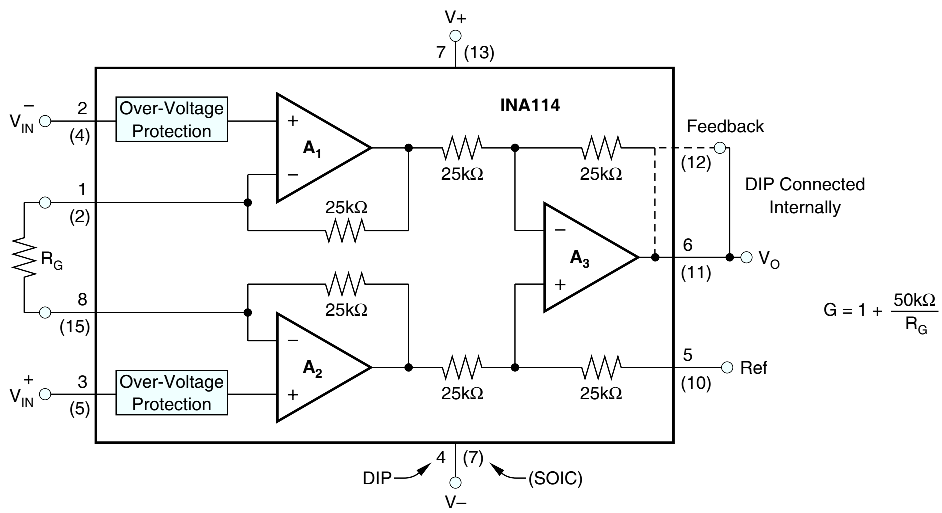
DESCRIPTION

The INA114 is a low cost, general purpose instrumentation amplifier offering excellent accuracy. Its versatile 3-op amp design and small size make it ideal for a wide range of applications.

A single external resistor sets any gain from 1 to 10,000. Internal input protection can withstand up to ±40V without damage.

The INA114 is laser trimmed for very low offset voltage (50µV), drift (0.25µV/°C) and high common-mode rejection (115dB at G = 1000). It operates with power supplies as low as ±2.25V, allowing use in battery operated and single 5V supply systems. Quiescent current is 3mA maximum.

The INA114 is available in 8-pin plastic and SOL-16 surface-mount packages. Both are specified for the –40°C to +85°C temperature range.



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Internet: http://www.burr-brown.com/ • FAXLine: (800) 548-6133 (US/Canada Only) • Cable: BBRCORP • Telex: 066-6491 • FAX: (520) 889-1510 • Immediate Product Info: (800) 548-6132

PDS-1142D

Printed in U.S.A. March, 1998

SBOS014

SPECIFICATIONS

ELECTRICAL

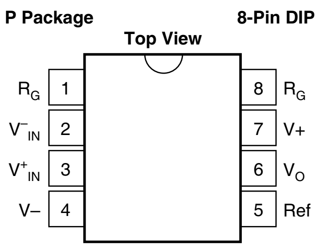
At T_A = +25°C, V_S = ±15V, R_L = 2kΩ, unless otherwise noted.

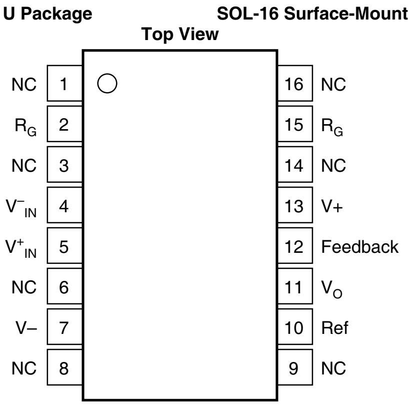
		INA114BP, BU			INA114AP, AU			
PARAMETER	**CONDITIONS**	**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**UNITS**
INPUT								
Offset Voltage, RTI								
Initial	T_A = +25°C		±10 + 20/G	±50 + 100/G		±25 + 30/G	±125 + 500/G	μV
vs Temperature	$T_A = T_{MIN}$ to T_{MAX}		±0.1 + 0.5/G	±0.25 + 5/G		±0.25 + 5/G	±1 + 10/G	μV/°C
vs Power Supply	V_S = ±2.25V to ±18V		0.5 + 2/G	3 + 10/G		✻	✻	μV/V
Long-Term Stability			±0.2 + 0.5/G			✻		μV/mo
Impedance, Differential			10^{10} ∥ 6			✻		Ω ∥ pF
Common-Mode			10^{10} ∥ 6			✻		Ω ∥ pF
Input Common-Mode Range		±11	±13.5		✻	✻		V
Safe Input Voltage				±40			✻	V
Common-Mode Rejection	V_{CM} = ±10V, ΔR_S = 1kΩ							
	G = 1	80	96		75	90		dB
	G = 10	96	115		90	106		dB
	G = 100	110	120		106	110		dB
	G = 1000	115	120		106	110		dB
BIAS CURRENT			±0.5	±2		✻	±5	nA
vs Temperature			±8			✻		pA/°C
OFFSET CURRENT			±0.5	±2		✻	±5	nA
vs Temperature			±8			✻		pA/°C
NOISE VOLTAGE, RTI	G = 1000, R_S = 0Ω							
f = 10Hz			15			✻		nV/√Hz
f = 100Hz			11			✻		nV/√Hz
f = 1kHz			11			✻		nV/√Hz
f_B = 0.1Hz to 10Hz			0.4			✻		μVp-p
Noise Current								
f=10Hz			0.4			✻		pA/√Hz
f=1kHz			0.2			✻		pA/√Hz
f_B = 0.1Hz to 10Hz			18			✻		pAp-p
GAIN								
Gain Equation			1 + (50kΩ/R_G)			✻		V/V
Range of Gain		1		10000	✻		✻	V/V
Gain Error	G = 1		±0.01	±0.05		✻	✻	%
	G = 10		±0.02	±0.4		✻	±0.5	%
	G = 100		±0.05	±0.5		✻	±0.7	%
	G = 1000		±0.5	±1		✻	±2	%
Gain vs Temperature	G = 1		±2	±10		✻	±10	ppm/°C
50kΩ Resistance(1)			±25	±100		✻	✻	ppm/°C
Nonlinearity	G = 1		±0.0001	±0.001		✻	±0.002	% of FSR
	G = 10		±0.0005	±0.002		✻	±0.004	% of FSR
	G = 100		±0.0005	±0.002		✻	±0.004	% of FSR
	G = 1000		±0.002	±0.01		✻	±0.02	% of FSR
OUTPUT								
Voltage	I_O = 5mA, T_{MIN} to T_{MAX}	±13.5	±13.7		✻	✻		V
	V_S = ±11.4V, R_L = 2kΩ	±10	±10.5		✻	✻		V
	V_S = ±2.25V, R_L = 2kΩ	±1	±1.5		✻	✻		V
Load Capacitance Stability			1000			✻		pF
Short Circuit Current			+20/–15			✻		mA
FREQUENCY RESPONSE								
Bandwidth, –3dB	G = 1		1			✻		MHz
	G = 10		100			✻		kHz
	G = 100		10			✻		kHz
	G = 1000		1			✻		kHz
Slew Rate	V_O = ±10V, G = 10	0.3	0.6		✻	✻		V/μs
Settling Time, 0.01%	G = 1		18			✻		μs
	G = 10		20			✻		μs
	G = 100		120			✻		μs
	G = 1000		1100			✻		μs
Overload Recovery	50% Overdrive		20			✻		μs
POWER SUPPLY								
Voltage Range		±2.25	±15	±18	✻	✻	✻	V
Current	V_{IN} = 0V		±2.2	±3		✻	✻	mA
TEMPERATURE RANGE								
Specification		–40		85	✻		✻	°C
Operating		–40		125	✻		✻	°C
θ_{JA}			80			✻		°C/W

✻ Specification same as INA114BP/BU.

NOTE: (1) Temperature coefficient of the “50kΩ” term in the gain equation.

PIN CONFIGURATIONS





ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)	TEMPERATURE RANGE
INA114AP	8-Pin Plastic DIP	006	–40°C to +85°C
INA114BP	8-Pin Plastic DIP	006	–40°C to +85°C
INA114AU	SOL-16 Surface-Mount	211	–40°C to +85°C
INA114BU	SOL-16 Surface-Mount	211	–40°C to +85°C

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

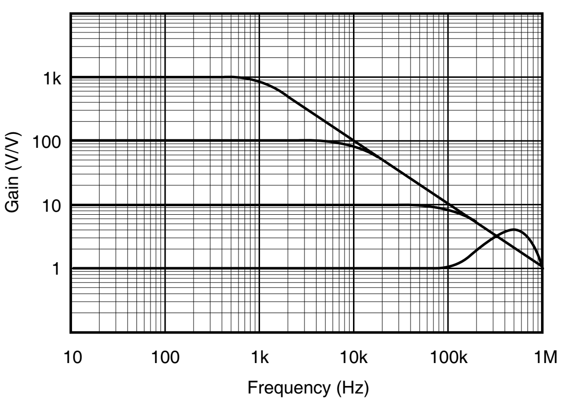
ABSOLUTE MAXIMUM RATINGS(1)

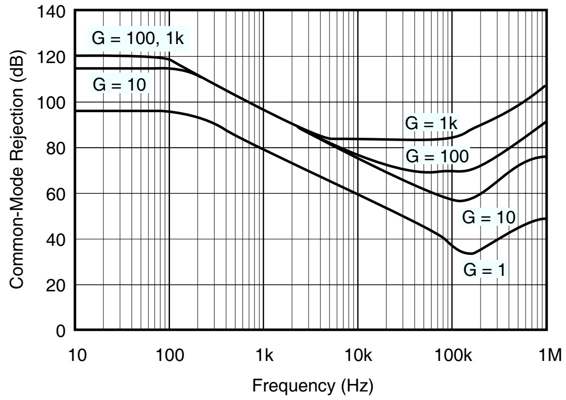
Supply Voltage	±18V
Input Voltage Range	±40V
Output Short-Circuit (to ground)	Continuous
Operating Temperature	–40°C to +125°C
Storage Temperature	–40°C to +125°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

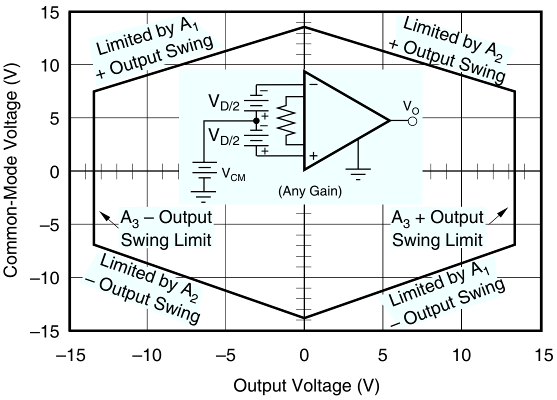
NOTE: (1) Stresses above these ratings may cause permanent damage.

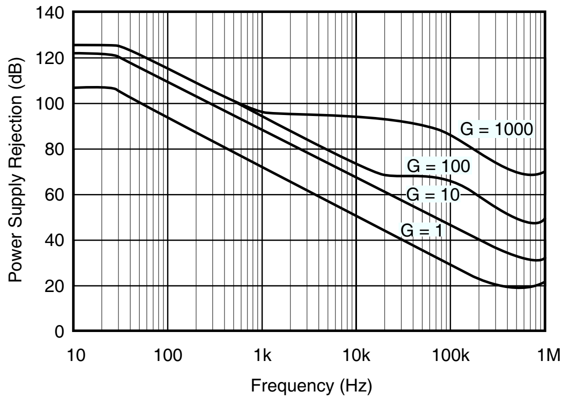
TYPICAL PERFORMANCE CURVES

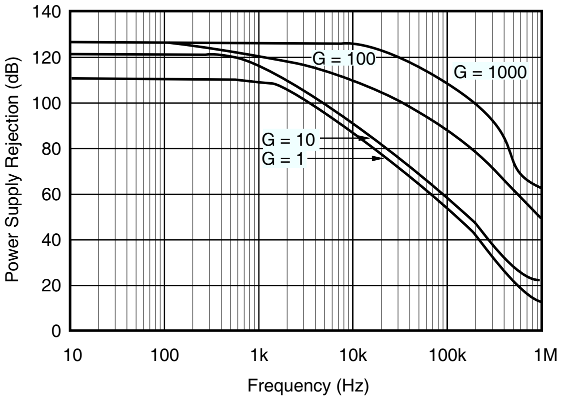
At T_A = +25°C, V_S = ±15V, unless otherwise noted.

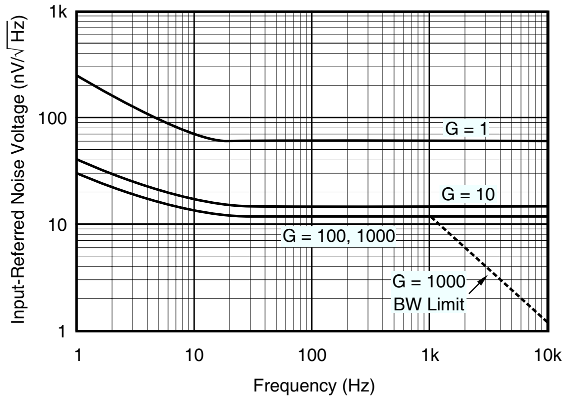








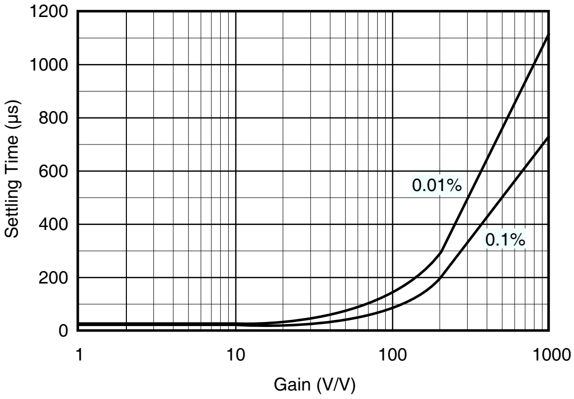




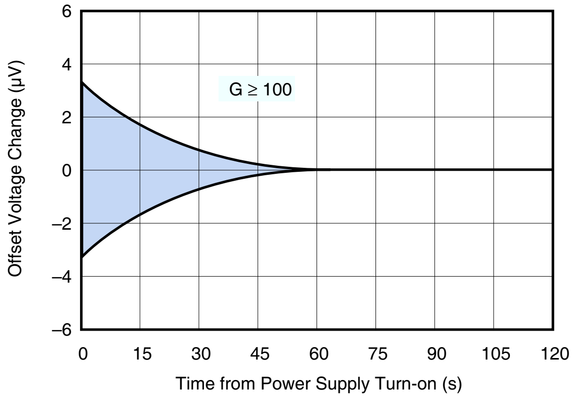
TYPICAL PERFORMANCE CURVES (CONT)

At T_A = +25°C, V_S = ±15V, unless otherwise noted.

