ORKUSTOFNUN
Jarðhitadeild

HITAMÆLAR

Lýsing á nýjum hitamælum fyrir hitastafi og rúllur

Sverrir Hákonarson

OS-89055/JHD-27 B Desember 1989

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EFNISYFIRLIT

1. INNGANGUR

Í skýrslu þessari er fjallað um hitamæla sem voru hannaðir og smíðaðir á rafeindastofu Orkustofnunar. Um er að ræða rás sem breytir straummerki frá hitanema í spennumerki, 1 mV/°C. Hún er notuð bæði í hitamælistafi og einnig í ýmsar hitamælirúllur. Spennuna frá rásinni má síðan mæla með ýmsu móti t.d. með venjulegum fjölsviðsmæli eða með sérstökum skjá eins og lýst er hér í skýrslunni.

Fyrst er fjallað almennt um notkun mælanna og gerð grein fyrir kvörðun þeirra, en síðan um tæknilegu hliðina, hvernig rásin virkar, tengingar og annað. Í viðauka aftast í skýrslunni eru teikningar af prentplötunni og upplýsingar um ýmsa rásaíhluti.

2. LEIÐBEININGAR UM NOTKUN

Hitamælar þessir virka á svipaðan hátt og gömlu mælarnir. Kveikt er á þeim með því að setja nemann í samband. Hitaneminn og stafurinn eru þeir sömu. En rásin, sem breytir merkinu frá nemanum í spennumerki hefur verið endurnýjuð. Einnig er skjárinn mun nákvæmari en sá sem var í gömlu mælunum. Þegar rásin hefur verið kvörðuð við 0 °C og 100 °C, má gera ráð fyrir að skekkjan sé innan við 0,2 °C

Mælirinn notar 9 V rafhlöðu og eyðir um 2,6 mA. Ef notuð er Alkaline rafhlaða sem er um 0,2 Ahr, ætti hún að endast í um 80 tíma. Þegar hún er orðinn léleg, birtist á skjánum athugasemd, LO BAT. Þá er nauðsynlegt að skipta um rafhlöðuna. Hægt er að komast að henni með því að opna lok á botni mæliboxins.

Boxið er ekki vatnshelt og má það ekki blotna. Örlítill raki getur auðveldlega ruglað mælinn.

Hitaneminn er viðkvæmur og þolir lítið álag. Hann er látinn standa 3 til 4 cm fram úr stafnum til þess að minnka varmaáhrif frá stafnum, en það styttir þann tíma sem tekur nemann að ná réttu hitastigi. En það veldur því að neminn þolir minni áraun og því verður að nota annað verkfæri t.d. járnstaf til að gera holur í jarðveginn fyrir hitastafinn.

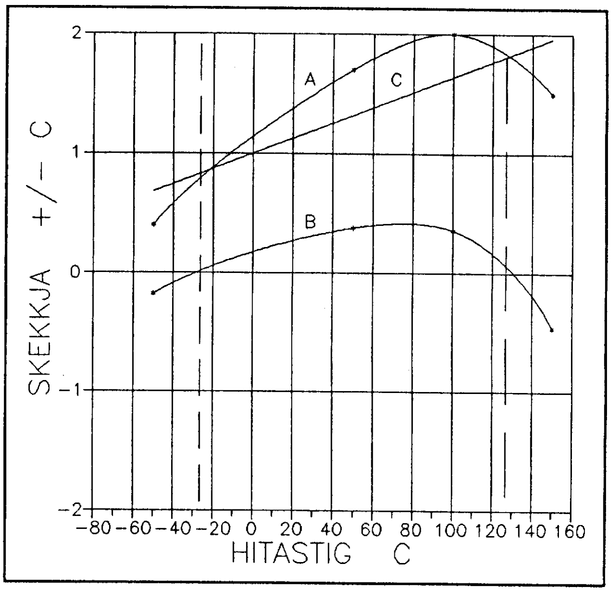
Hámarkshitastig sem neminn þolir er 150 °C og lágmarkshitastig er -55 °C. Hiti utan þessara marka eyðileggur hann.

3. KVÖRÐUN MÆLISINS

Nauðsynlegt er að kvarða stafinn og mæliboxið saman á nokkurra mánaða fresti. Það stafar af því að með tímanum geta ýmsir hlutir mælisins breytt sér, t.d. hitaneminn.

Neminn er ekki línulegur og getur hann verið töluvert ónákvæmur ef hann hefur ekki verið kvarðaður. Á Mynd 1 sýnir ferill A skekkju fyrir dæmigerðan ókvarðaðann nema. X-ásinn sýnir hitastig en y-ásinn frávik nemans frá réttu hitastigi.

Við kvörðun má ímynda sér að dreginn sé línan C, gegnum ferilinn. Hún sker ferilinn í tveim punktum. Í þessum punktum kemur mælirinn til með að sýna rétt hitastig. Mismunur línunnar og ferilsins A er skekkja mælisins. Ferill B er sá sami og A en honum hefur verið hliðrað þannig að línan fellur saman við x-ásinn. Nú má lesa skekkjuna beint af y-ásnum.

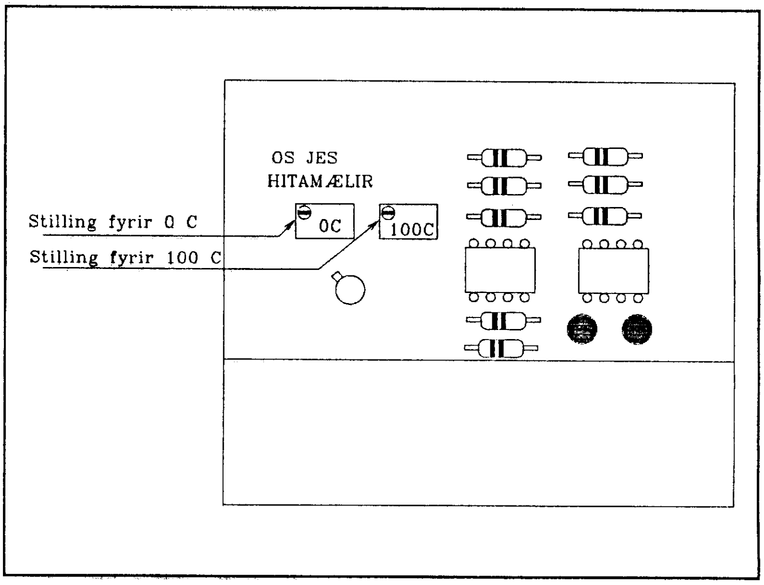


Mynd 1 Ónákvæmni Hitanemans

Á myndinni hefur mælirinn verið kvarðaður við -25 °C og 130 °C. Mesta skekkja er við 80 °C, þar sem hún er 0,4 °C. Ef valið er þrengra kvörðunarbil t.d. 0 - 100 °C minnkar skekkjan á því bili, verður minni en 0,2 °C, en vex um leið lengra frá bilinu. Tekið skal fram að þetta er aðeins dæmi um nema, en þeir eru mjög mismunandi og eiga þessar tölur ekki við um neinn sérstakann.

Á rásinni eru tvö stillanleg viðnám, annað merkt 0 °C og hitt merkt 100 °C. Mynd 2 sýnir hvar viðnámin eru staðsett. Með þeim má ákveða legu línunnar C á Mynd 1. Viðnámið til vinstri, merkt 0 °C, hliðrar línunni upp eða niður, en hægra viðnámið breytir halla línunnar.

Til að kvarða mælinn þarf að hafa vatn við þau hitastig sem kvarða á við. T.d. vatn með ís molum og vatn við suðumark, og glerhitamælir með ±0,1 °C náknæmni. Viðnámin eru síðan stillt þannig að mælirinn sýni sama gildi og glerhitamælirinn.

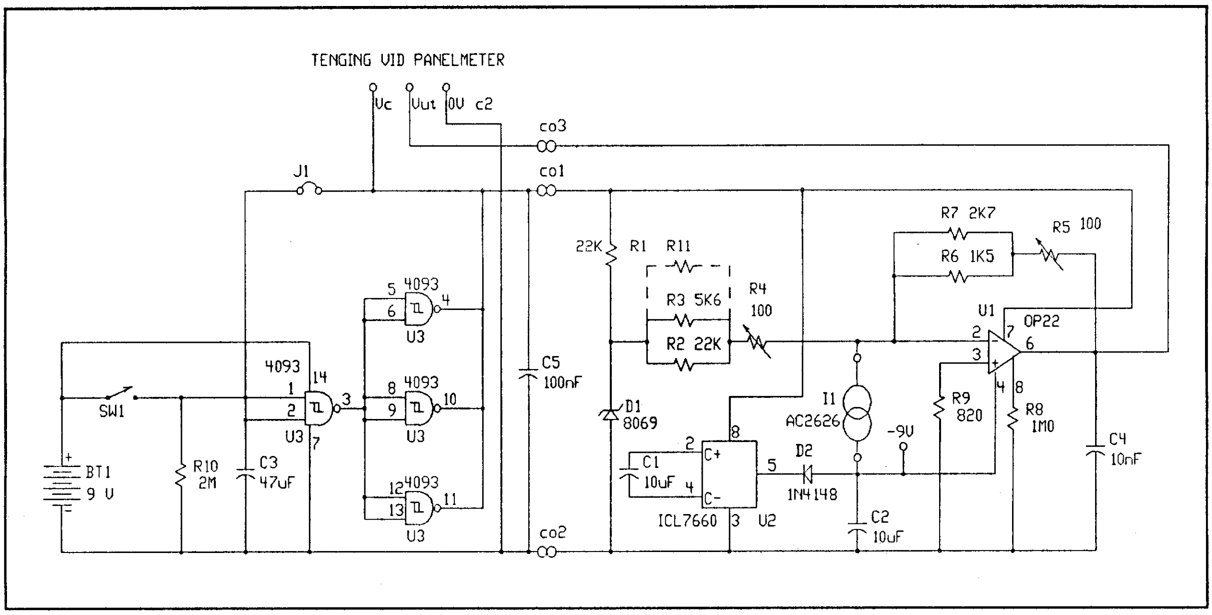


Mynd 2 Hitamælirásin

Athuga ber að við það að breyta 0 °C viðnáminu, breytist einnig hin viðnámsstillingin þar sem að allri línunni er hliðraði til. Það getur því þurft að endurtaka stillinguna nokkrum sinnum, bæði við lægsta og hæsta hitastigið.

4. TÆKNILEGAR UPPLÝSINGAR

Prentplötunni, sem sýnd er á Mynd 2, er skipt í tvennt. Efri hlutinn er sá sem breytir merkinu frá nemanum í spennumerki, en neðri hlutinn er sjálfvirkur rofabúnaður. Á Mynd 3 er rásarteikning af prentplötunni.



Mynd 3 Rásarteikning

4.1 Hitamælirásin

Neminn I1, er af tegundinni AC2626. Hann gefur straum í réttu hlutfalli við hita sem er 1 μA/°K. Rásin breytir straummerkinu í spennumerki sem er 1 mV/°C. Til þess að fá 0 mV við 0 °C eða 273,15 °K, þarf fastann straumgjafa sem gefur 273,15 μA straum sem dreginn er frá straumnum frá nemanum. Það er gert með fastri viðmiðunarspennu og viðnámum. Díóðan D1 sem er ICL 8069 gefur 1,2 V fasta spennu og viðnámið R1 skammtar strauminn í gegnum hana. Viðnámin R2, R3 og R4 eru samanlagt 4,4 KΩ og gefa því 273,15 μA straum. Aðgerðarmagnarinn er af tegundinni OP 22, en frekari upplýsingar um hann er að finna í viðauka.

Straum umfram þessi 273,15 μA sem neminn þarf eru dreginn í gegnum afturverkunarviðnám aðgerðarmagnarans U1, sem eru R5, R6 og R7. Þessi viðnám eru samanlagt 1 KΩ, þannig að fyrir 1 μA aukningu í straum um nemann, vex útspenna aðgerðarmagnarans um 1 mV.

Negatífur spennugjafi U2 sem er ICL 7660, sér nemanum fyrir spennu, ásamt því að fæða aðgerðarmagnarann. Við hann eru tengdir tveir 10 μF þéttar C1 og C2.

Eins og fram hefur komið eru breytilegu viðnámin R4 og R5 notuð til að kvarða mælinn. Með R4 sem er 100 Ω má hliðra kvörðunarlínunni til um ±3,0 °C. Og með R5 má breyta 100°C um ±5,0 °C.

Viðmiðunar spenna [V]	Viðnám R11 [KΩ]
1,20	180
1,21	220
1,22	390
1,23	∞

Tafla 1 Spennugildi og samsvarandi viðnám

Í ljós hefur komið að viðmiðunarspennan sem díóðan D1 gefur getur verið mismunandi eftir einstaklingum. Hún getur verið á bilinu 1,20 V til 1,24 V. Lítil breyting á spennunni getur valdið því að ekki næst að stilla núllpunktinn inn með breytilega viðnáminu R4. Því hefur þurft að breyta viðnámsgildinu sem R2, R3 og R4 gefa með því að bæta við viðnáminu R11. Ef spennan er 1,230 V þarf ekkert viðnám, en ef hún fer niður í 1,20 V þarf R11 að vera 180 kΩ. Tafla 1 sýnir nokkur spennugildi og samsvarandi viðnám.

4.2 Rás fyrir rofabúnað

Neðri hlutinn af prentrásinni er sjálfvirkur rofabúnaður. Við hann þarf rofa sem þrýst er á og logar þá á mælinum í ákveðinn tíma. Þessi búnaður henntar vel í t.d. hitamælirúllur þar sem óhentugt er að nota venjulegann rofa. Rásarbrettið er þannig hannað að hægt er að klippa það í tvennt og fjarlægja rofabúnaðinn. Hann er ekki notaður í hitastöfunum.

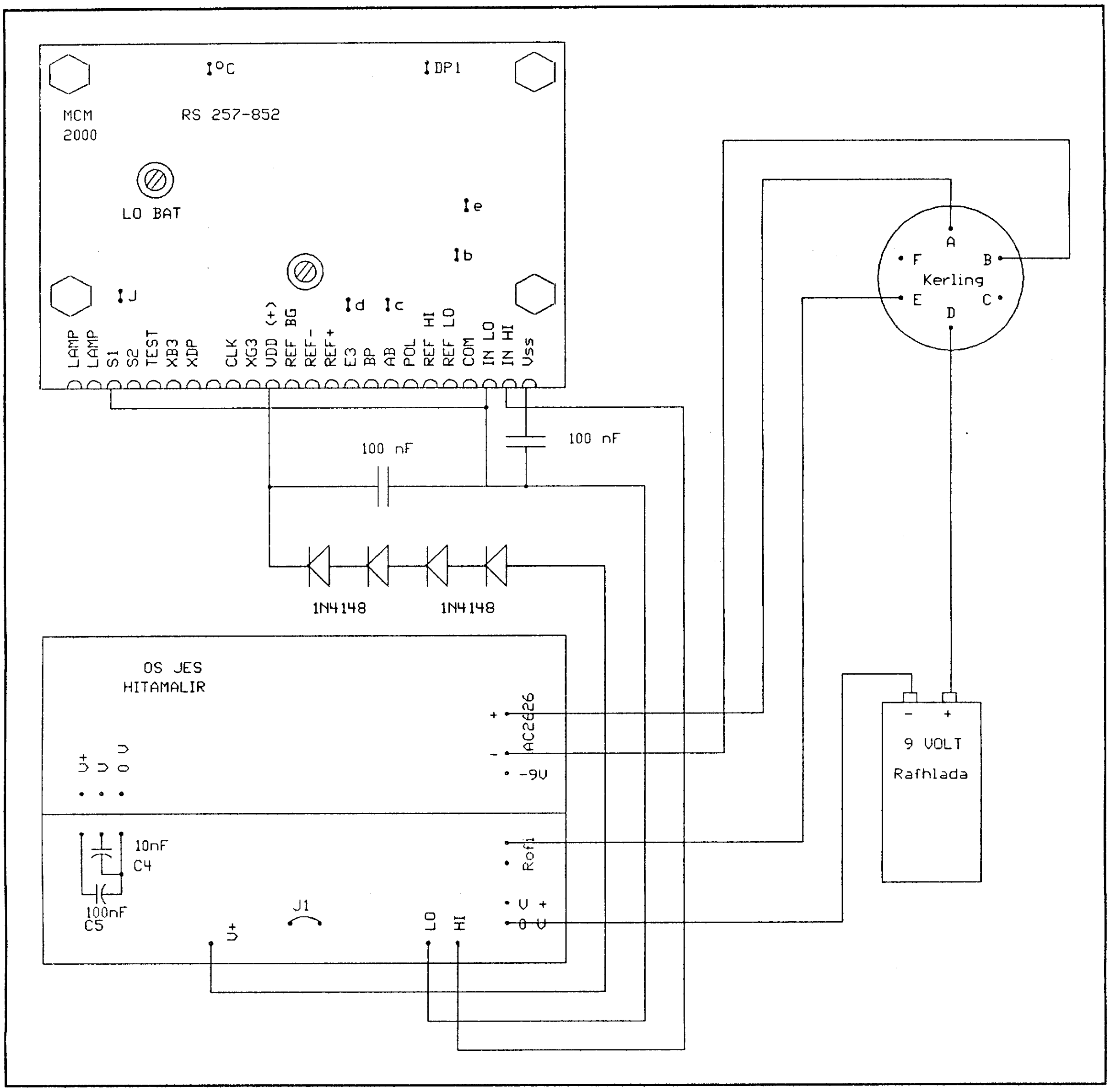
Rásin vinnur þannig að inn á inngang á NAND-hlið er tengdur þéttir C3 sem afhleðst í gegnum viðnám R10. Þegar þrýst er á rofann SW1 hleðst þéttirinn upp. Við það fara útgangar hliðanna þriggja upp og sjá hitamælirásinni fyrir spennu. Tímastuðull RC-rásarinnar ræður því hversu lengi kveikt er á henni. Nú er þéttirinn 47 μF og viðnámið

2 MΩ. Það þýðir að tímastuðullinn er 90 sek en þessum gildum má breyta að vild.

Ef þessi hluti er ekki notaður má tengja fram hjá honum með því að lóða vír í J1. (Sjá Mynd 3 Rásarteikning)

5. TENGINGAR INNAN BOXINS

5.1 Mælibox fyrir hitamælistaf



Mynd 4 Tengingar innan boxins

Pinnanúmer á tenginu	Merki
A	Nemi +
B	Nemi -
C	
D	Aflrofi
E	Aflrofi
F	

Tafla 2 Tengingar fyrir 6 pinna tengi

Mynd 4 sýnir allar tengingar milli íhluta inni í boxinu. Spennan fyrir skjáinn má ekki vera hærri en 7,5 V. Spennan frá 9,0 V rafhlöðunni er lækkuð um 3 V með fjórum

raðtengdum díóðum. Tveir þéttar eru á aflinu á skjánum sem báðir eru 100 nF. Einnig er 100 nF þéttir á aflinu á hitamælirásinni, merktur C5 og annar 10 nF á útgangnum á aðgerðarmagnaranum merktur C4. Þessir tveir þéttar C4 og C5 eru seinni tíma viðbót og eru þeir staðsettir eins og Mynd 4 sýnir.

Á myndinni eru sýnir allir tengipunktarnir á skjánum sem þarf að lóða, sjö að tölu. En það eru b, c, d, e, j, °C, og DP1.