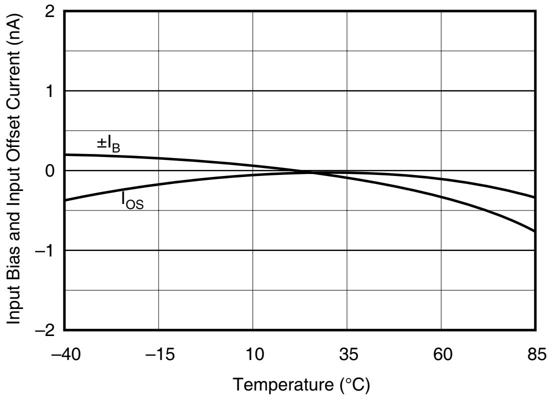
SETTLING TIME vs GAIN



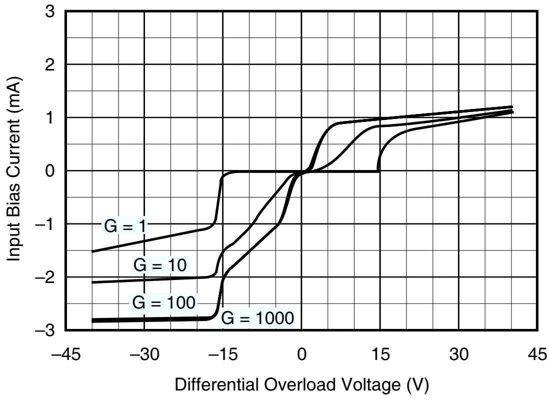
OFFSET VOLTAGE WARM-UP vs TIME



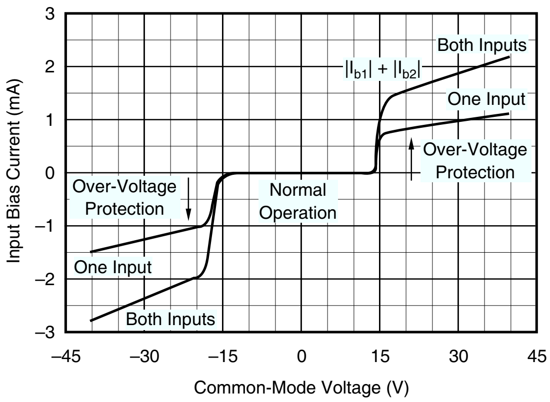
INPUT BIAS AND INPUT OFFSET CURRENT vs TEMPERATURE



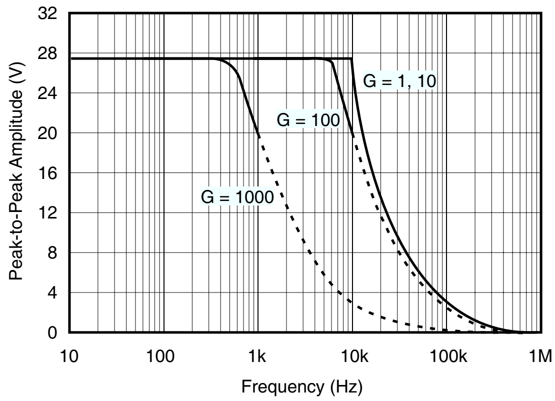
INPUT BIAS CURRENT vs DIFFERENTIAL INPUT VOLTAGE



INPUT BIAS CURRENT vs COMMON-MODE INPUT VOLTAGE

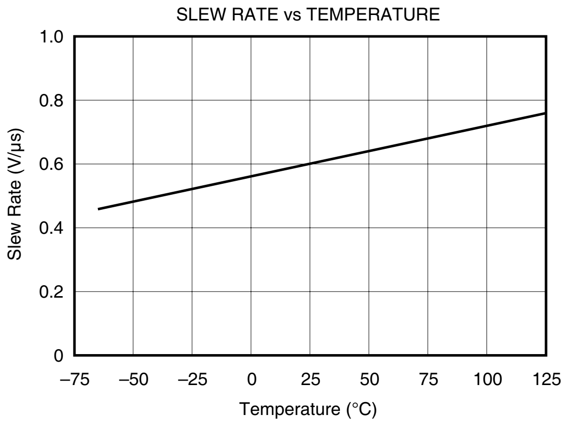


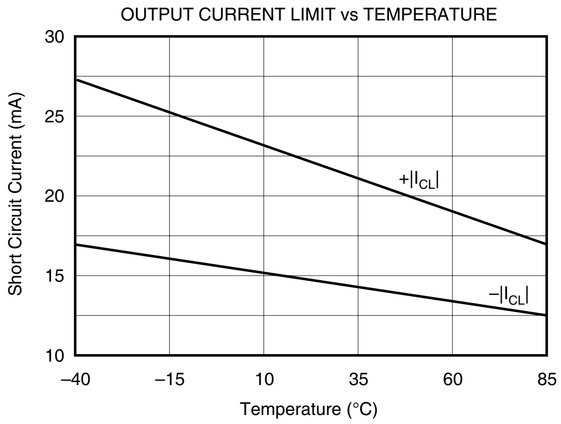
MAXIMUM OUTPUT SWING vs FREQUENCY

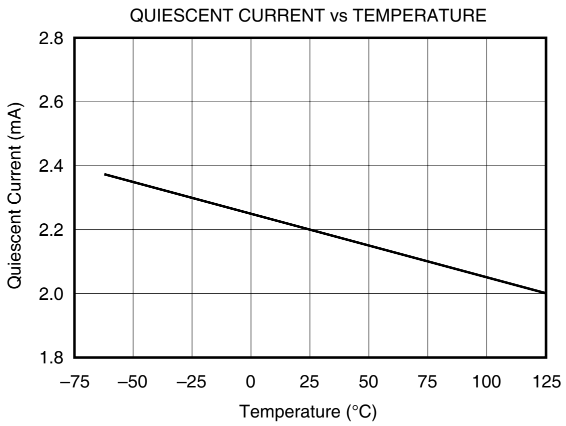


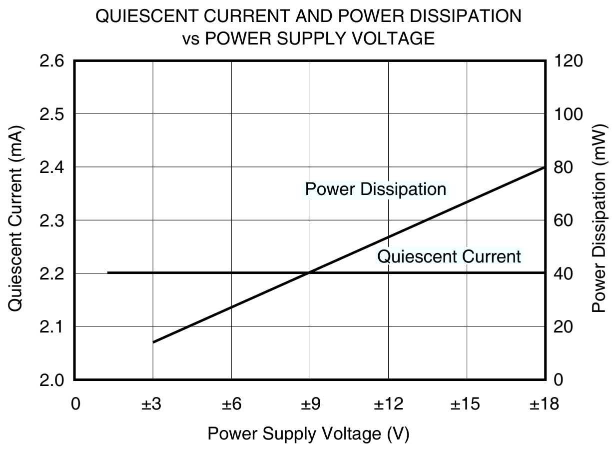
TYPICAL PERFORMANCE CURVES (CONT)

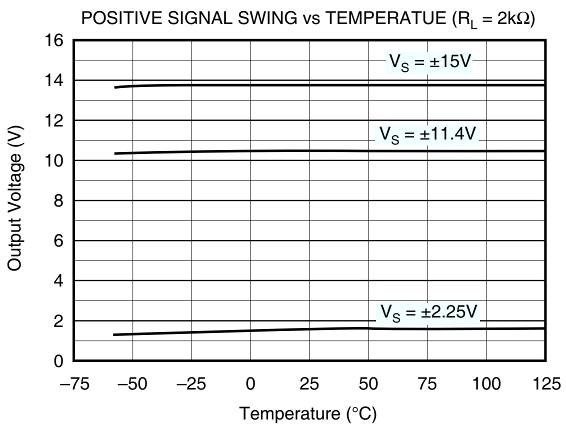
At T_A = +25°C, V_S = ±15V, unless otherwise noted.

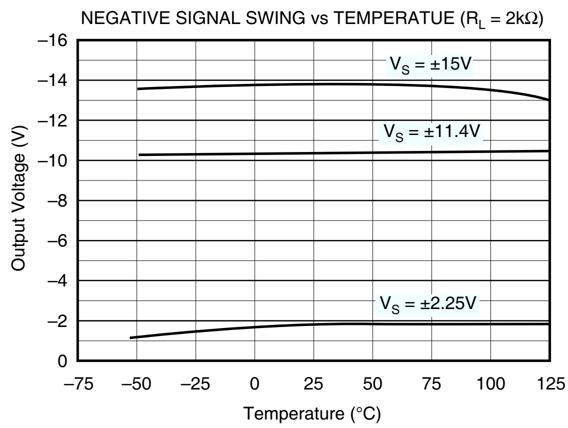






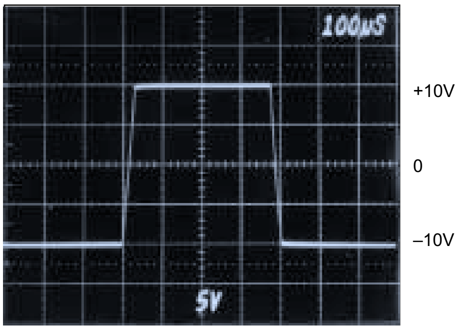




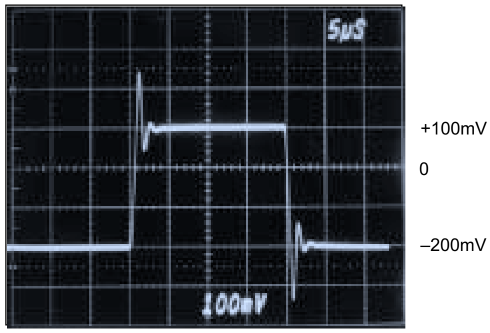


TYPICAL PERFORMANCE CURVES (CONT)

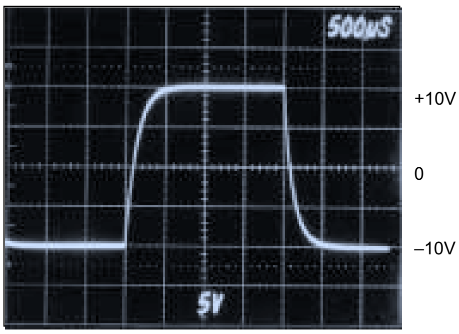
At T_A = +25°C, V_S = ±15V, unless otherwise noted.



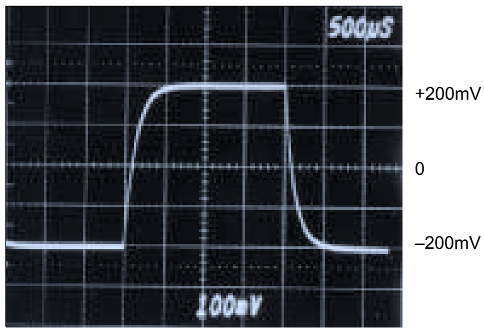
LARGE SIGNAL RESPONSE, G = 1



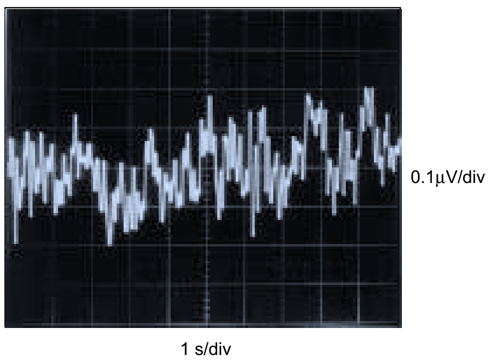
SMALL SIGNAL RESPONSE, G = 1



LARGE SIGNAL RESPONSE, G = 1000



SMALL SIGNAL RESPONSE, G = 1000



INPUT-REFERRED NOISE, 0.1 to 10Hz

APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA114. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins as shown.

The output is referred to the output reference (Ref) terminal which is normally grounded. This must be a low-impedance connection to assure good common-mode rejection. A resistance of 5Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR (G = 1).

SETTING THE GAIN

Gain of the INA114 is set by connecting a single external resistor, R_G:

$$G = 1 + \frac{50\ k\Omega}{R_G} \quad (1)$$

Commonly used gains and resistor values are shown in Figure 1.

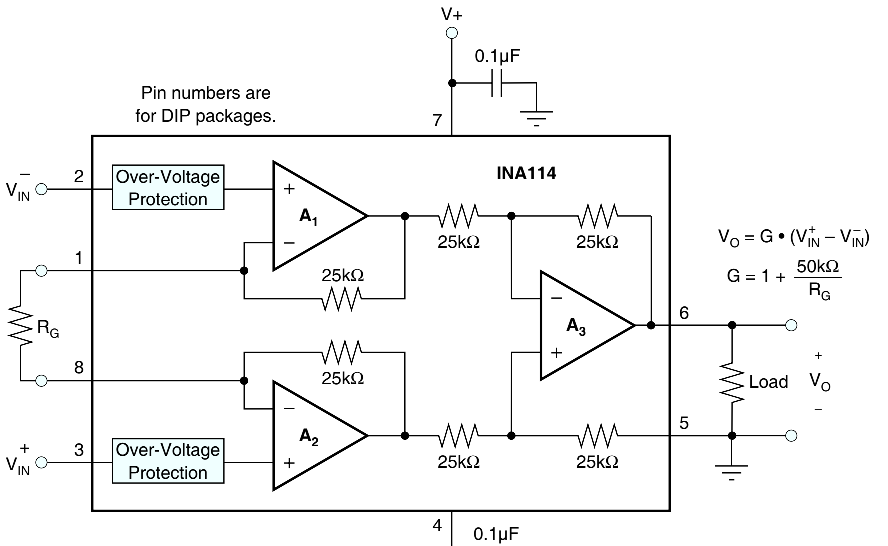
The 50kΩ term in equation (1) comes from the sum of the two internal feedback resistors. These are on-chip metal film resistors which are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA114.

The stability and temperature drift of the external gain setting resistor, R_G, also affects gain. R_G's contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance which will contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater.

NOISE PERFORMANCE

The INA114 provides very low noise in most applications. For differential source impedances less than 1kΩ, the INA103 may provide lower noise. For source impedances greater than 50kΩ, the INA111 FET-input instrumentation amplifier may provide lower noise.

Low frequency noise of the INA114 is approximately 0.4μVp-p measured from 0.1 to 10Hz. This is approximately one-tenth the noise of "low noise" chopper-stabilized amplifiers.



DESIRED GAIN	R_G (Ω)	NEAREST 1% R_G (Ω)
1	No Connection	No Connection
2	50.00k	49.9k
5	12.50k	12.4k
10	5.556k	5.62k
20	2.632k	2.61k
50	1.02k	1.02k
100	505.1	511
200	251.3	249
500	100.2	100
1000	50.05	49.9
2000	25.01	24.9
5000	10.00	10
10000	5.001	4.99

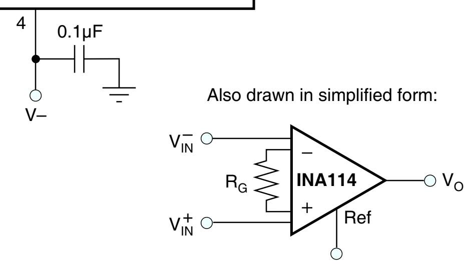


FIGURE 1. Basic Connections.

OFFSET TRIMMING

The INA114 is laser trimmed for very low offset voltage and drift. Most applications require no external offset adjustment. Figure 2 shows an optional circuit for trimming the output offset voltage. The voltage applied to Ref terminal is summed at the output. Low impedance must be maintained at this node to assure good common-mode rejection. This is achieved by buffering trim voltage with an op amp as shown.