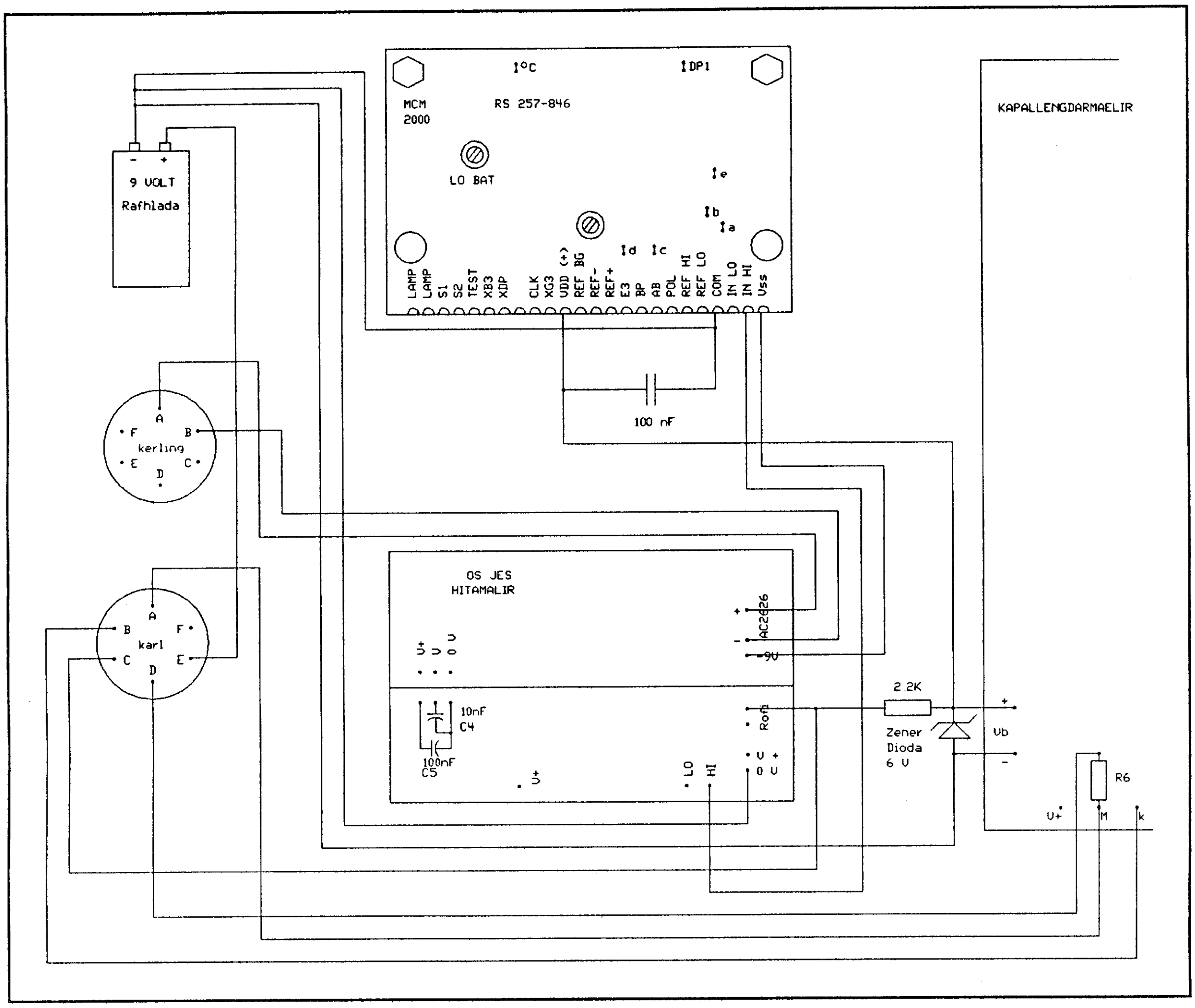
Tafla 2 sýnir tengingar við 6 pinna tengið sem er kerling. Annars vegar er neminn tengdur við það og hins vegar virkar tengið sem rofi fyrir aflið því í karltenginu er tengt á milli pinna D og E.

5.2 Mælibox fyrir hitamælirúllu

Mynd 5 sýnir aftur á móti tengingu í mæliboxi hitamælirúllu þar sem einnig er kapallengdarmælir. Hann þarf 6 V aflspennu sem er fengin með 2,2 KΩ viðnámi og 6 volta zenerdíóðu. Sú spenna er einnig notuð sem aflspenna fyrir skjáinn. Á þessari mynd er sýnd tenging fyrir skjá sem er af tegundinni RS 257-846. Hann er frábrugðinn RS 257-852 að því leiti að hann hefur ekki negatífann spennugjafa. Því er Vss (0 V) á skjánum tengt í -9 V á mælirásinni. Frekari upplýsingar um skjáina er að finna í viðauka.

Á þessari tegund RS 257-846, þarf að lóða eftirfarandi sjö tengipunkta: a, b, c, d, e, °C og DP1.

Hér eru tvö tengi, kerling sem er aðeins fyrir hitanemann og karl sem er fyrir kapallengdarmælinn og aflrofann. Tegingarnar eru tíundaðar í Töflu III. Að öðru leiti eru tengingarnar eins og á Mynd 4.



Mynd 5 Tengingar innan mæliboxins ásamt kapallengdarmæli

Pinnanúmer á tenginu	Kerling	Karl
A	Nemi +	K. +
B	Nemi -	K. -
C		Aflrofi
D		K. jörð
E		Aflrofi
F		

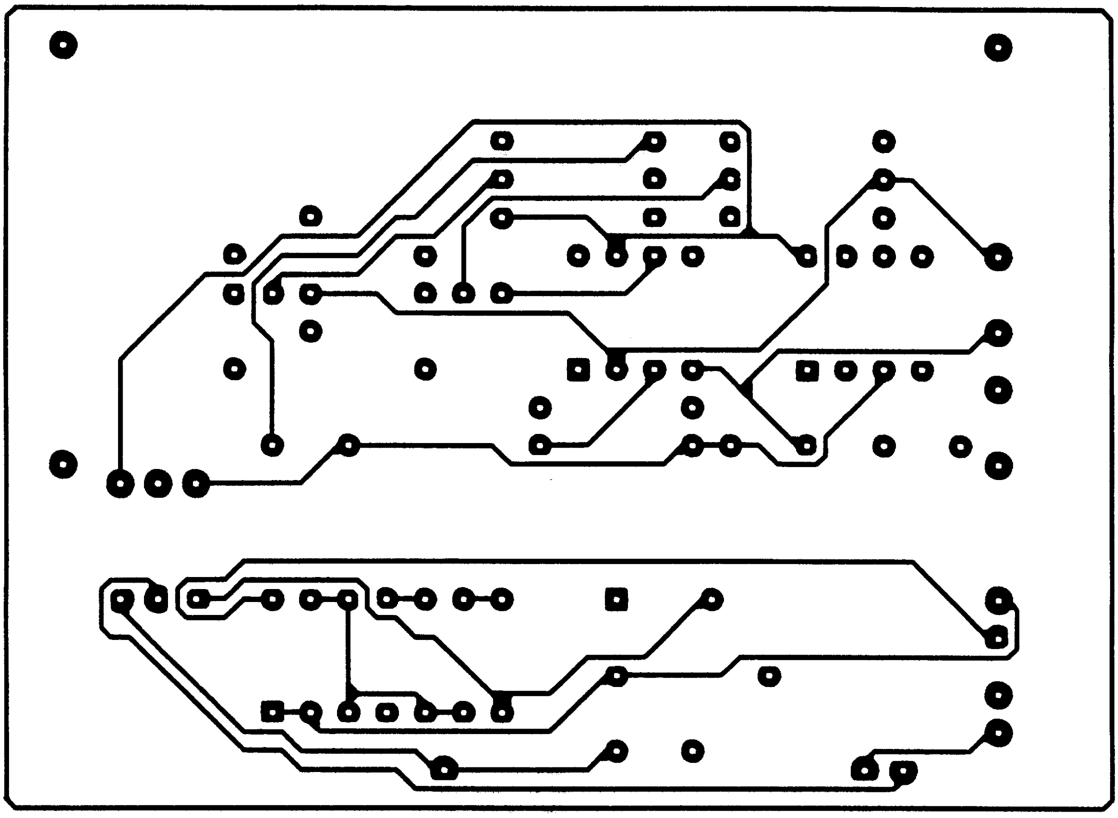
K. stendur fyrir Kapallengdarmæli

Tafla 3 Tengingar fyrir 6 pinna tengi

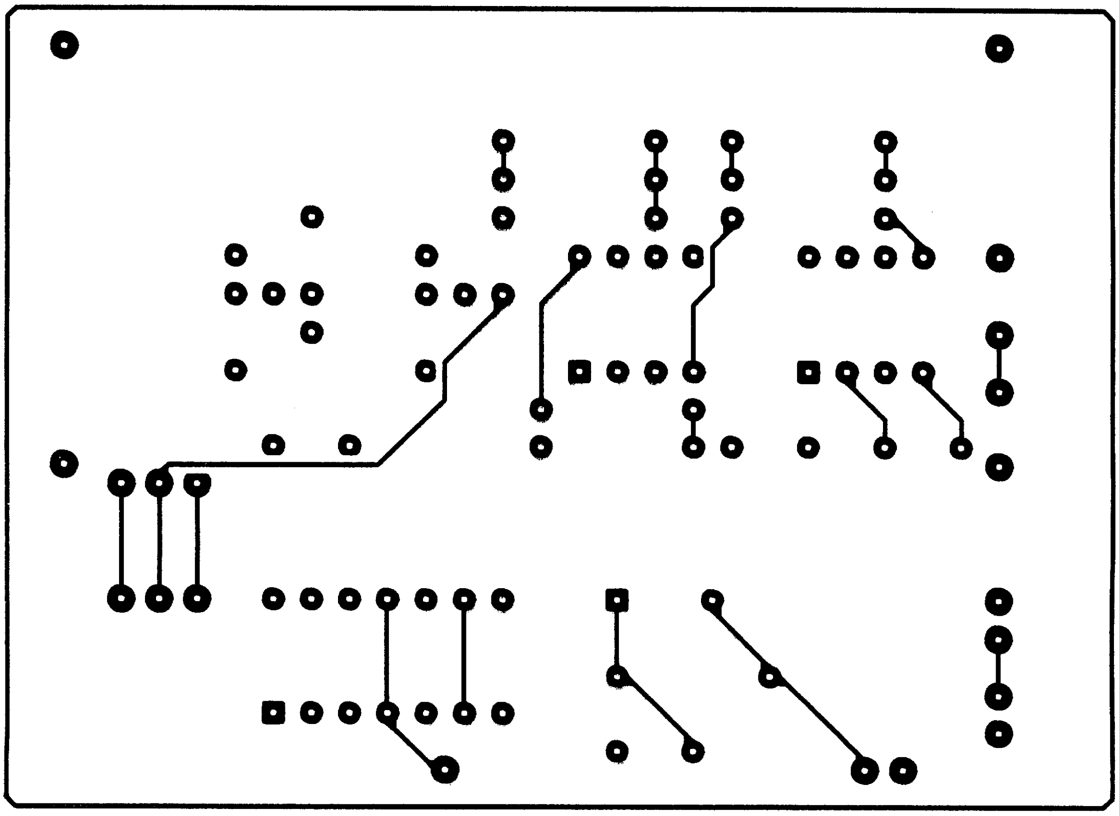
Í viðauka A, Teikningar af prentplötu, eru allar teikningar sem þarf til þess að smíða hana.