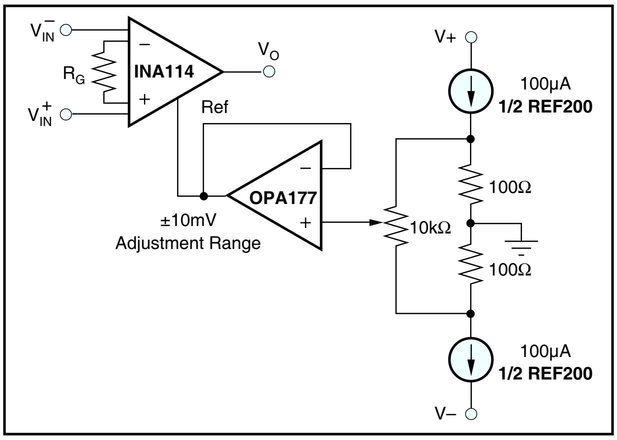


FIGURE 2. Optional Trimming of Output Offset Voltage.

INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA114 is extremely high—approximately $10^{10}\Omega$. However, a path must be provided for the input bias current of both inputs. This input bias current is typically less than ±1nA (it can be either polarity due to cancellation circuitry). High input impedance means that this input bias current changes very little with varying input voltage.

Input circuitry must provide a path for this input bias current if the INA114 is to operate properly. Figure 3 shows various provisions for an input bias current path. Without a bias current return path, the inputs will float to a potential which exceeds the common-mode range of the INA114 and the input amplifiers will saturate. If the differential source resistance is low, bias current return path can be connected to one input (see thermocouple example in Figure 3). With higher source impedance, using two resistors provides a balanced input with possible advantages of lower input offset voltage due to bias current and better common-mode rejection.

INPUT COMMON-MODE RANGE

The linear common-mode range of the input op amps of the INA114 is approximately ±13.75V (or 1.25V from the power supplies). As the output voltage increases, however, the linear input range will be limited by the output voltage swing of the input amplifiers, A_1 and A_2. The common-mode range is related to the output voltage of the complete amplifier—see performance curve "Input Common-Mode Range vs Output Voltage."

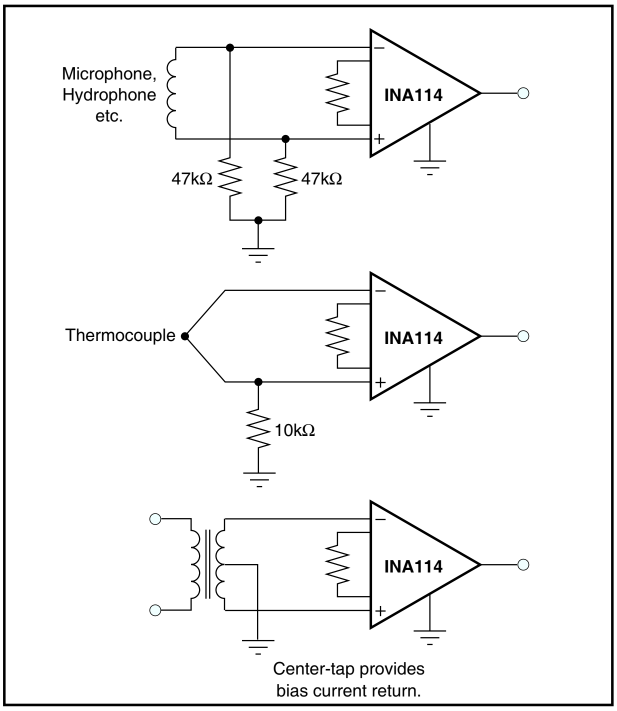


FIGURE 3. Providing an Input Common-Mode Current Path.

A combination of common-mode and differential input signals can cause the output of A_1 or A_2 to saturate. Figure 4 shows the output voltage swing of A_1 and A_2 expressed in terms of a common-mode and differential input voltages. Output swing capability of these internal amplifiers is the same as the output amplifier, A_3. For applications where input common-mode range must be maximized, limit the output voltage swing by connecting the INA114 in a lower gain (see performance curve "Input Common-Mode Voltage Range vs Output Voltage"). If necessary, add gain after the INA114 to increase the voltage swing.

Input-overload often produces an output voltage that appears normal. For example, an input voltage of +20V on one input and +40V on the other input will obviously exceed the linear common-mode range of both input amplifiers. Since both input amplifiers are saturated to nearly the same output voltage limit, the difference voltage measured by the output amplifier will be near zero. The output of the INA114 will be near 0V even though both inputs are overloaded.

INPUT PROTECTION

The inputs of the INA114 are individually protected for voltages up to ±40V. For example, a condition of –40V on one input and +40V on the other input will not cause damage. Internal circuitry on each input provides low series impedance under normal signal conditions. To provide equivalent protection, series input resistors would contribute excessive noise. If the input is overloaded, the protection circuitry limits the input current to a safe value (approximately 1.5mA). The typical performance curve "Input Bias Current vs Common-Mode Input Voltage" shows this input current limit behavior. The inputs are protected even if no power supply voltage is present.

OUTPUT VOLTAGE SENSE (SOL-16 package only)

The surface-mount version of the INA114 has a separate output sense feedback connection (pin 12). Pin 12 must be connected to the output terminal (pin 11) for proper operation. (This connection is made internally on the DIP version of the INA114.)

The output sense connection can be used to sense the output voltage directly at the load for best accuracy. Figure 5 shows how to drive a load through series interconnection resistance. Remotely located feedback paths may cause instability. This can be generally be eliminated with a high frequency feedback path through C_1. Heavy loads or long lines can be driven by connecting a buffer inside the feedback path (Figure 6).

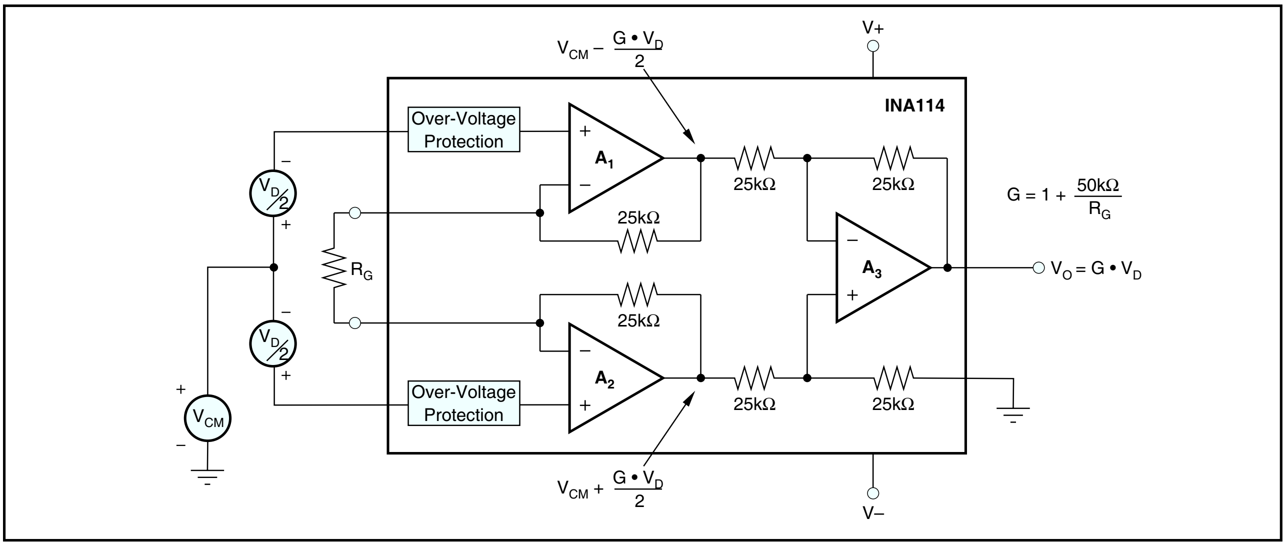


FIGURE 4. Voltage Swing of A_1 and A_2.

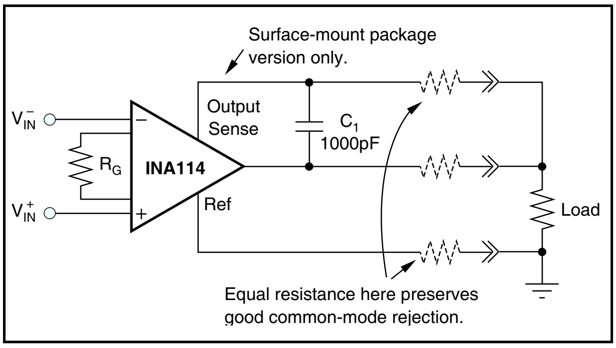


FIGURE 5. Remote Load and Ground Sensing.

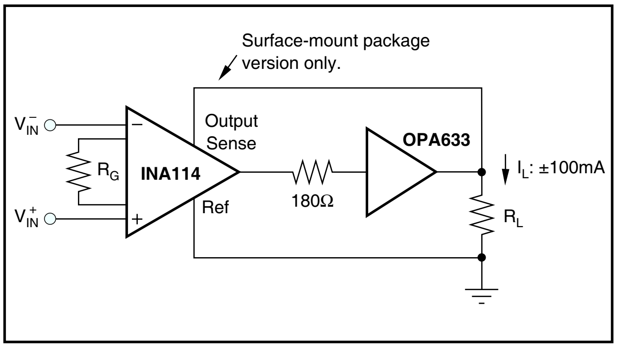


FIGURE 6. Buffered Output for Heavy Loads.

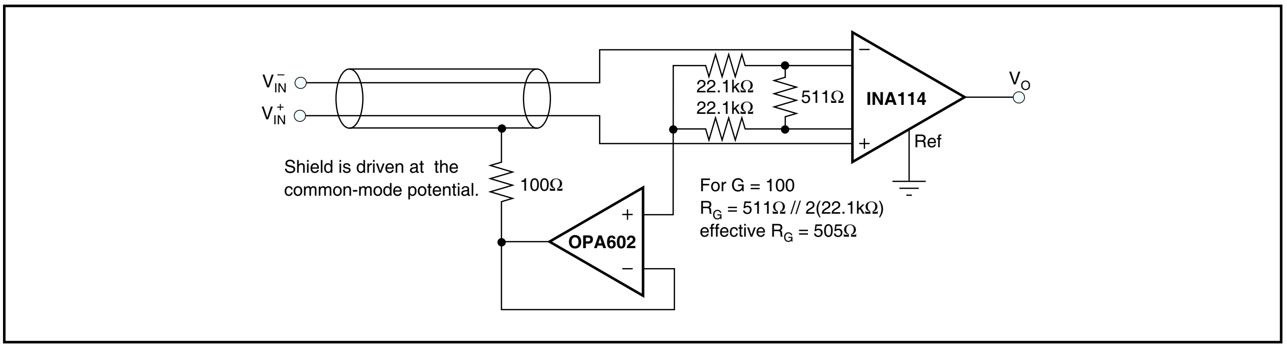


FIGURE 7. Shield Driver Circuit.

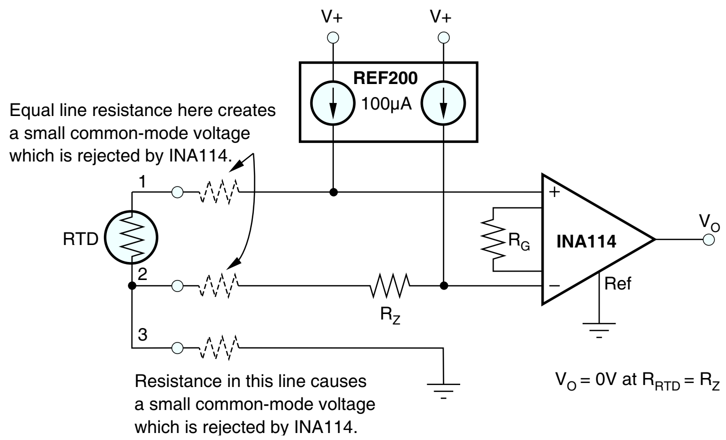
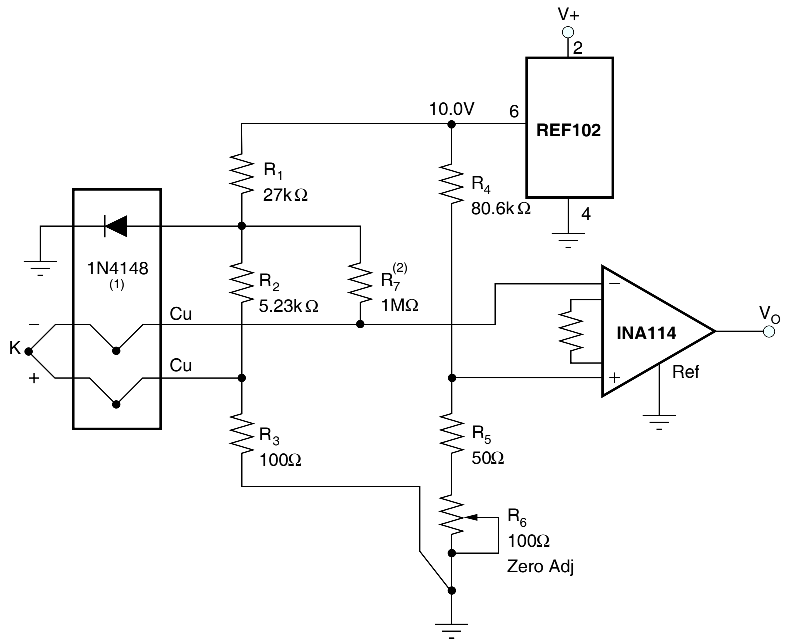


FIGURE 8. RTD Temperature Measurement Circuit.



ISA TYPE	MATERIAL	SEEBECK COEFFICIENT (µV/°C)	R_2 (R_3 = 100Ω)	R_4 ($R_5 + R_6$ = 100Ω)
E	Chromel Constantan	58.5	3.48kΩ	56.2kΩ
J	Iron Constantan	50.2	4.12kΩ	64.9kΩ
K	Chromel Alumel	39.4	5.23kΩ	80.6kΩ
T	Copper Constantan	38.0	5.49kΩ	84.5kΩ

NOTES: (1) –2.1mV/°C at 200µA. (2) R_7 provides down-scale burn-out indication.

FIGURE 9. Thermocouple Amplifier With Cold Junction Compensation.

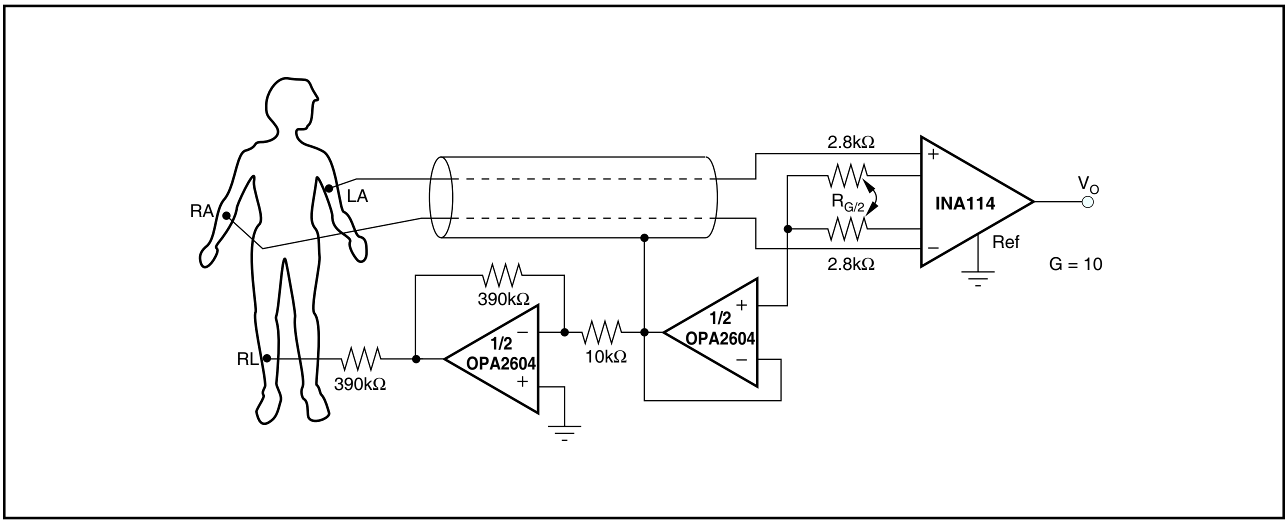


FIGURE 10. ECG Amplifier With Right-Leg Drive.