VIÐAUKAR

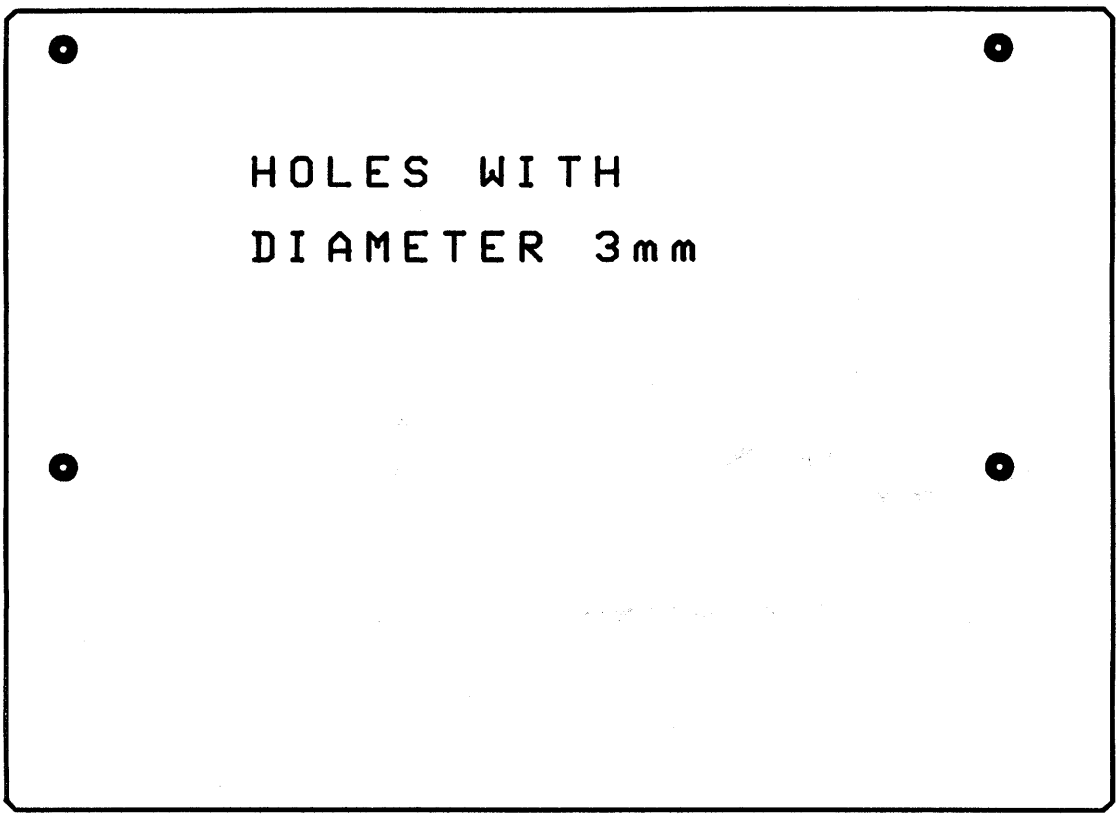
A. Teikningar af prentplötu



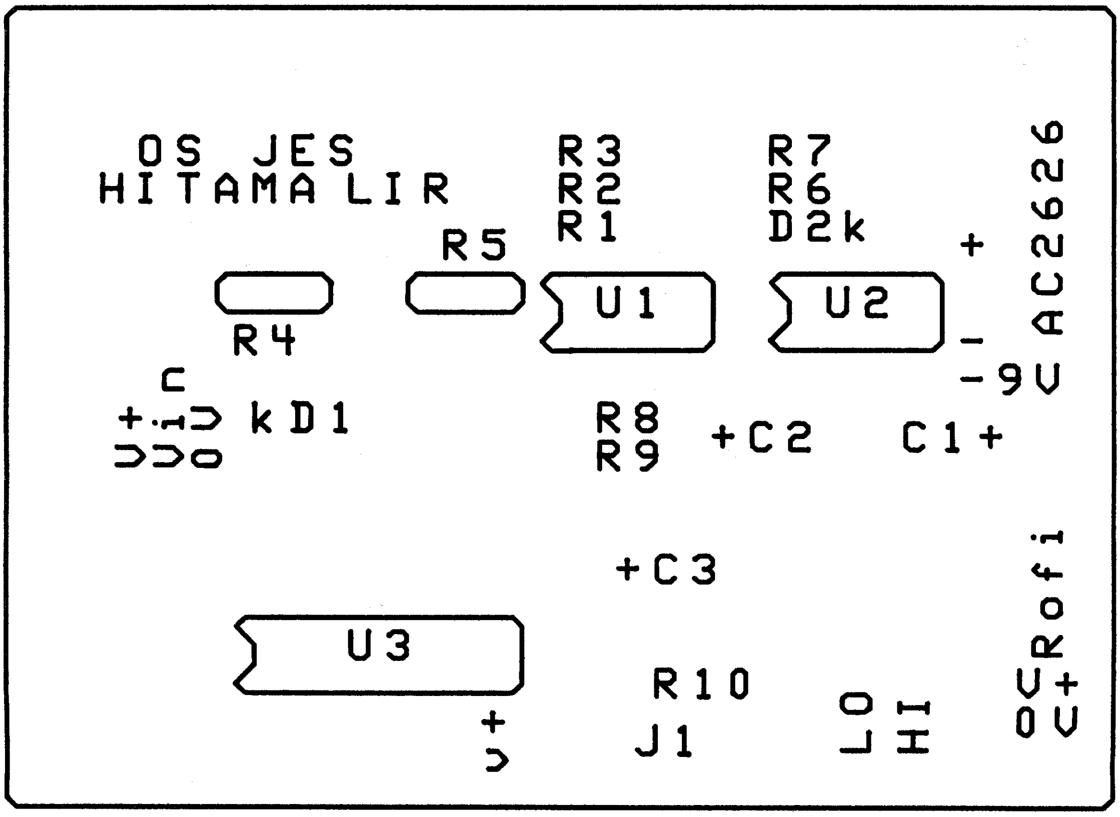
Leiðarar. (Neðri hliðin)



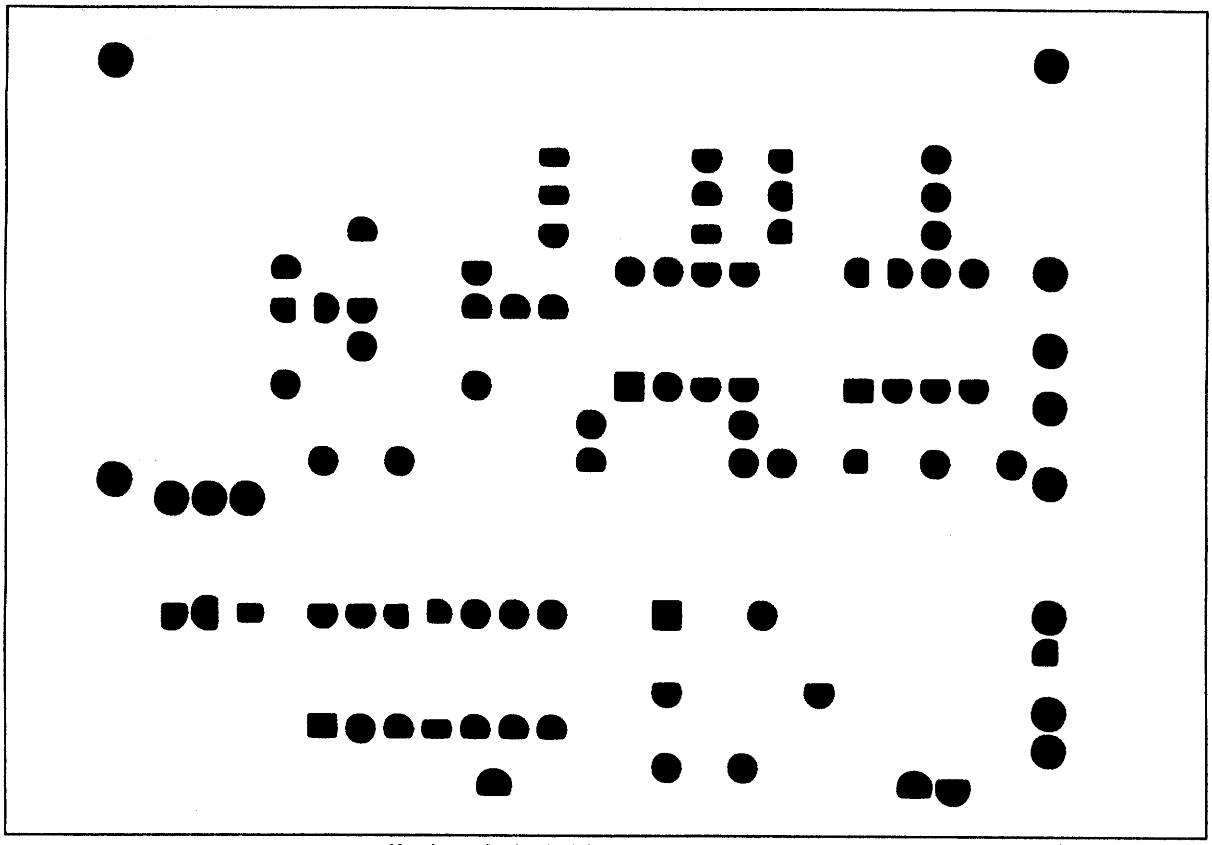
Leiðarar (Efri hlið)