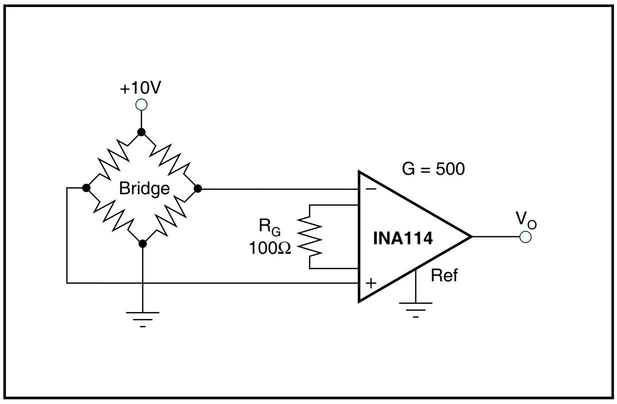


FIGURE 11. Bridge Transducer Amplifier.

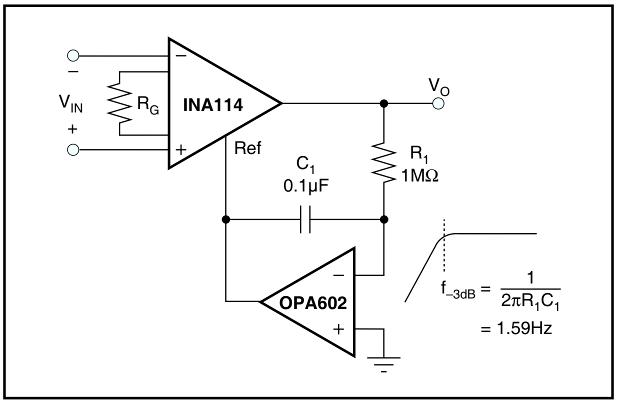
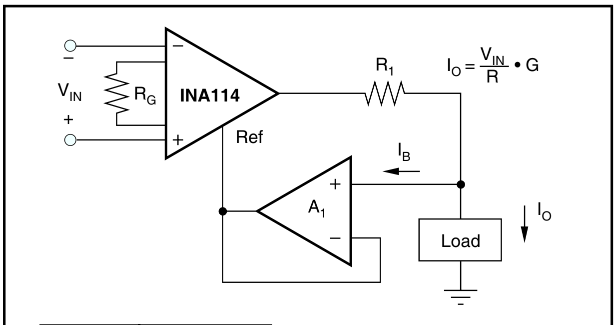


FIGURE 12. AC-Coupled Instrumentation Amplifier.



A_1	I_B Error
OPA177	±1.5nA
OPA602	1pA
OPA128	75fA

FIGURE 13. Differential Voltage-to-Current Converter.

IMPORTANT NOTICE

National Semiconductor

February 2003

LM3914
Dot/Bar Display Driver

General Description

The LM3914 is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. A single pin changes the display from a moving dot to a bar graph. Current drive to the LEDs is regulated and programmable, eliminating the need for resistors. This feature is one that allows operation of the whole system from less than 3V.

The circuit contains its own adjustable reference and accurate 10-step voltage divider. The low-bias-current input buffer accepts signals down to ground, or V^-, yet needs no protection against inputs of 35V above or below ground. The buffer drives 10 individual comparators referenced to the precision divider. Indication non-linearity can thus be held typically to ½%, even over a wide temperature range.

Versatility was designed into the LM3914 so that controller, visual alarm, and expanded scale functions are easily added on to the display system. The circuit can drive LEDs of many colors, or low-current incandescent lamps. Many LM3914s can be "chained" to form displays of 20 to over 100 segments. Both ends of the voltage divider are externally available so that 2 drivers can be made into a zero-center meter.

The LM3914 is very easy to apply as an analog meter circuit. A 1.2V full-scale meter requires only 1 resistor and a single 3V to 15V supply in addition to the 10 display LEDs. If the 1 resistor is a pot, it becomes the LED brightness control. The simplified block diagram illustrates this extremely simple external circuitry.

When in the dot mode, there is a small amount of overlap or "fade" (about 1 mV) between segments. This assures that at no time will all LEDs be "OFF", and thus any ambiguous display is avoided. Various novel displays are possible.

Much of the display flexibility derives from the fact that all outputs are individual, DC regulated currents. Various effects can be achieved by modulating these currents. The individual outputs can drive a transistor as well as a LED at the same time, so controller functions including "staging" control can be performed. The LM3914 can also act as a programmer, or sequencer.

The LM3914 is rated for operation from 0˚C to +70˚C. The LM3914N-1 is available in an 18-lead molded (N) package.

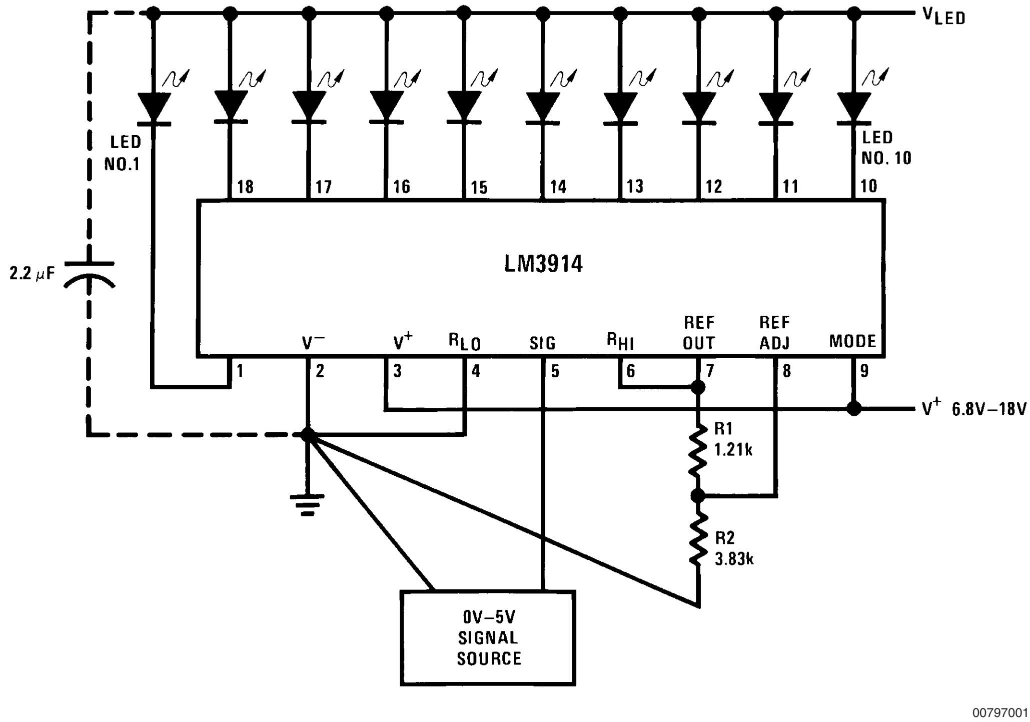
The following typical application illustrates adjusting of the reference to a desired value, and proper grounding for accurate operation, and avoiding oscillations.

Features

- Drives LEDs, LCDs or vacuum fluorescents
- Bar or dot display mode externally selectable by user
- Expandable to displays of 100 steps
- Internal voltage reference from 1.2V to 12V
- Operates with single supply of less than 3V
- Inputs operate down to ground
- Output current programmable from 2 mA to 30 mA
- No multiplex switching or interaction between outputs
- Input withstands ±35V without damage or false outputs
- LED driver outputs are current regulated, open-collectors
- Outputs can interface with TTL or CMOS logic
- The internal 10-step divider is floating and can be referenced to a wide range of voltages

Typical Applications

0V to 5V Bar Graph Meter



$$\text{Ref Out V} = 1.25\left(1 + \frac{R2}{R1}\right)$$

$$I_{LED} \cong \frac{12.5}{R1}$$

Note: Grounding method is typical of *all* uses. The 2.2µF tantalum or 10 µF aluminum electrolytic capacitor is needed if leads to the LED supply are 6" or longer.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Power Dissipation (Note 6)	
Molded DIP (N)	1365 mW
Supply Voltage	25V
Voltage on Output Drivers	25V
Input Signal Overvoltage (Note 4)	±35V
Divider Voltage	–100 mV to V^+
Reference Load Current	10 mA
Storage Temperature Range	–55˚C to +150˚C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260˚C
Plastic Chip Carrier Package	
Vapor Phase (60 seconds)	215˚C
Infrared (15 seconds)	220˚C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

Electrical Characteristics (Notes 2, 4)

Parameter	Conditions (Note 2)		Min	Typ	Max	Units
COMPARATOR						
Offset Voltage, Buffer and First Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	10	mV
Offset Voltage, Buffer and Any Other Comparator	$0V \le V_{RLO} = V_{RHI} \le 12V$, $I_{LED} = 1$ mA			3	15	mV
Gain ($\Delta I_{LED}/\Delta V_{IN}$)	$I_{L(REF)} = 2$ mA, $I_{LED} = 10$ mA		3	8		mA/mV
Input Bias Current (at Pin 5)	$0V \le V_{IN} \le V^+ - 1.5V$			25	100	nA
Input Signal Overvoltage	No Change in Display		–35		35	V
VOLTAGE-DIVIDER						
Divider Resistance	Total, Pin 6 to 4		8	12	17	kΩ
Accuracy	(Note 3)			0.5	2	%
VOLTAGE REFERENCE						
Output Voltage	$0.1 \text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$		1.2	1.28	1.34	V
Line Regulation	$3V \le V^+ \le 18V$			0.01	0.03	%/V
Load Regulation	$0.1 \text{ mA} \le I_{L(REF)} \le 4$ mA, $V^+ = V_{LED} = 5V$			0.4	2	%
Output Voltage Change with Temperature	$0˚C \le T_A \le +70˚C$, $I_{L(REF)} = 1$ mA, $V^+ = 5V$			1		%
Adjust Pin Current				75	120	µA
OUTPUT DRIVERS						
LED Current	$V^+ = V_{LED} = 5V$, $I_{L(REF)} = 1$ mA		7	10	13	mA
LED Current Difference (Between Largest and Smallest LED Currents)	$V_{LED} = 5V$	$I_{LED} = 2$ mA		0.12	0.4	mA
		$I_{LED} = 20$ mA		1.2	3	
LED Current Regulation	$2V \le V_{LED} \le 17V$	$I_{LED} = 2$ mA		0.1	0.25	mA
		$I_{LED} = 20$ mA		1	3	
Dropout Voltage	$I_{LED(ON)} = 20$ mA, $V_{LED} = 5V$, $\Delta I_{LED} = 2$ mA				1.5	V
Saturation Voltage	$I_{LED} = 2.0$ mA, $I_{L(REF)} = 0.4$ mA			0.15	0.4	V
Output Leakage, Each Collector	(Bar Mode) (Note 5)			0.1	10	µA
Output Leakage	(Dot Mode) (Note 5)	Pins 10–18		0.1	10	µA
		Pin 1	60	150	450	µA
SUPPLY CURRENT						
Standby Supply Current (All Outputs Off)	$V^+ = 5V$, $I_{L(REF)} = 0.2$ mA			2.4	4.2	mA
	$V^+ = 20V$, $I_{L(REF)} = 1.0$ mA			6.1	9.2	mA

Electrical Characteristics (Notes 2, 4) (Continued)

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

Note 2: Unless otherwise stated, all specifications apply with the following conditions:

$3\ V_{DC} \leq V^+ \leq 20\ V_{DC}$ $V_{REF}, V_{RHI}, V_{RLO} \leq (V^+ - 1.5V)$

$3\ V_{DC} \leq V_{LED} \leq V^+$ $0V \leq V_{IN} \leq V^+ - 1.5V$

$-0.015V \leq V_{RLO} \leq 12V_{DC}$ $T_A = +25^\circ C$, $I_{L(REF)} = 0.2$ mA, $V_{LED} = 3.0V$, pin 9 connected to pin 3 (Bar Mode).

$-0.015V \leq V_{RHI} \leq 12\ V_{DC}$

For higher power dissipations, pulse testing is used.

Note 3: Accuracy is measured referred to $+10.000V_{DC}$ at pin 6, with 0.000 V_{DC} at pin 4. At lower full-scale voltages, buffer and comparator offset voltage may add significant error.

Note 4: Pin 5 input current must be limited to ±3mA. The addition of a 39k resistor in series with pin 5 allows ±100V signals without damage.

Note 5: Bar mode results when pin 9 is within 20mV of V^+. Dot mode results when pin 9 is pulled at least 200mV below V^+ or left open circuit. LED No. 10 (pin 10 output current) is disabled if pin 9 is pulled 0.9V or more below V_{LED}.

Note 6: The maximum junction temperature of the LM3914 is 100˚C. Devices must be derated for operation at elevated temperatures. Junction to ambient thermal resistance is 55˚C/W for the molded DIP (N package).

Definition of Terms

Accuracy: The difference between the observed threshold voltage and the ideal threshold voltage for each comparator. Specified and tested with 10V across the internal voltage divider so that resistor ratio matching error predominates over comparator offset voltage.

Adjust Pin Current: Current flowing out of the reference adjust pin when the reference amplifier is in the linear region.

Comparator Gain: The ratio of the change in output current (I_{LED}) to the change in input voltage (V_{IN}) required to produce it for a comparator in the linear region.

Dropout Voltage: The voltage measured at the current source outputs required to make the output current fall by 10%.

Input Bias Current: Current flowing out of the signal input when the input buffer is in the linear region.

LED Current Regulation: The change in output current over the specified range of LED supply voltage (V_{LED}) as measured at the current source outputs. As the forward voltage of an LED does not change significantly with a small change in forward current, this is equivalent to changing the voltage at the LED anodes by the same amount.

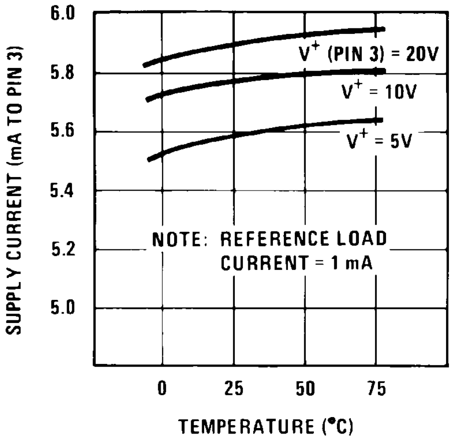
Line Regulation: The average change in reference output voltage over the specified range of supply voltage (V^+).

Load Regulation: The change in reference output voltage (V_{REF}) over the specified range of load current ($I_{L(REF)}$).