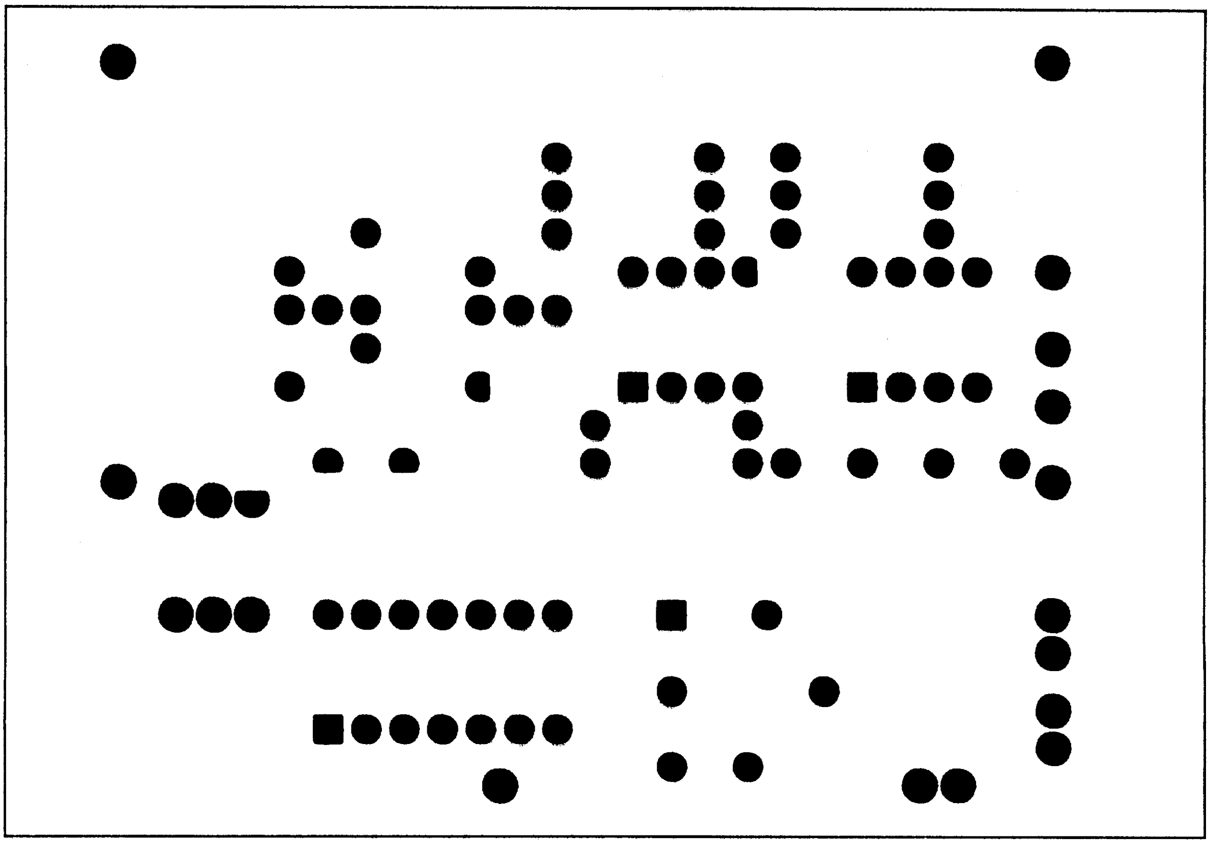
Teikning fyrir 3 mm holur.



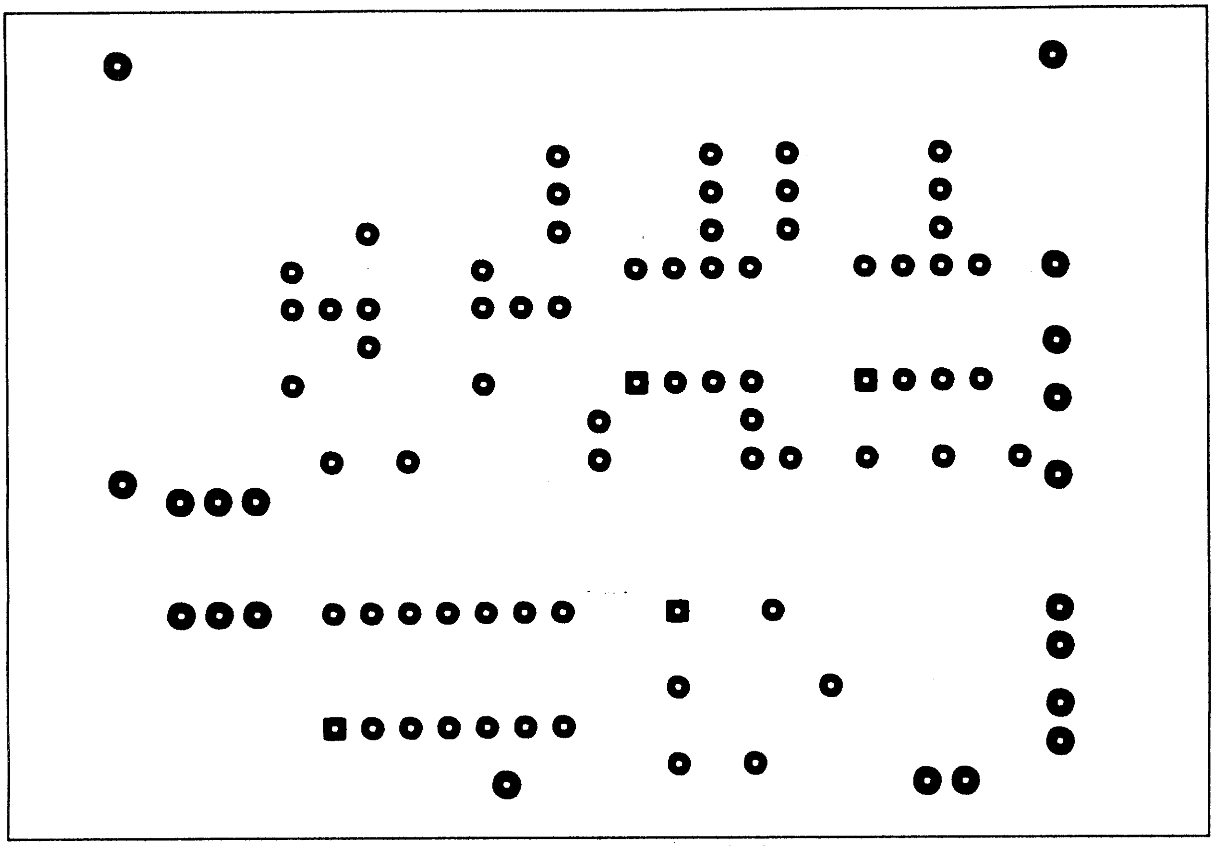
Teikning fyrir texta.



Teikning fyrir lakkhúð. (Neðri hliðin)



Teikning fyrir lakkhúð (Efri hlið)



Teikning fyrir 0.9 mm holur.

B. Upplýsingar um rásaíhluti

i.	OP 22	
ii.	AC 2626	
iii.	ICL 7660	
iv.	ICL 8069	
v.	MCM 2000	RS 257-852
vi.	MCM 2000	RS 257-846

OP-22 PROGRAMMABLE MICROPOWER OPERATIONAL AMPLIFIER (SINGLE OR DUAL SUPPLY)

FEATURES

- **Programmable Supply Current .... 1μA to 400μA**
- **Single Supply Operation .... +3V to +30V**
- **Dual Supply Operation .... ±1.5V to ±15V**
- **Low Input Offset Voltage 100μV**
- **Low Input Offset Voltage Drift .... 0.75μV/°C**
- **High Common-Mode Input Range ... V− to V+ (−1.5V)**
- **High CMRR and PSRR 115dB**
- **High Open-Loop Gain 1800V/mV**
- **±30V Input Overvoltage Protection**
- **Unity-Gain Stable**
- **LM4250 Pinout and Nulling**

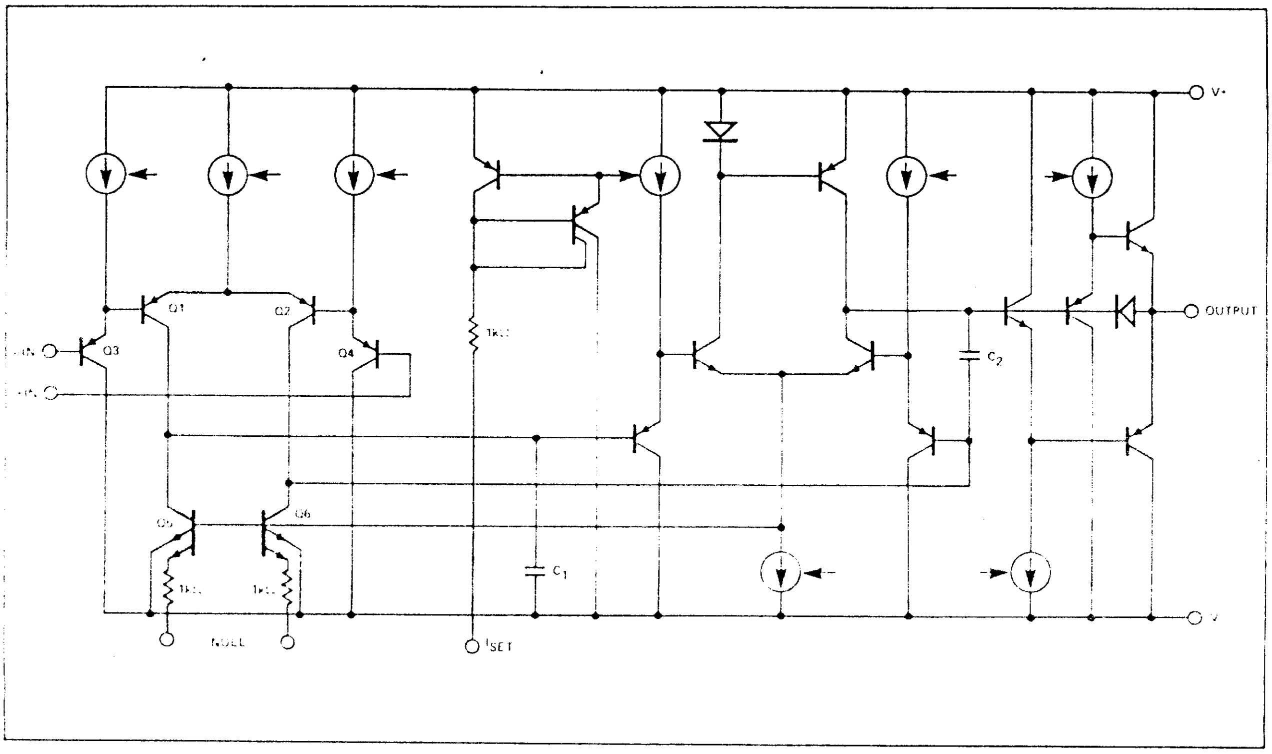
GENERAL DESCRIPTION

The OP-22 is a monolithic micropower operational amplifier designed to provide excellent accuracy in high-gain applications. Offsets are very low which generally eliminates any need for external nulling of V_{OS}. The OP-22 is internally compensated and unity-gain stable. It also features high open-loop gain, CMRR, and PSRR. This assures good gain accuracy and rejection of power supply variations even when used in circuits with high closed-loop gain. The low offsets and high gain accuracy of the OP-22 bring precision performance to the micropower field.

The OP-22 is a versatile op amp designed for operation from battery or solar-cell power sources. Supply current is programmable over a range of 1μA to 400μA with a single external resistor. Input voltage range is very wide and extends down to the negative rail, thus the common-mode input voltage range includes ground when operating from a single supply voltage. This ability to provide high DC performance over a wide input range is particularly useful in single-battery applications. In addition, the OP-22 is characterized over a wide supply range of ±1.5V to ±15V, or +3V to +30V for single supply.