Offset Voltage: The differential input voltage which must be applied to each comparator to bias the output in the linear region. Most significant error when the voltage across the internal voltage divider is small. Specified and tested with pin 6 voltage (V_{RHI}) equal to pin 4 voltage (V_{RLO}).

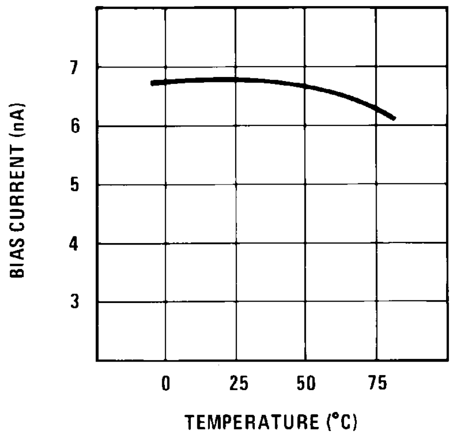
Typical Performance Characteristics

Supply Current vs Temperature



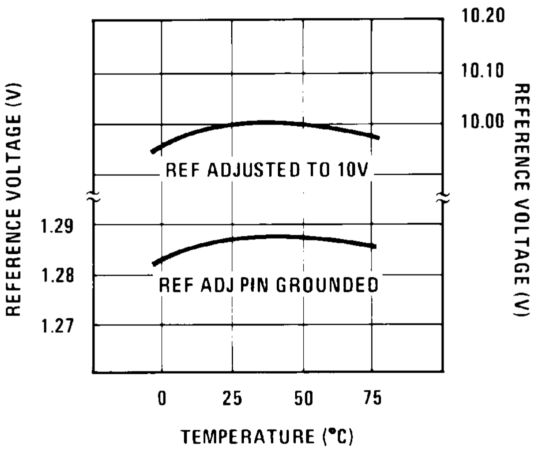
00797002

Operating Input Bias Current vs Temperature



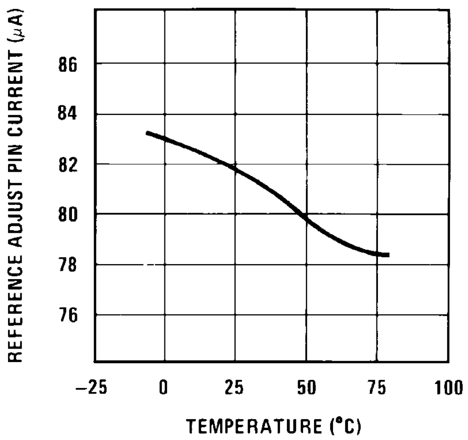
00797020

Reference Voltage vs Temperature



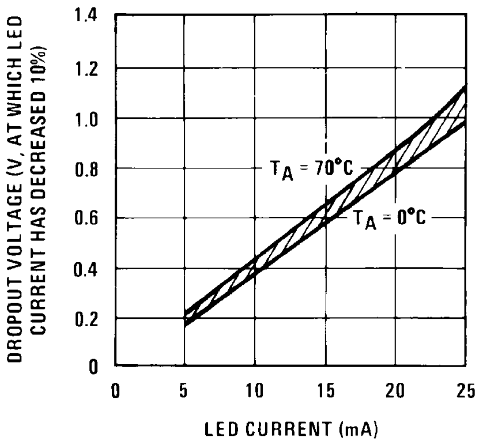
00797021

Reference Adjust Pin Current vs Temperature



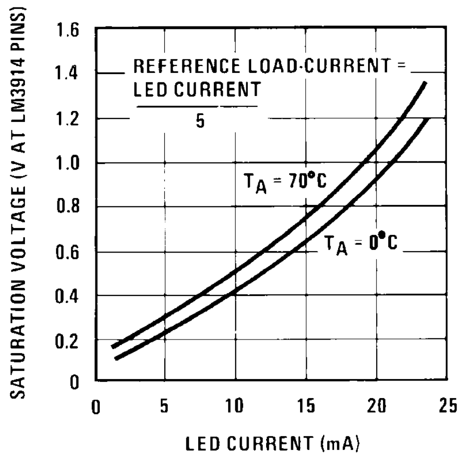
00797022

LED Current-Regulation Dropout



00797023

LED Driver Saturation Voltage



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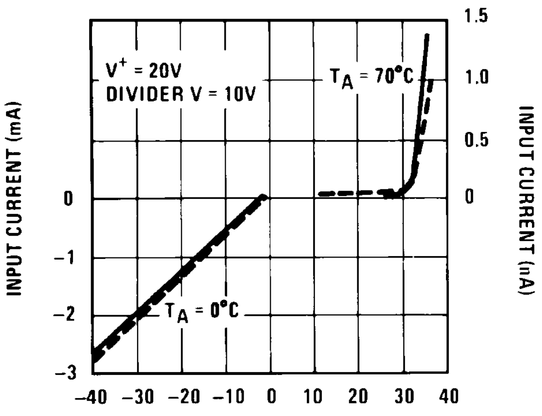
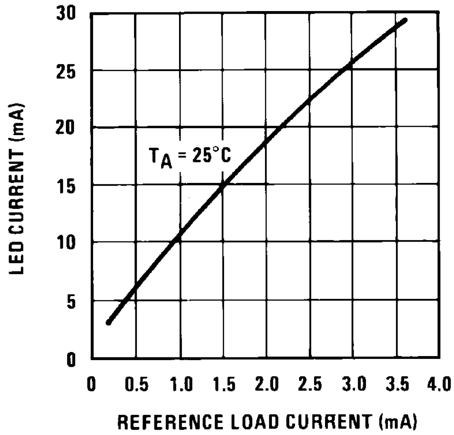
Typical Performance Characteristics (Continued)

Input Current Beyond Signal Range (Pin 5)



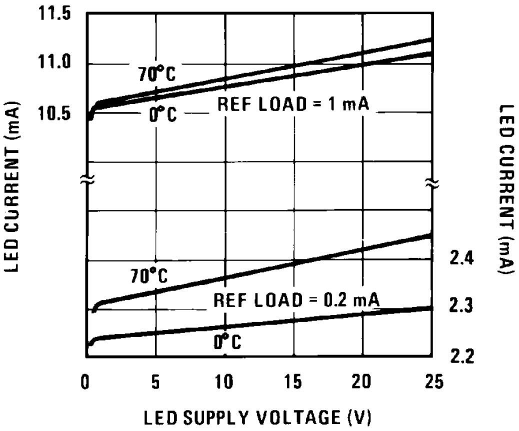
00797025

LED Current vs Reference Loading



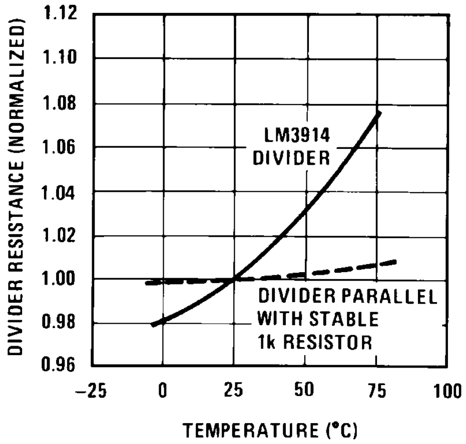
00797026

LED Driver Current Regulation



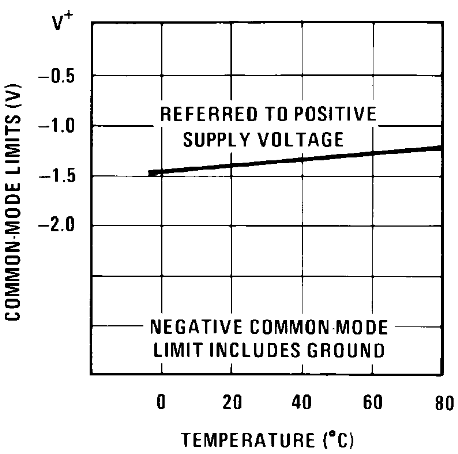
00797027

Total Divider Resistance vs Temperature



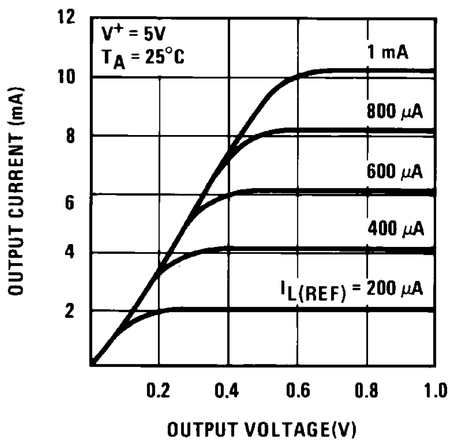
00797028

Common-Mode Limits



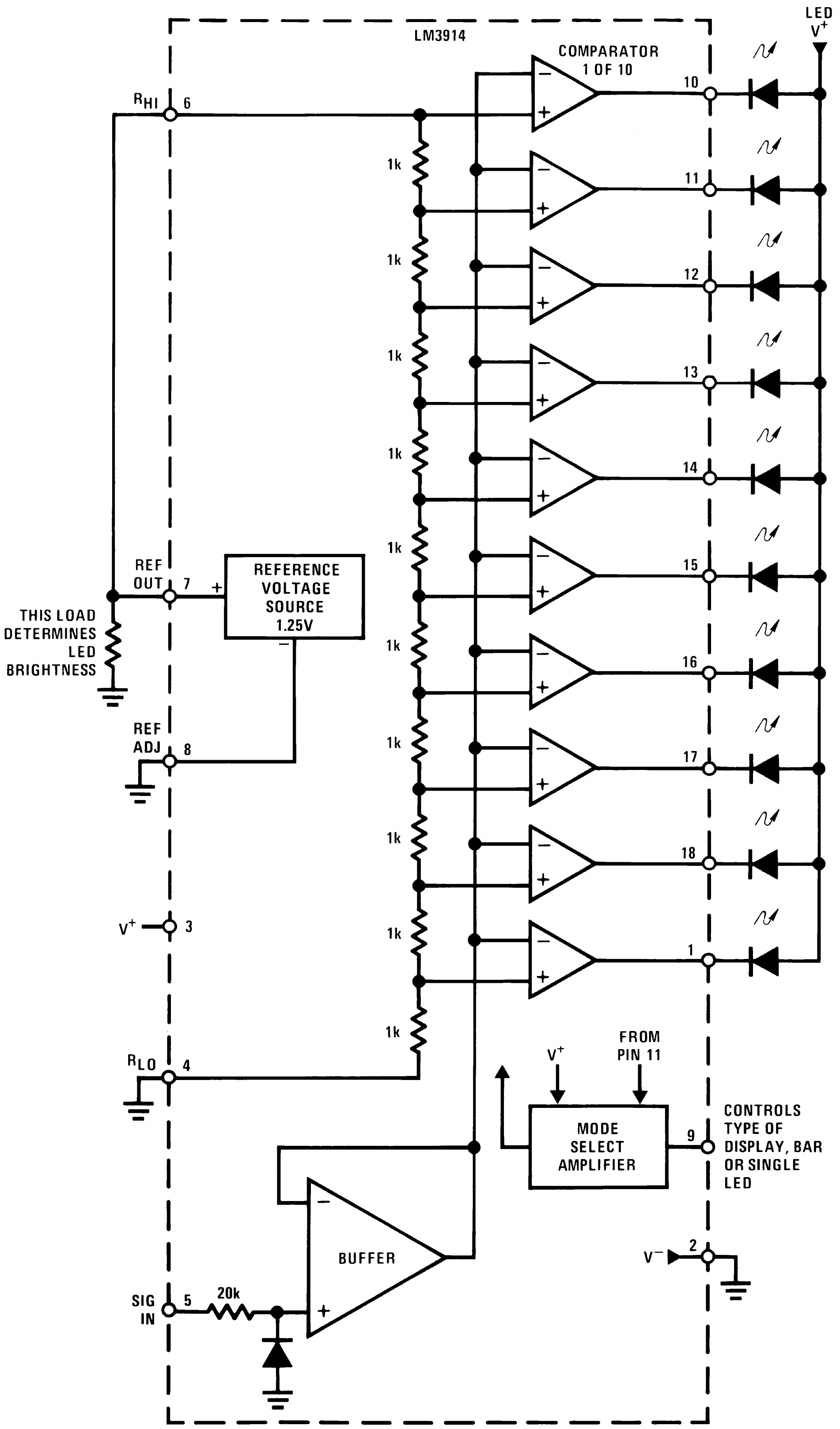
00797029

Output Characteristics



00797030

Block Diagram (Showing Simplest Application)



00797003

Functional Description

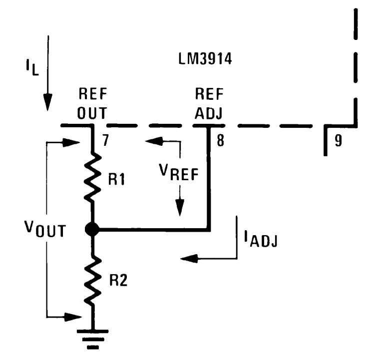
The simplifed LM3914 block diagram is to give the general idea of the circuit's operation. A high input impedance buffer operates with signals from ground to 12V, and is protected against reverse and overvoltage signals. The signal is then applied to a series of 10 comparators; each of which is biased to a different comparison level by the resistor string.

In the example illustrated, the resistor string is connected to the internal 1.25V reference voltage. In this case, for each 125mV that the input signal increases, a comparator will switch on another indicating LED. This resistor divider can be connected between any 2 voltages, providing that they are 1.5V below V^+ and no less than V^-. If an expanded scale meter display is desired, the total divider voltage can be as little as 200mV. Expanded-scale meter displays are more accurate and the segments light uniformly only if bar mode is used. At 50mV or more per step, dot mode is usable.

INTERNAL VOLTAGE REFERENCE

The reference is designed to be adjustable and develops a nominal 1.25V between the REF OUT (pin 7) and REF ADJ (pin 8) terminals. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2 giving an output voltage of:

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ} R_2$$



00797004

Since the 120µA current (max) from the adjust terminal represents an error term, the reference was designed to minimize changes of this current with V^+ and load changes.

CURRENT PROGRAMMING

A feature not completely illustrated by the block diagram is the LED brightness control. The current drawn out of the reference voltage pin (pin 7) determines LED current. Approximately 10 times this current will be drawn through each lighted LED, and this current will be relatively constant despite supply voltage and temperature changes. Current drawn by the internal 10-resistor divider, as well as by the external current and voltage-setting divider should be included in calculating LED drive current. The ability to modulate LED brightness with time, or in proportion to input voltage and other signals can lead to a number of novel displays or ways of indicating input overvoltages, alarms, etc.

MODE PIN USE

Pin 9, the Mode Select input controls chaining of multiple LM3914s, and controls bar or dot mode operation. The following tabulation shows the basic ways of using this input. Other more complex uses will be illustrated in the applications.

Bar Graph Display: Wire Mode Select (pin 9) *directly* to pin 3 (V^+ pin).

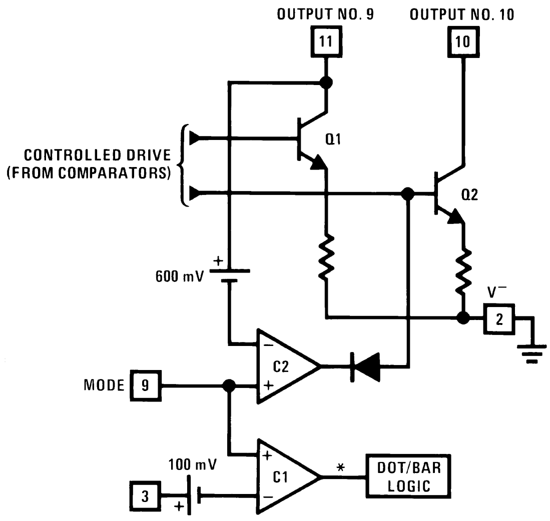
Dot Display, Single LM3914 Driver: Leave the Mode Select pin open circuit.

Dot Display, 20 or More LEDs: Connect pin 9 of the *first* driver in the series (i.e., the one with the lowest input voltage comparison points) to pin 1 of the next higher LM3914 driver. Continue connecting pin 9 of lower input drivers to pin 1 of higher input drivers for 30, 40, or more LED displays. The last LM3914 driver in the chain will have pin 9 wired to pin 11. All previous drivers should have a 20k resistor in parallel with LED No. 9 (pin 11 to V_{LED}).

Mode Pin Functional Description

This pin actually performs two functions. Refer to the simplified block diagram below.

Block Diagram of Mode Pin Description



00797005

*High for bar

DOT OR BAR MODE SELECTION

The voltage at pin 9 is sensed by comparator C1, nominally referenced to (V^+ – 100mV). The chip is in bar mode when pin 9 is above this level; otherwise it's in dot mode. The comparator is designed so that pin 9 can be left open circuit for dot mode.

Taking into account comparator gain and variation in the 100mV reference level, pin 9 should be no more than 20mV below V^+ for bar mode and more than 200mV below V^+ (or open circuit) for dot mode. In most applications, pin 9 is either open (dot mode) or tied to V^+ (bar mode). In bar mode, pin 9 should be connected directly to pin 3. Large currents drawn from the power supply (LED current, for example) should not share this path so that large IR drops are avoided.

Mode Pin Functional Description

(Continued)

DOT MODE CARRY

In order for the display to make sense when multiple LM3914s are cascaded in dot mode, special circuitry has been included to shut off LED No. 10 of the first device when LED No. 1 of the second device comes on. The connection for cascading in dot mode has already been described and is depicted below.

As long as the input signal voltage is below the threshold of the second LM3914, LED No. 11 is off. Pin 9 of LM3914 No. 1 thus sees effectively an open circuit so the chip is in dot mode. As soon as the input voltage reaches the threshold of LED No. 11, pin 9 of LM3914 No. 1 is pulled an LED drop (1.5V or more) below V_{LED}. This condition is sensed by comparator C2, referenced 600mV below V_{LED}. This forces the output of C2 low, which shuts off output transistor Q2, extinguishing LED No. 10.

V_{LED} is sensed via the 20k resistor connected to pin 11. The very small current (less than 100µA) that is diverted from LED No. 9 does not noticeably affect its intensity.

An auxiliary current source at pin 1 keeps at least 100µA flowing through LED No. 11 even if the input voltage rises high enough to extinguish the LED. This ensures that pin 9 of LM3914 No. 1 is held low enough to force LED No. 10 off when *any* higher LED is illuminated. While 100µA does not normally produce significant LED illumination, it may be noticeable when using high-efficiency LEDs in a dark environment. If this is bothersome, the simple cure is to shunt LED No. 11 with a 10k resistor. The 1V IR drop is more than the 900mV worst case required to hold off LED No. 10 yet small enough that LED No. 11 does not conduct significantly.

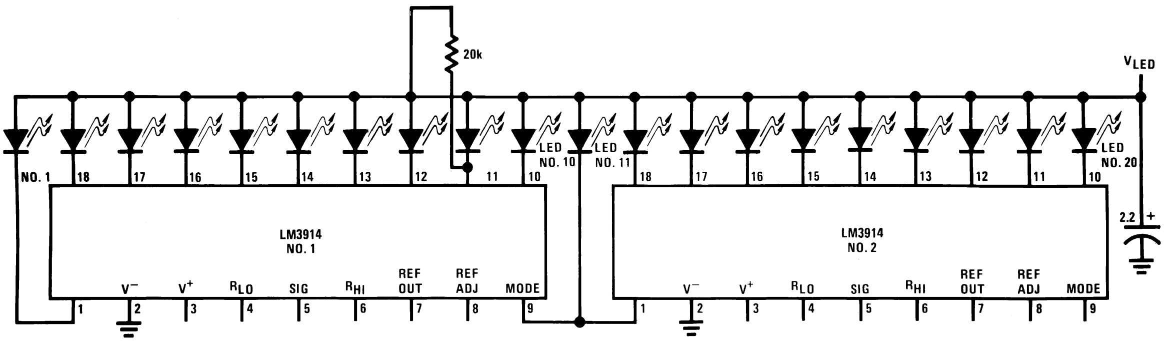
OTHER DEVICE CHARACTERISTICS

The LM3914 is relatively low-powered itself, and since any number of LEDs can be powered from about 3V, it is a very efficient display driver. Typical standby supply current (all LEDs OFF) is 1.6mA (2.5mA max). However, any reference loading adds 4 times that current drain to the V^+ (pin 3) supply input. For example, an LM3914 with a 1mA reference pin load (1.3k), would supply almost 10mA to every LED while drawing only 10mA from its V^+ pin supply. At full-scale, the IC is typically drawing less than 10% of the current supplied to the display.

The display driver does not have built-in hysteresis so that the display does not jump instantly from one LED to the next. Under rapidly changing signal conditions, this cuts down high frequency noise and often an annoying flicker. An "overlap" is built in so that at no time between segments are all LEDs completely OFF in the dot mode. Generally 1 LED fades in while the other fades out over a mV or more of range (Note 3). The change may be much more rapid between LED No. 10 of one device and LED No. 1 of a *second* device "chained" to the first.

The LM3914 features individually current regulated LED driver transistors. Further internal circuitry detects when any driver transistor goes into saturation, and prevents other circuitry from drawing excess current. This results in the ability of the LM3914 to drive and regulate LEDs powered from a pulsating DC power source, i.e., largely unfiltered. (Due to possible oscillations at low voltages a nominal bypass capacitor consisting of a 2.2µF solid tantalum connected from the pulsating LED supply to pin 2 of the LM3914 is recommended.) This ability to operate with low or fluctuating voltages also allows the display driver to interface with logic circuitry, opto-coupled solid-state relays, and low-current incandescent lamps.

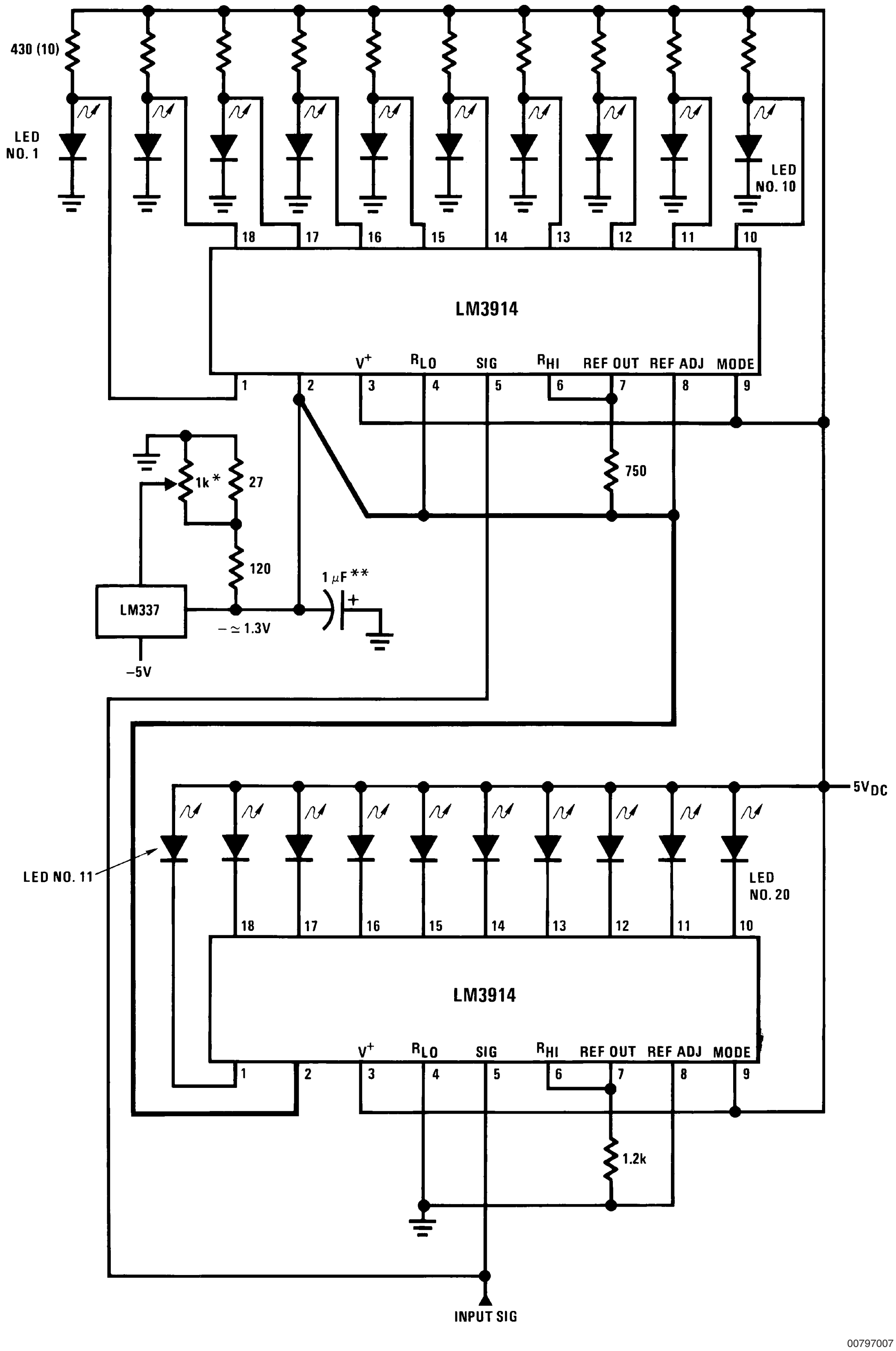
Cascading LM3914s in Dot Mode



00797006

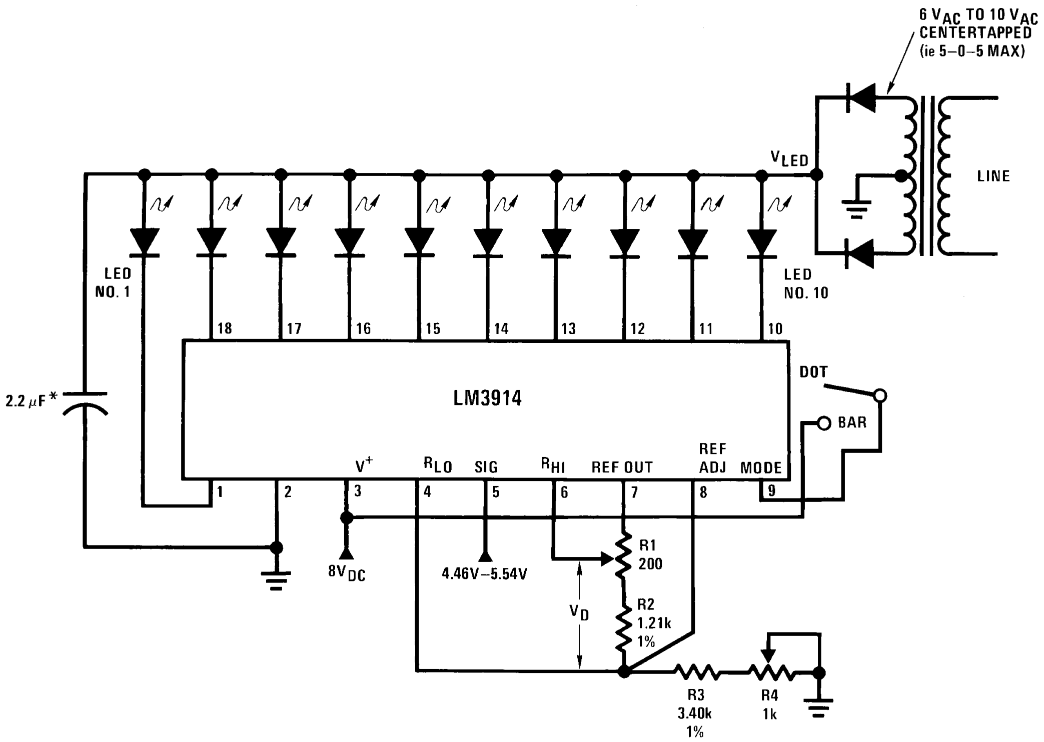
Typical Applications

Zero-Center Meter, 20-Segment



Typical Applications (Continued)

Expanded Scale Meter, Dot or Bar



00797008

*This application illustrates that the LED supply needs practically no filtering

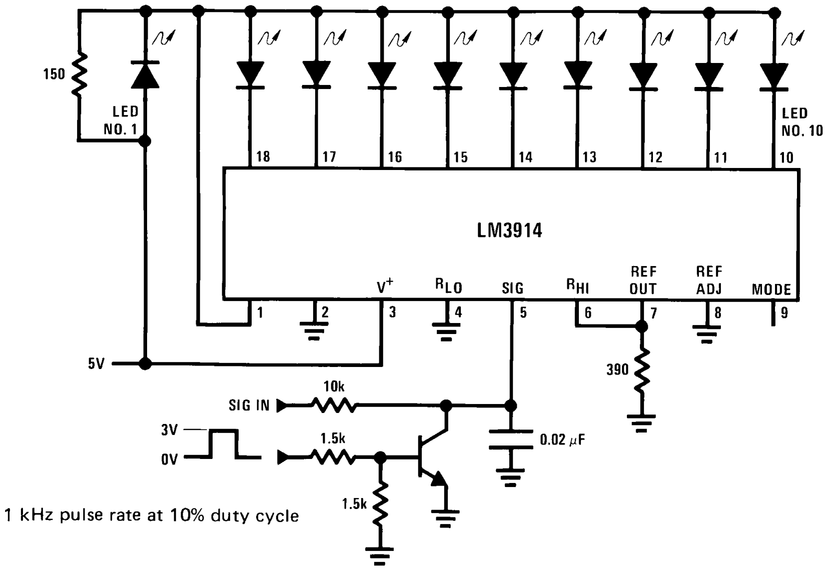
Calibration: With a precision meter between pins 4 and 6 adjust R1 for voltage V_D of 1.20V. Apply 4.94V to pin 5, and adjust R4 until LED No. 5 just lights. The adjustments are non-interacting.