The OP-22 pin-out and offset nulling are identical to the LM4250 and many other micropower operational amplifiers. This functional commonality allows easy upgrading of system performance. By selection of set resistor value, the circuit designer can readily use the OP-22 in place of such amplifiers as the LM108, LM112, LM4250, μA776, and ICL8021 in high-gain, low-frequency applications.

SIMPLIFIED SCHEMATIC



ABSOLUTE MAXIMUM RATINGS (Note 2)

Supply Voltage .... ±18V
Power Dissipation (Note 1) 500mW
Differential Input Voltage .... ±30V
Input Voltage .... Supply Voltage
Storage Temperature Range
J and Z Packages .... −65°C to +150°C
Operating Temperature Range
OP-22A, OP-22B (J or Z package) ... −55°C to +125°C
OP-22E, OP-22F (J or Z package) .... −25°C to +85°C
OP-22HJ, OP-22HZ .... 0°C to +70°C
Lead Temperature Range (Soldering, 60 sec.) ..... 300°C
DICE Junction Temperature .... −65°C to +150°C

NOTES:

1. See table for maximum ambient temperature rating.
2. Absolute ratings apply to both DICE and packaged parts, unless otherwise noted.

	MAXIMUM AMBIENT TEMPERATURE $V_S = \pm 15V$ and $I_{SET} = 10\mu A$	DERATE ABOVE MAXIMUM AMBIENT TEMPERATURE
TO-99 (J)	124°C	—
8-Pin Hermetic DIP (Z)	124°C	—

ELECTRICAL CHARACTERISTICS at $V_S = \pm 1.5V$ to $\pm 15V$, $1\mu A \le I_{SET} \le 10\mu A$, $T_A = +25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	OP-22A/E MIN	OP-22A/E TYP	OP-22A/E MAX	OP-22B/F MIN	OP-22B/F TYP	OP-22B/F MAX	OP-22H MIN	OP-22H TYP	OP-22H MAX	UNITS
Input Offset Voltage	V_{OS}		—	100	300	—	200	500	—	400	1000	μV
Input Offset Current	I_{OS}		—	0.2	1	—	0.3	2	—	0.5	3	nA
Input Bias Current	I_B	$I_{SET} = 1\mu A$	—	2.6	5	—	3.0	7.5	—	4.0	10	nA
		$I_{SET} = 10\mu A$	—	19	30	—	24	35	—	30	50	
Input Voltage Range	IVR	V+ = +5V, V− = 0V	0/3.5	—	—	0/3.5	—	—	0/3.5	—	—	V
		$V_S = \pm 15V$	−15/+13.5	—	—	−15/+13.5	—	—	−15/+13.5	—	—	
Common-Mode Rejection Ratio	CMRR	$V_S = \pm 15V$, $-15V \le V_{CM} \le +13.5V$	100	115	—	95	105	—	85	95	—	dB
Power Supply Rejection Ratio (Note 1)	PSRR	$V_S = \pm 1.5V$ to $\pm 15V$; and V− = 0V, V+ = 3V to 30V	—	1.8	6	—	6	18	—	10	32	dB
Large-Signal Voltage Gain	A_{VO}	$V_S = \pm 15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$	1000	1800	—	500	900	—	250	500	—	V/mV
		$V_S = \pm 15V$, $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	1000	1800	—	500	900	—	300	500	—	V/mV
Output Voltage Swing	V_O	$V_S = \pm 1.5V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±0.8	±0.82	—	±0.8	±0.82	—	±0.75	±0.8	—	V
		$V_S = \pm 15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±14	±14.2	—	±14	±14.2	—	±13.5	±14	—	V
Closed-Loop Bandwidth	BW	$A_{VCL} = +1.0$, $V_S = \pm 15V$, $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	—	250	—	—	250	—	—	250	—	kHz
Slew Rate	SR	$V_S = \pm 15V$, $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	—	0.08	—	—	0.08	—	—	0.08	—	V/μs
Supply Current No Load	I_{SY}	$V_S = \pm 15V$, $I_{SET} = 1\mu A$	—	15	17	—	16	19	—	18	21	μA
		$V_S = \pm 15V$, $I_{SET} = 10\mu A$	—	150	170	—	160	190	—	180	210	
		$V_S = \pm 1.5V$, $I_{SET} = 1\mu A$	—	10.5	12.5	—	14	16	—	17	20	
		$V_S = \pm 1.5V$, $I_{SET} = 10\mu A$	—	105	125	—	140	160	—	170	200	

NOTE:

1. Sample tested for single-supply operation, 100% tested for dual-supply operation.

ELECTRICAL CHARACTERISTICS at $V_S = \pm 1.5V$ to $\pm 15V$, $1\mu A \le I_{SET} \le 10\mu A$, $-55°C \le T_A \le +125°C$ for OP-22AJ/AZ and OP-22BJ/BZ, $-25°C \le T_A \le +85°C$ for OP-22EJ/EZ and OP-22FJ/FZ, and $0°C \le T_A \le +70°C$ for OP-22HJ and OP-22HZ, unless otherwise noted.

			OP-22A/E			OP-22B/F			OP-22H			
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
Average Input Offset Voltage Drift (Note 1)	TCV_{OS}	Unnulled	—	0.75	1.5	—	1.0	2.0	—	1.5	3.0	μV/°C
Input Offset Voltage	V_{OS}	—	—	175	400	—	350	600	—	500	1200	μV
Input Offset Current	I_{OS}	—	—	0.2	1	—	0.3	2	—	0.5	3	nA
Average Input Offset Current Drift	TCI_{OS}	(Note 1)	—	2	10	—	3	15	—	5	25	pA/°C
Input Bias Current	I_B	$I_{SET} = 1\mu A$	—	2.8	5	—	3.3	7.5	—	4.5	10	nA
		$I_{SET} = 10\mu A$	—	21	30	—	27	35	—	34	50	
Input Voltage Range	IVR	$V+ = +5V$, $V- = 0V$	0/3.2	—	—	0/3.2	—	—	0/3.2	—	—	V
		$V_S = \pm 15V$	−15/+13.2	—	—	−15/+13.2	—	—	−15/+13.2	—	—	
Common-Mode Rejection Ratio	CMRR	$V_S = \pm 15V$, $-15V \le V_{CM} \le +13.2V$	90	115	—	86	105	—	80	90	—	dB
Power Supply Rejection Ratio (Note 2)	PSRR	$V_S = \pm 1.5V$ to $\pm 15V$ & $V- = 0V$, $V+ = 3V$ to $30V$	—	3.2	10	—	10	32	—	32	56	μV/V
Large-Signal Voltage Gain	A_{VO}	$V_S = \pm 15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$	400	900	—	250	500	—	100	250	—	V/mV
		$V_S = \pm 15V$, $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	500	1000	—	250	500	—	150	300	—	
Output Voltage Swing	V_O	$V_S = \pm 1.5V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±0.65	±0.75	—	±0.65	±0.75	—	±0.6	±0.7	—	V
		$V_S = \pm 15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±13.6	±13.8	—	±13.6	±13.8	—	±13.0	±13.5	—	V
Supply Current No Load	I_{SY}	$V_S = \pm 15V$, $I_{SET} = 1\mu A$	—	16	18	—	17	20	—	20	25	μA
		$V_S = \pm 15V$, $I_{SET} = 10\mu A$	—	160	180	—	170	200	—	200	250	
		$V_S = \pm 1.5V$, $I_{SET} = 1\mu A$	—	12	14	—	15	18	—	19	25	
		$V_S = \pm 1.5V$, $I_{SET} = 10\mu A$	—	120	140	—	150	180	—	190	250	

NOTES:
1. Sample tested.
2. 100% tested for dual supply operation, sample tested for single supply operation.

ORDERING INFORMATION†

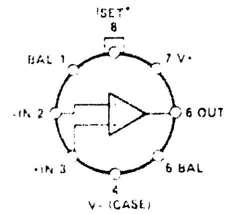
$T_A = 25°C$ V_{OS} MAX (μV)	PACKAGE: TO-99 8-PIN	PACKAGE: HERMETIC DIP 8-PIN	OPERATING TEMPERATURE RANGE
300	OP22AJ*	OP22AZ*	MIL
300	OP22EJ	OP22EZ	IND
500	OP22BJ*	OP22BZ*	MIL
500	OP22FJ	OP22FZ	IND
1000	OP22HJ	OP22HZ	COM

*Also available with MIL-STD-883B Processing. To order add /883 as a suffix to the part number. See Section 3 for screening procedure.

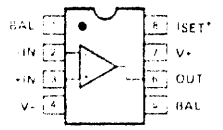
†All commercial and industrial temperature range parts are available with burn-in per MIL-STD-883. See Ordering Information, Section 2.

PIN CONNECTIONS

* NOTE: DO NOT SHORT PIN 8 TO V− OR GROUND. SEE APPLICATIONS INFORMATION.

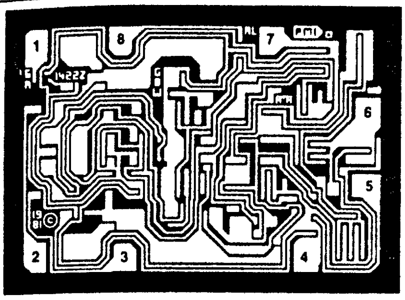


TO-99
(J-Suffix)



8-PIN HERMETIC DIP
(Z-Suffix)

DICE CHARACTERISTICS



DIE SIZE 0.069 × 0.049 inch, 3381 sq. mils
(1.75 × 1.24 mm, 2.18 sq. mm)

1. BALANCE
2. INVERTING INPUT
3. NONINVERTING INPUT
4. V−
5. BALANCE
6. OUTPUT
7. V+
8. I_{SET}

For additional DICE information refer to Section 2.

WAFER TEST LIMITS at $V_S = \pm1.5V$ to $\pm15V$, $1\mu A \le I_{SET} \le 10\mu A$, $T_A = 25°C$, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	OP-22N LIMIT	OP-22G LIMIT	OP-22GR LIMIT	UNITS
Input Offset Voltage	V_{OS}		300	500	1000	µV MAX
Input Offset Current	I_{OS}		1	2	3	nA MAX
Input Bias Current	I_B	$I_{SET} = 1\mu A$	5	7.5	10	nA MAX
		$I_{SET} = 10\mu A$	30	35	50	
Input Voltage Range	IVR	V+ = +5V, V− = 0V	0/3.5	0/3.5	0/3.5	V MIN
		$V_S = \pm15V$	−15/+13.5	−15/+13.5	−15/+13.5	
Common-Mode Rejection Ratio	CMRR	$V_S = \pm15V$, $-15V \le V_{CM} \le +13.5V$	100	95	85	dB MIN
Power Supply Rejection Ratio	PSRR	$V_S = \pm1.5V$ to $\pm15V$; V− = 0V, V+ = 3V to 30V	6	18	32	µV/V MIN
Large-Signal Voltage Gain	A_{VO}	$V_S = \pm15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$	1000	500	250	V/mV MIN
		$V_S = \pm15V$, $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	1000	500	300	
Output Voltage Swing	V_O	$V_S = \pm1.5V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±0.8	±0.8	±0.75	V MIN
		$V_S = \pm15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	±14	±14	±13.5	
Supply Current No Load	I_{SY}	$V_S = \pm15V$, $I_{SET} = 1\mu A$	17	19	21	µA MAX
		$V_S = \pm15V$, $I_{SET} = 10\mu A$	170	190	210	
		$V_S = \pm1.5V$, $I_{SET} = 1\mu A$	12.5	16	20	
		$V_S = \pm1.5V$, $I_{SET} = 10\mu A$	125	160	200	

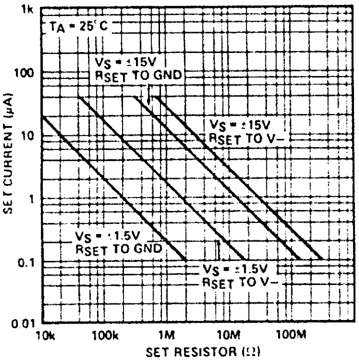
Note: Electrical tests are performed at wafer probe to the limits shown. Due to variations in assembly methods and normal yield loss, yield after packaging is not guaranteed for standard product dice. Consult factory to negotiate specifications based on dice lot qualification through sample lot assembly and testing.

TYPICAL ELECTRICAL CHARACTERISTICS at $V_S = \pm1.5V$ to $\pm15V$, $1\mu A \le I_{SET} \le 10\mu A$, $T_A = +25°C$, unless otherwise noted.

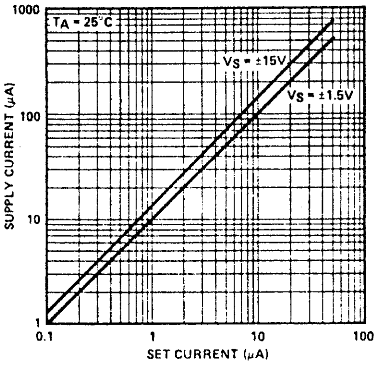
PARAMETER	SYMBOL	CONDITIONS	OP-22N TYPICAL	OP-22G TYPICAL	OP-22GR TYPICAL	UNITS
Average Input Offset Voltage Drift	TCV_{OS}	Unnulled	1.0	1.5	2.5	µV/°C
Large-Signal Voltage Gain	A_{VO}	$V_S = \pm15V$, $I_{SET} = 1\mu A$, $R_L = 100k\Omega$ & $I_{SET} = 10\mu A$, $R_L = 10k\Omega$	1800	900	500	V/mV

TYPICAL PERFORMANCE CHARACTERISTICS

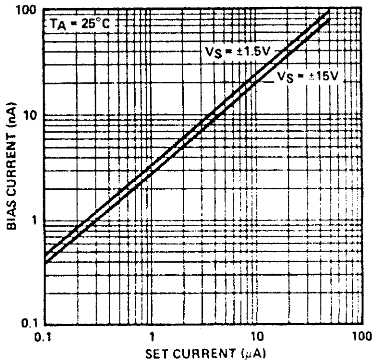
SET CURRENT vs SET RESISTOR



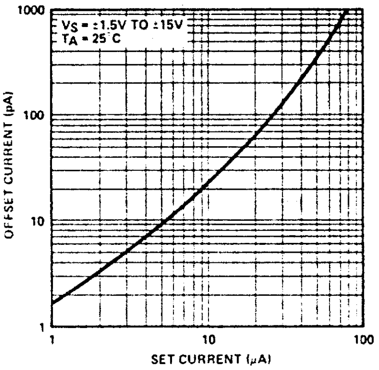
SUPPLY CURRENT vs SET CURRENT



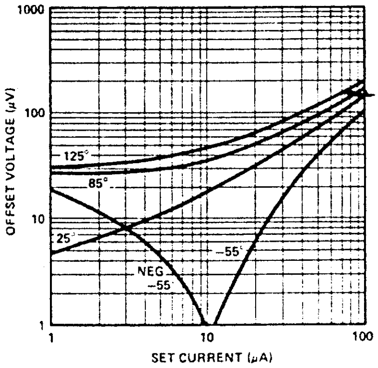
BIAS CURRENT vs SET CURRENT



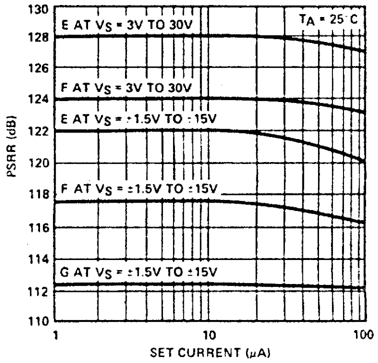
OFFSET CURRENT vs SET CURRENT



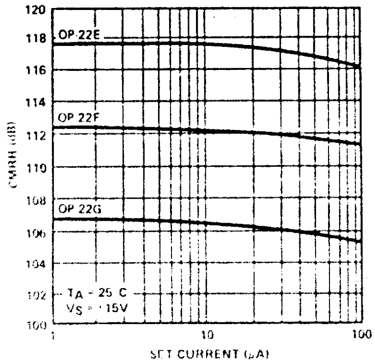
OFFSET VOLTAGE vs SET CURRENT



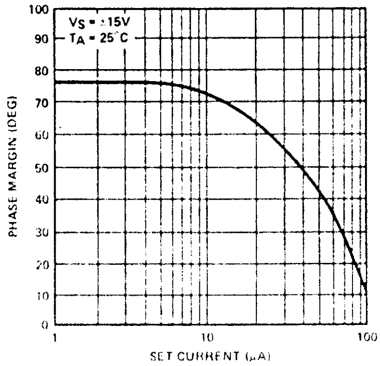
POWER SUPPLY REJECTION vs SET CURRENT



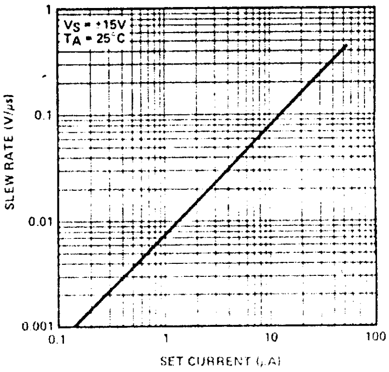
COMMON-MODE REJECTION vs SET CURRENT



PHASE MARGIN vs SET CURRENT

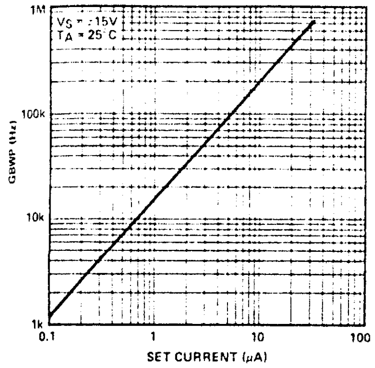


SLEW RATE vs SET CURRENT

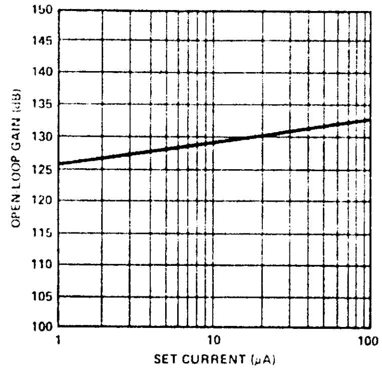


TYPICAL PERFORMANCE CHARACTERISTICS

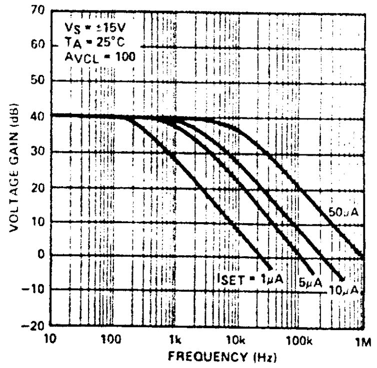
GAIN-BANDWIDTH PRODUCT vs SET CURRENT



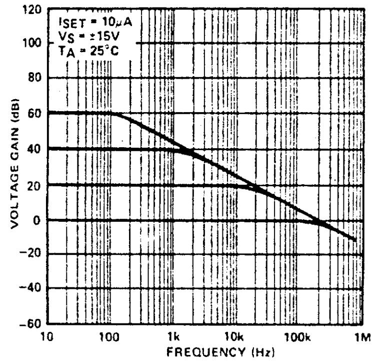
OPEN-LOOP GAIN vs SET CURRENT



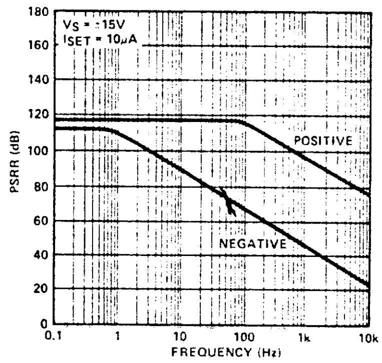
FREQUENCY RESPONSE vs SET CURRENT



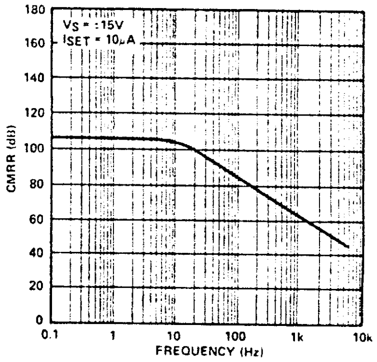
CLOSED-LOOP FREQUENCY RESPONSE



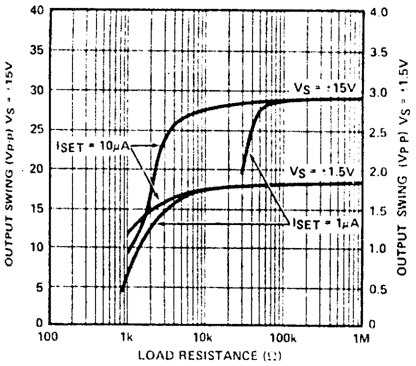
POWER SUPPLY REJECTION vs FREQUENCY



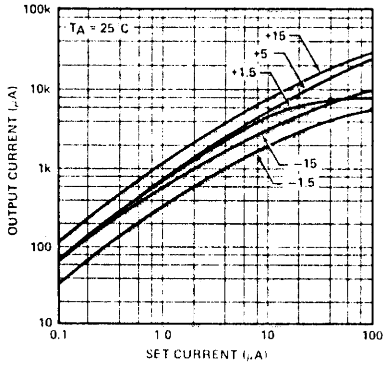
COMMON-MODE REJECTION vs FREQUENCY



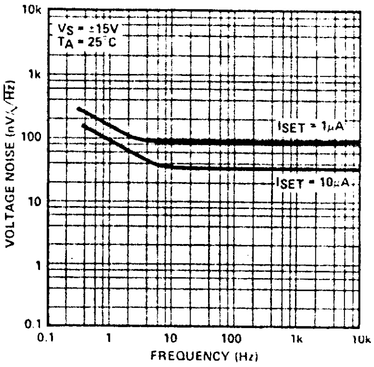
PEAK-TO-PEAK OUTPUT SWING vs LOAD RESISTANCE