Application Example: Grading 5V Regulators

Highest No. LED on	Color	$V_{OUT(MIN)}$
10	Red	5.54
9	Red	5.42
8	Yellow	5.30
7	Green	5.18
6	Green	5.06
	5V	
5	Green	4.94
4	Green	4.82
3	Yellow	4.7
2	Red	4.58
1	Red	4.46

Typical Applications (Continued)

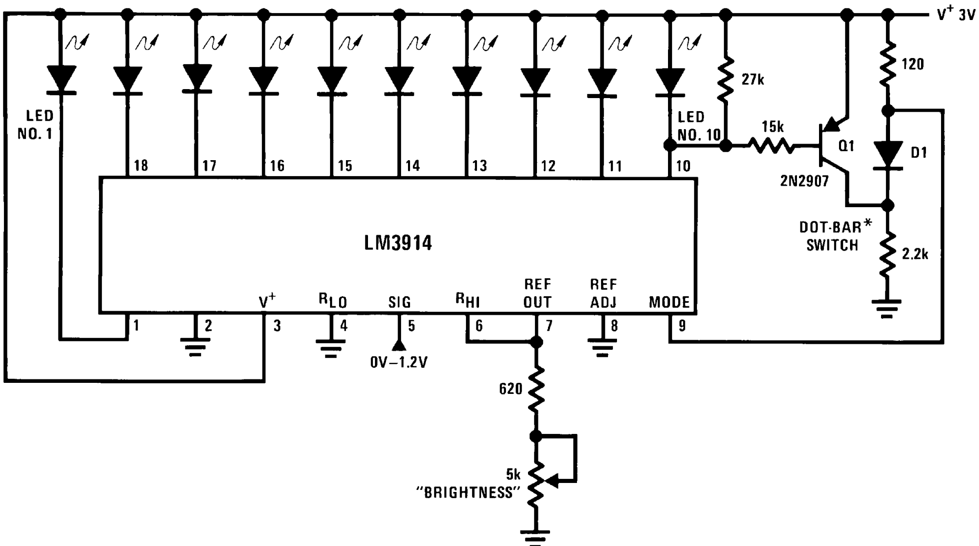
"Exclamation Point" Display



00797009

LEDs light up as illustrated with the upper lit LED indicating the actual input voltage. The display appears to increase resolution and provides an analog indication of overrange.

Indicator and Alarm, Full-Scale Changes Display from Dot to Bar

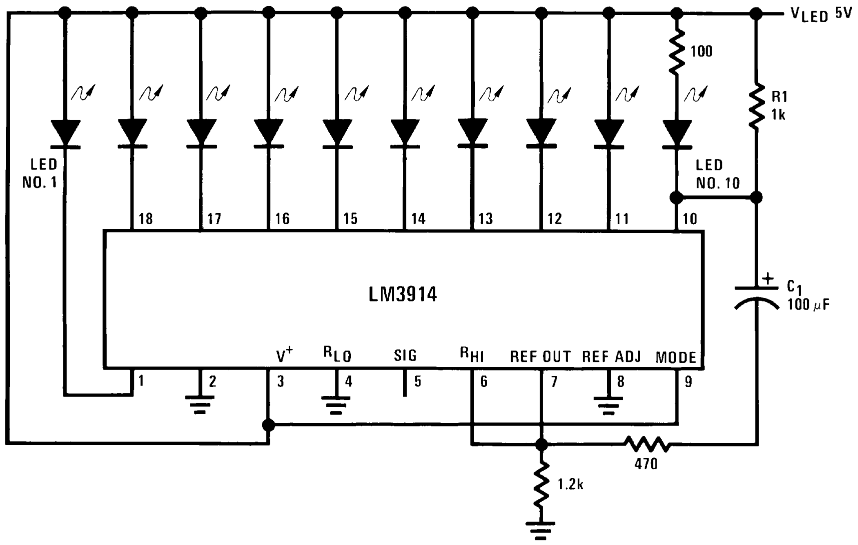


00797010

*The input to the Dot-Bar Switch may be taken from cathodes of other LEDs. Display will change to bar as soon as the LED so selected begins to light.

Typical Applications (Continued)

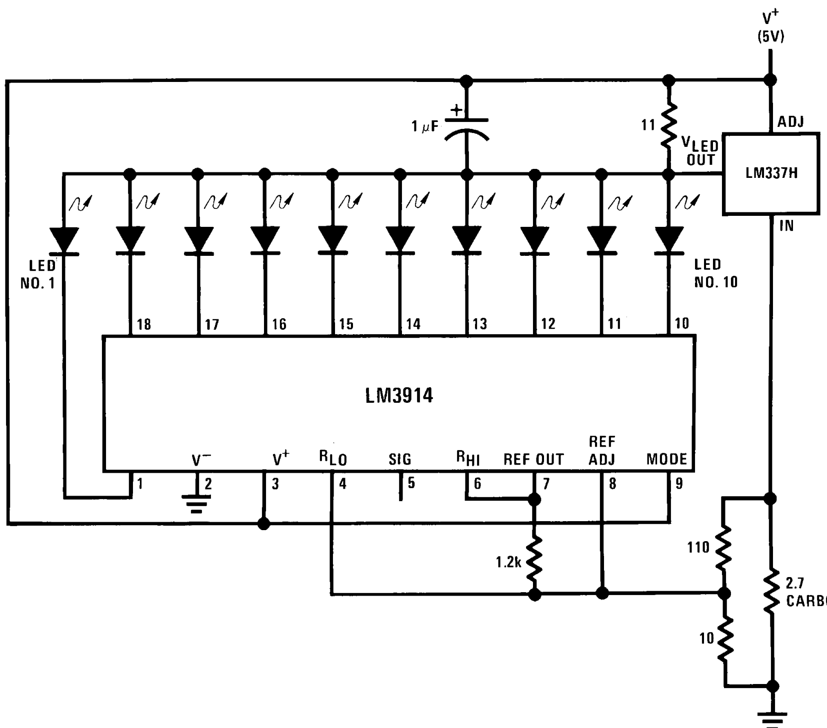
Bar Display with Alarm Flasher



00797011

Full-scale causes the full bar display to flash. If the junction of R1 and C1 is connected to a different LED cathode, the display will flash when that LED lights, and at any higher input signal.

Adding Hysteresis (Single Supply, Bar Mode Only)

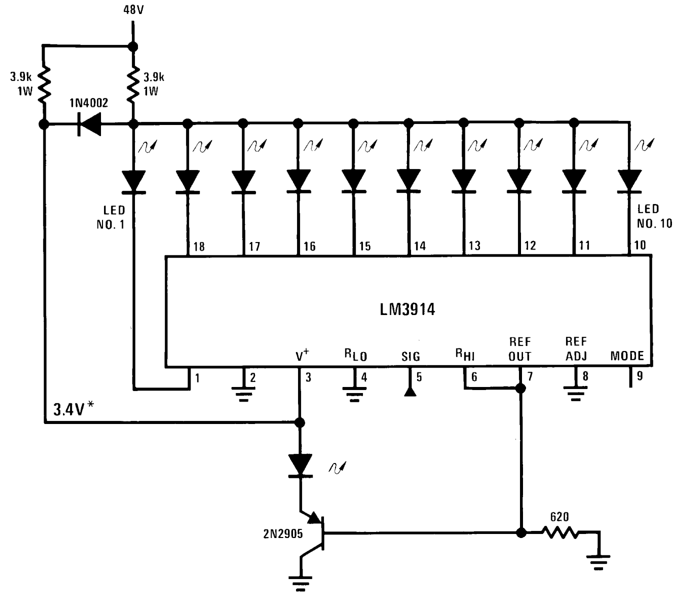


00797012

Hysteresis is 0.5 mV to 1 mV

Typical Applications (Continued)

Operating with a High Voltage Supply (Dot Mode Only)



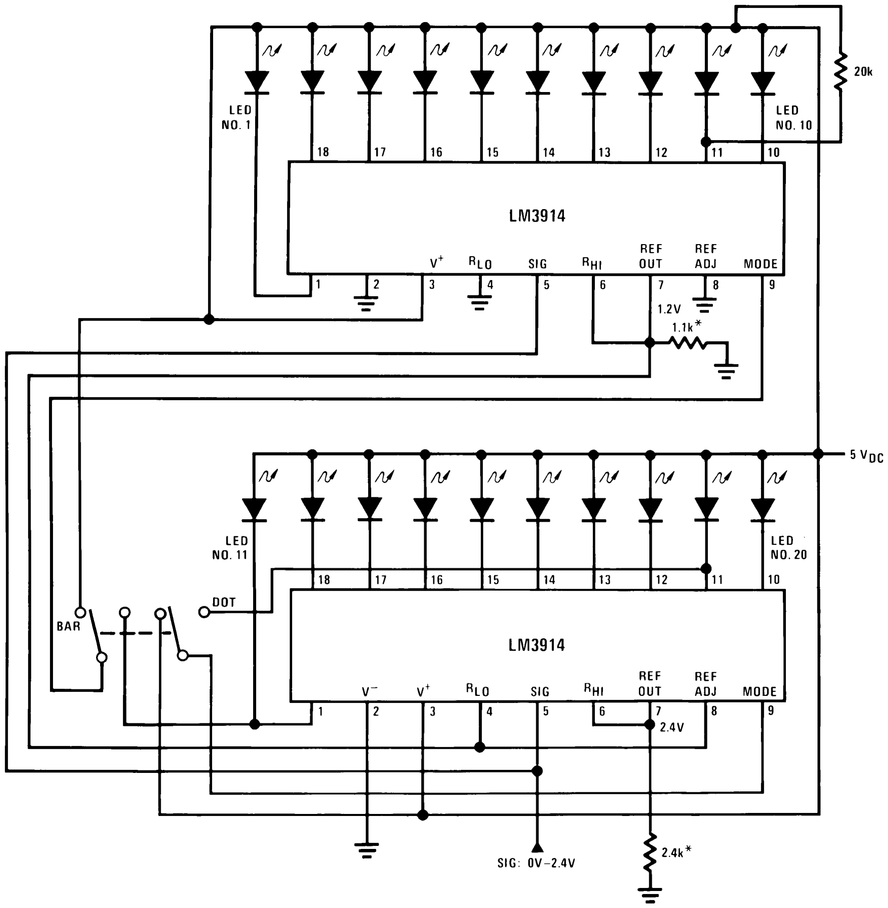
00797013

The LED currents are approximately 10mA, and the LM3914 outputs operate in saturation for minimum dissipation.

*This point is partially regulated and decreases in voltage with temperature. Voltage requirements of the LM3914 also decrease with temperature.

Typical Applications (Continued)

20-Segment Meter with Mode Switch



00797014

*The exact wiring arrangement of this schematic shows the need for Mode Select (pin 9) to sense the V^+ voltage exactly as it appears on pin 3.

Programs LEDs to 10mA

Application Hints

Three of the most commonly needed precautions for using the LM3914 are shown in the first typical application drawing showing a 0V–5V bar graph meter. The most difficult problem occurs when large LED currents are being drawn, especially in bar graph mode. These currents flowing out of the ground pin cause voltage drops in external wiring, and thus errors and oscillations. Bringing the return wires from signal sources, reference ground and bottom of the resistor string (as illustrated) to a single point very near pin 2 is the best solution.

Long wires from V_{LED} to LED anode common can cause oscillations. Depending on the severity of the problem 0.05µF to 2.2µF decoupling capacitors from LED anode common to pin 2 will damp the circuit. If LED anode line wiring is inaccessible, often similar decoupling from pin 1 to pin 2 will be sufficient.

If LED turn ON seems slow (bar mode) or several LEDs light (dot mode), oscillation or excessive noise is usually the problem. In cases where proper wiring and bypassing fail to stop oscillations, V^+ voltage at pin 3 is usually below suggested limits. Expanded scale meter applications may have one or both ends of the internal voltage divider terminated at relatively high value resistors. These high-impedance ends should be bypassed to pin 2 with at least a 0.001µF capacitor, or up to 0.1µF in noisy environments.

Power dissipation, especially in bar mode should be given consideration. For example, with a 5V supply and all LEDs programmed to 20mA the driver will dissipate over 600mW. In this case a 7.5Ω resistor in series with the LED supply will cut device heating in half. The negative end of the resistor should be bypassed with a 2.2µF solid tantalum capacitor to pin 2 of the LM3914.

Turning OFF of most of the internal current sources is accomplished by pulling positive on the reference with a current source or resistance supplying 100µA or so. Alternately, the input signal can be gated OFF with a transistor switch.

Other special features and applications characteristics will be illustrated in the following applications schematics. Notes have been added in many cases, attempting to cover any special procedures or unusual characteristics of these applications. A special section called “Application Tips for the LM3914 Adjustable Reference” has been included with these schematics.

Application Hints (Continued)

APPLICATION TIPS FOR THE LM3914 ADJUSTABLE REFERENCE

Greatly Expanded Scale (Bar Mode Only)

Placing the LM3914 internal resistor divider in parallel with a section (≈230Ω) of a stable, low resistance divider greatly reduces voltage changes due to IC resistor value changes with temperature. Voltage V_1 should be trimmed to 1.1V first by use of R2. Then the voltage V_2 across the IC divider string can be adjusted to 200mV, using R5 without affecting V_1. LED current will be approximately 10mA.

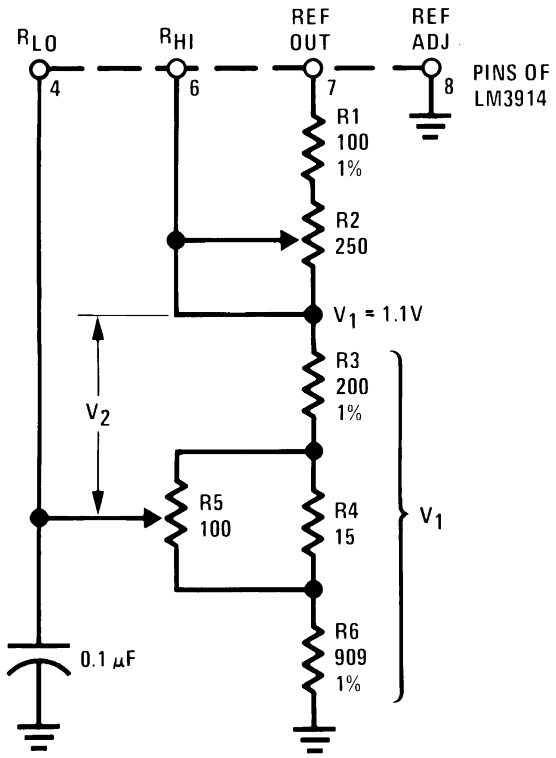
Non-Interacting Adjustments For Expanded Scale Meter (4.5V to 5V, Bar *or* Dot Mode)

This arrangement allows independent adjustment of LED brightness regardless of meter span and zero adjustments.

First, V_1 is adjusted to 5V, using R2. Then the span (voltage across R4) can be adjusted to exactly 0.5V using R6 without affecting the previous adjustment.

R9 programs LED currents within a range of 2.2mA to 20mA after the above settings are made.

Greatly Expanded Scale (Bar Mode Only)



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Adjusting Linearity Of Several Stacked dividers

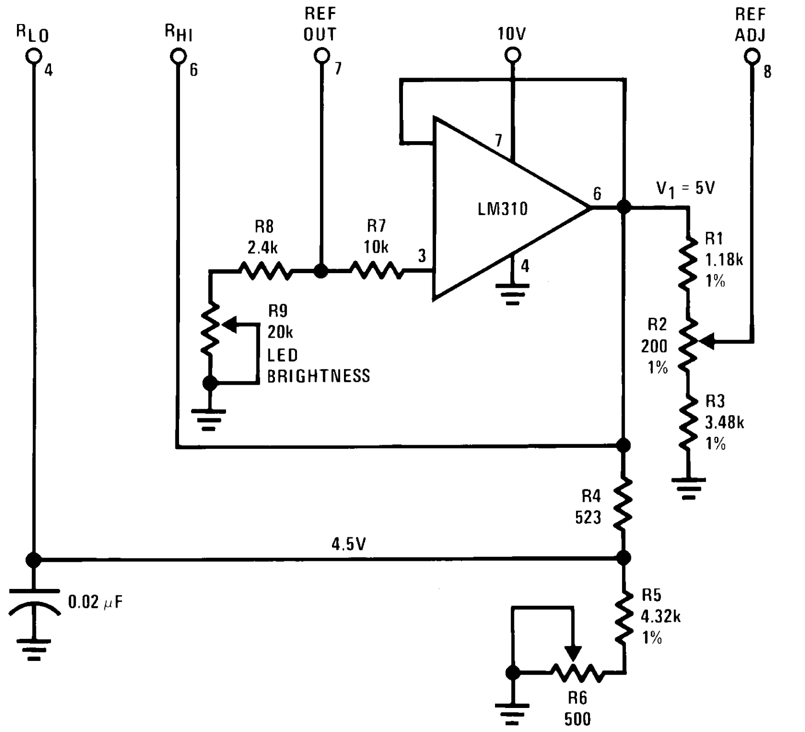
Three internal voltage dividers are shown connected in series to provide a 30-step display. If the resulting analog meter is to be accurate and linear the voltage on each divider must be adjusted, preferably without affecting any other adjustments. To do this, adjust R2 first, so that the voltage across R5 is exactly 1V. Then the voltages across R3 and R4 can be independently adjusted by shunting each with selected resistors of 6kΩ or higher resistance. This is possible because the reference of LM3914 No. 3 is acting as a constant current source.

The references associated with LM3914s No. 1 and No. 2 should have their Ref Adj pins (pin 8) wired to ground, and their Ref Outputs loaded by a 620Ω resistor to ground. This makes available similar 20mA current outputs to all the LEDs in the system.

If an independent LED brightness control is desired (as in the previous application), a unity gain buffer, such as the LM310, should be placed between pin 7 and R1, similar to the previous application.

Application Hints (Continued)

Non-Interacting Adjustments for Expanded Scale Meter (4.5V to 5V, Bar *or* Dot Mode)



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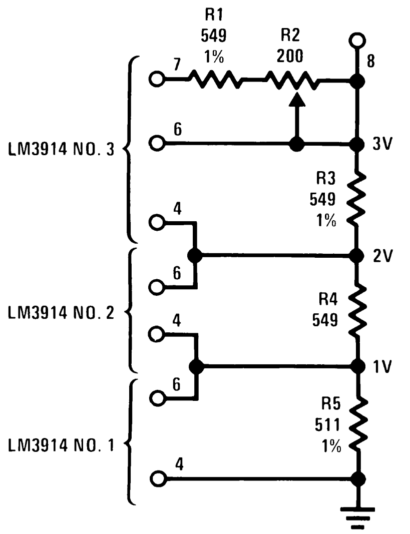
Adjusting Linearity of Several Stacked Dividers



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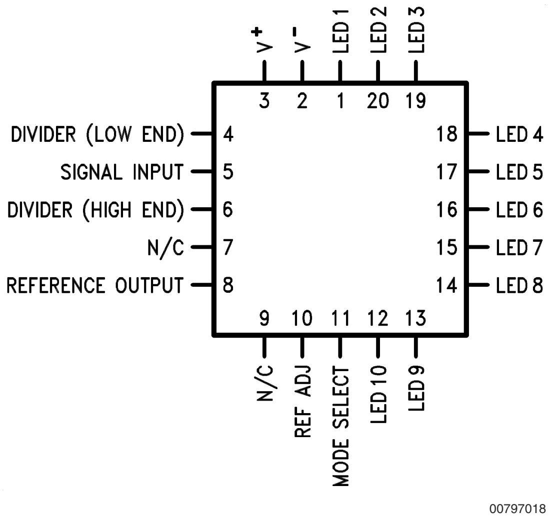
Other Applications

- "Slow"—fade bar or dot display (doubles resolution)
- 20-step meter with single pot brightness control
- 10-step (or multiples) programmer
- Multi-step or "staging" controller
- Combined controller and process deviation meter
- Direction and rate indicator (to add to DVMs)
- Exclamation point display for power saving
- Graduations can be added to dot displays. Dimly light every other LED using a resistor to ground
- Electronic "meter-relay"—display could be circle or semi-circle
- Moving "hole" display—indicator LED is dark, rest of bar lit
- Drives vacuum-fluorescent and LCDs using added passive parts

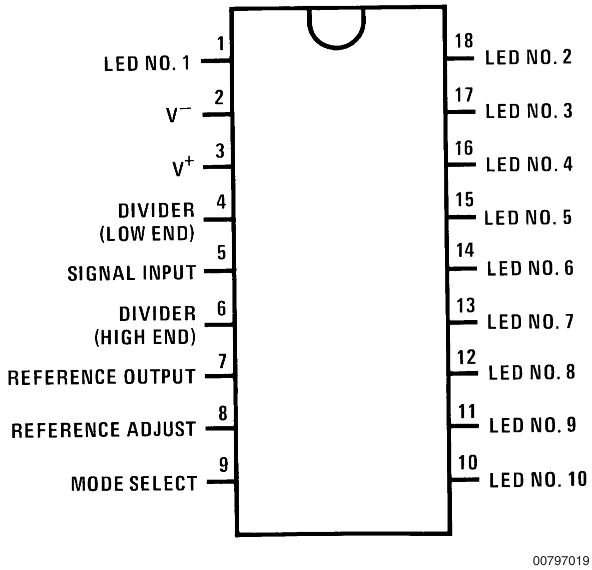
Connection Diagrams

Plastic Chip Carrier Package



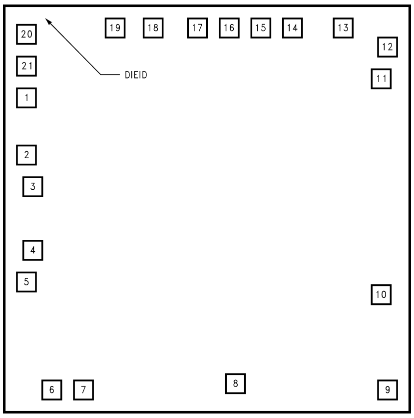
Top View
Order Number LM3914V
See NS Package Number V20A

Dual-in-Line Package



Top View
Order Number LM3914N-1
See NS Package Number NA18A
Order Number LM3914N *
See NS Package Number N18A
*** Discontinued, Life Time Buy date 12/20/99**

LM3914 MDC MWC Dot/Bar Display Driver



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Die Layout (D - Step)

Die/Wafer Characteristics

Fabrication Attributes		General Die Information	
Physical Die Identification	3914	Bond Pad Opening Size (min)	94µm x 105µm
Die Step	D	Bond Pad Metalization	ALUMINUM
Physical Attributes		Passivation	VOM NITRIDE
Wafer Diameter	150mm	Back Side Metal	Bare Back
Dise Size (Drawn)	2591µm x 2438µm 102.0mils x 96.0mils	Back Side Connection	Floating
Thickness	330µm Nominal		
Min Pitch	175µm Nominal		

Special Assembly Requirements:

Note: Actual die size is rounded to the nearest micron.

Die Bond Pad Coordinate Locations (D - Step)						
(Referenced to die center, coordinates in µm) NC = No Connection, N.U. = Not Used						
SIGNAL NAME	PAD# NUMBER	X/Y COORDINATES		PAD SIZE		
		X	Y	X		Y
LED NO.1	1	-1086	732	105	x	105
V-	2	-1086	343	105	x	105
V-	3	-1040	171	105	x	105
V+	4	-1052	-206	105	x	105
DIV LOW END	5	-1086	-377	105	x	105
SIG INPUT	6	-903	-1154	101	x	105
DIV HIGH END	7	-745	-1160	105	x	94
REF OUTPUT	8	224	-1126	105	x	94
REF ADJ	9	1086	-1154	105	x	105
MODE SEL	10	1057	-475	94	x	105
LED NO.10	11	1057	869	94	x	128
LED NO.9	12	1086	1052	105	x	105
LED NO.8	13	846	1160	105	x	94
NC	14	537	1154	105	x	105
LED NO.7	15	343	1154	105	x	105
NC	16	171	1154	82	x	105
LED NO.6	17	0	1154	105	x	105

Die/Wafer Characteristics (Continued)

LED NO.5	18	-320	1154	105	x	105
LED NO.4	19	-526	1154	105	x	105
LED NO.3	20	-1086	1086	105	x	105
LED NO.2	21	-1086	903	105	x	105

IN U.S.A	
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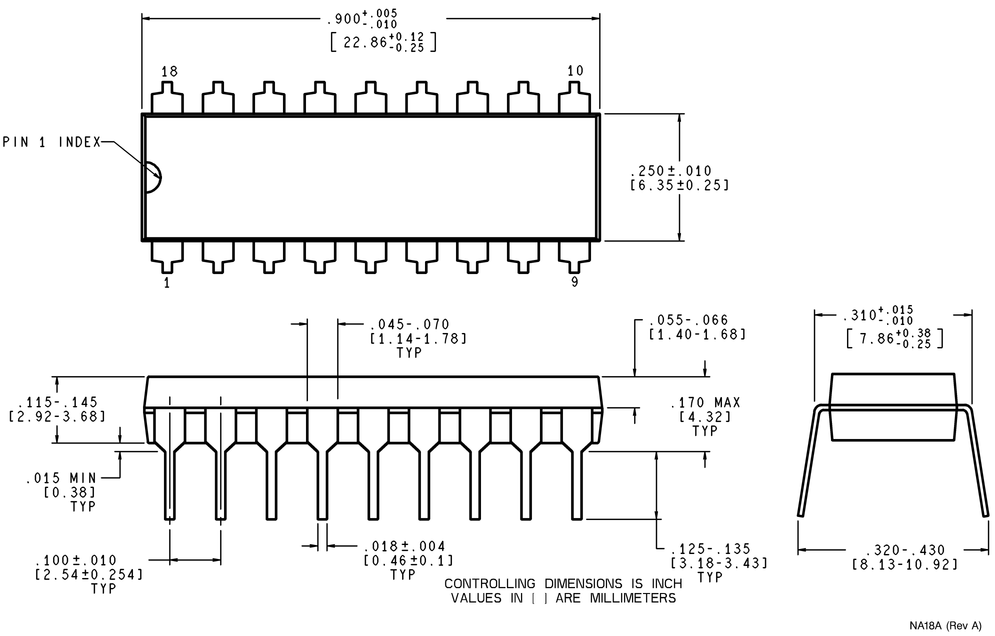
Fax:	1 207 541 6140
IN EUROPE	
Tel:	49 (0) 8141 351492 / 1495
Fax:	49 (0) 8141 351470
IN ASIA PACIFIC	
Tel:	(852) 27371701
IN JAPAN	
Tel:	81 043 299 2308

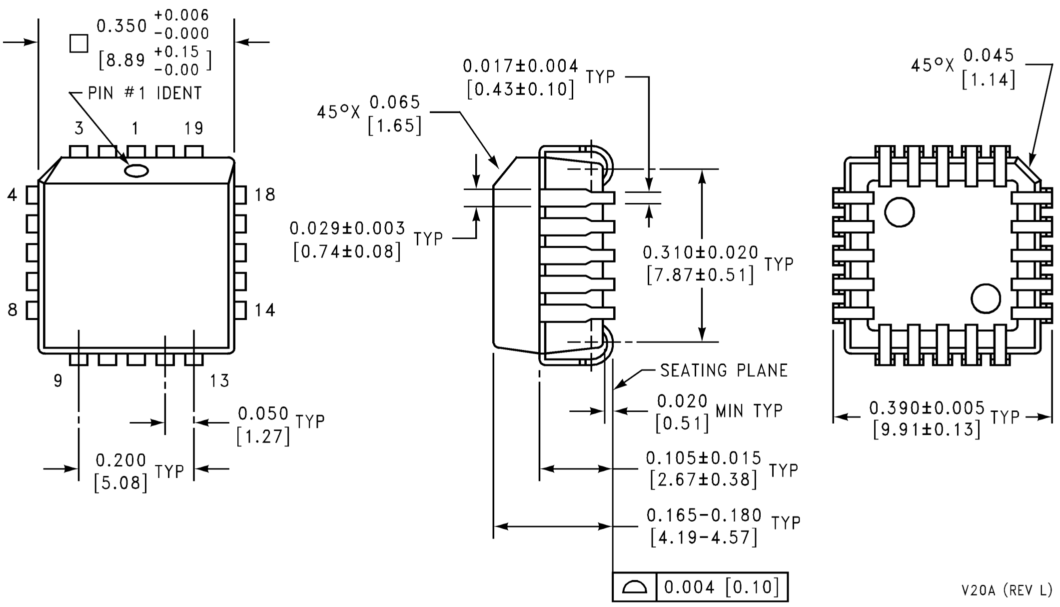
Physical Dimensions inches (millimeters) unless otherwise noted



Note: Unless otherwise specified.

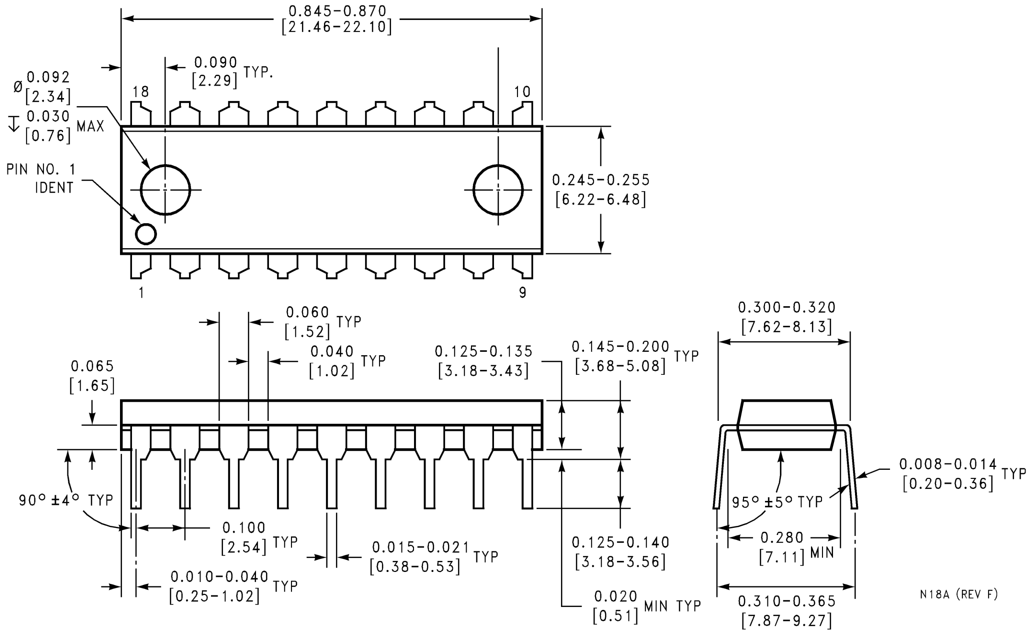
1. Standard Lead Finish:
   200 microinches /5.08 micrometer minimum
   lead/tin 37/63 or 15/85 on alloy 42 or equivalent or copper
2. Reference JEDEC registration MS-001, Variation AC, dated May 1993.

Dual-In-Line Package (N)
Order Number LM3914N-1
NS Package Number NA18A



Plastic Chip Carrier Package (V)
Order Number LM3914V
NS Package Number V20A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Dual-In-Line Package (N)
Order Number LM3914N *
NS Package Number N18A
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