MAXIMUM OUTPUT CURRENT vs SET CURRENT AT $V_S = \pm15V$, +5 AND ±1.5

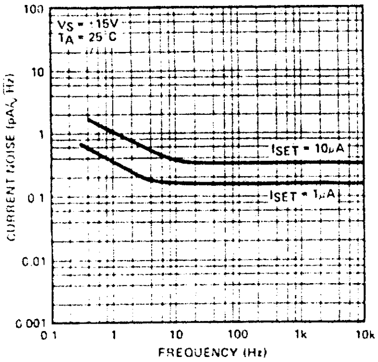


VOLTAGE NOISE vs FREQUENCY

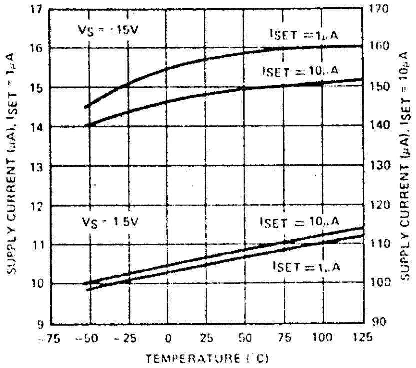


TYPICAL PERFORMANCE CHARACTERISTICS

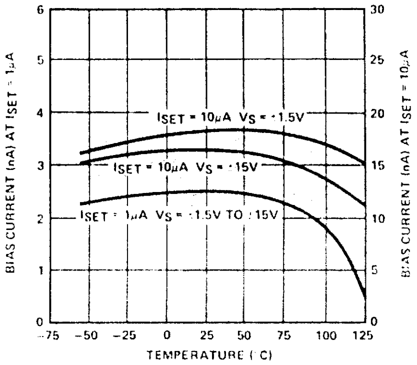
CURRENT NOISE vs FREQUENCY



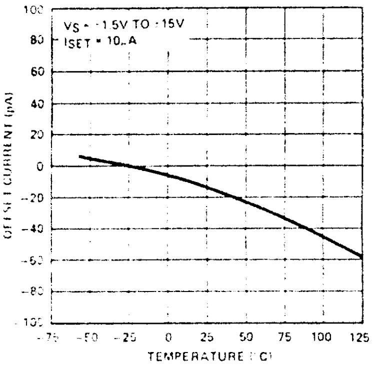
SUPPLY CURRENT vs TEMPERATURE



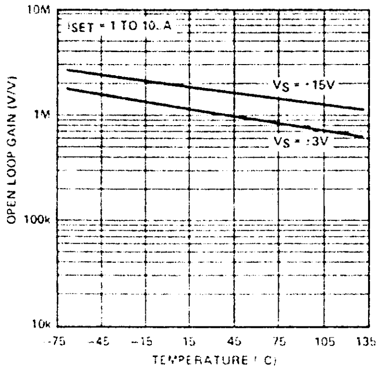
BIAS CURRENT vs TEMPERATURE



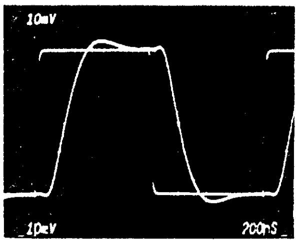
OFFSET CURRENT vs TEMPERATURE



OPEN-LOOP GAIN vs TEMPERATURE

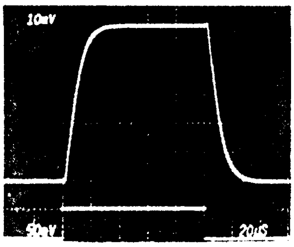


SMALL-SIGNAL TRANSIENT RESPONSE



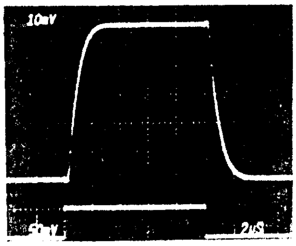
AV = +1, CL = 30pF
ISET = 50μA
VS = ±15V

SMALL-SIGNAL TRANSIENT RESPONSE



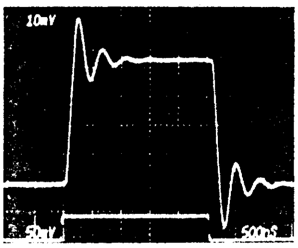
AV = +1, CL = 30pF

SMALL-SIGNAL TRANSIENT RESPONSE



AV = +1, CL = 30pF
ISET = 10μA
VS = ±15V

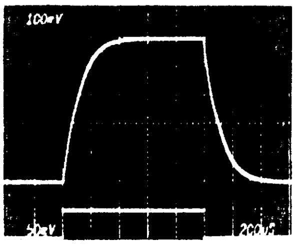
SMALL-SIGNAL TRANSIENT RESPONSE



AV = +1, CL = 30pF
ISET = 100μA
VS = ±15V

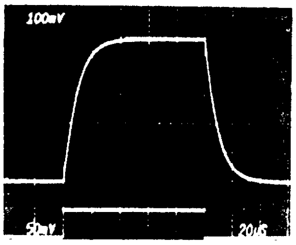
TYPICAL PERFORMANCE CHARACTERISTICS

SMALL-SIGNAL TRANSIENT RESPONSE



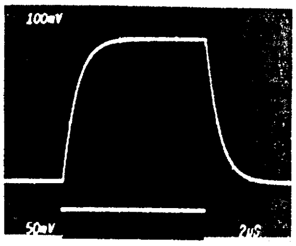
$A_V = +10$, $C_L = 30pF$
$I_{SET} = 1\mu A$
$V_S = \pm15V$

SMALL-SIGNAL TRANSIENT RESPONSE



$A_V = +10$, $C_L = 30pF$
$I_{SET} = 10\mu A$
$V_S = \pm15V$

SMALL-SIGNAL TRANSIENT RESPONSE



$A_V = +10$, $C_L = 30pF$
$I_{SET} = 100\mu A$
$V_S = \pm15V$

APPLICATIONS INFORMATION

OP-22 series units may be inserted directly into LM4250, µA776 and ICL8021 sockets with or without removal of external nulling components. The value of set resistor for a given supply current varies between types and the manufacturer's data sheets should be consulted for this information. Table 1 compares set resistor values for the OP-22 and the LM4250. (R_{SET} connected to V−).

TABLE 1
Supply Current vs. Set Resistor for OP-22 and LM4250

	$I_{SY} = 10\mu A$		$I_{SY} = 30\mu A$		$I_{SY} = 100\mu A$	
V_{SUPPLY}	OP-22	LM4250	OP-22	LM4250	OP-22	LM4250
±1.5V	2.2MΩ	1.3MΩ	680kΩ	430kΩ	220kΩ	120kΩ
±3.0V	6.8MΩ	2.7MΩ	2.2MΩ	910kΩ	680kΩ	270kΩ
±5.0V	13MΩ	4.7MΩ	4.3MΩ	1.5MΩ	1.3MΩ	470kΩ
±12V	33MΩ	12MΩ	11MΩ	3.9MΩ	3.3MΩ	1.2MΩ
±15V	43MΩ	15MΩ	15MΩ	5.1MΩ	4.3MΩ	1.5MΩ
I_{SET}	0.67µA	1.8µA	2.0µA	6.0µA	6.7µA	20µA

SET-RESISTOR SELECTION

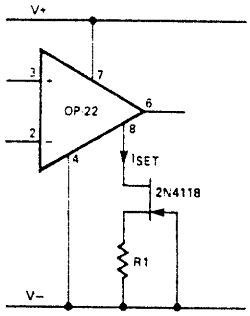
The value of set resistor for selected supply current may be calculated using the "Supply current vs. Set current" curve and the formula;

$$R_{SET} = \frac{(V_{SUPPLY} - 2V_{BE})}{I_{SET}} \quad \ldots\ldots\ldots (1)$$

Alternatively, the "Supply Current vs. Set Current" graph may be used in conjunction with the "Set Current vs. Set Resistor" graph. V_{SUPPLY} in formula (1) refers to the total supply voltage with R_{SET} connected between pin 8 and negative supply. R_{SET} may be connected to ground in which case V_{SUPPLY} in (1) is the positive supply.

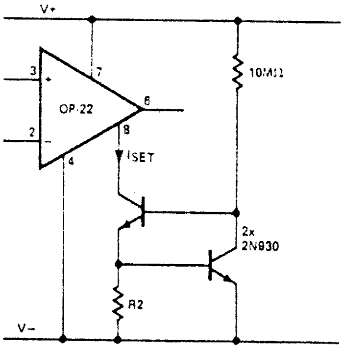
Biasing the OP-22 with a fixed resistor produces a supply current approximately proportional to supply voltage. In applications where a constant drain is required with varying supply, R_{SET} can be replaced by current generators. Two suggested arrangements are shown below:

(a)



$I_{SET} = \frac{V_P}{2R1}$, $I_{DSS} > I_{SET}$

(b)



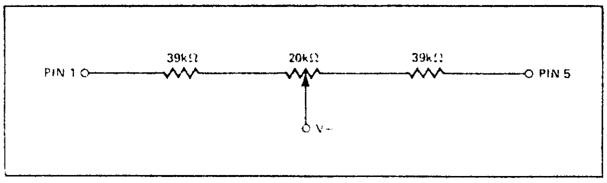
$I_{SET} = \frac{V_{BE}}{R2}$

CAUTION: Shorting of pin 8 to negative supply or ground will cause excessive I_{SET} which in turn will cause excessive supply current to flow. I_{SET} should always be limited.

25

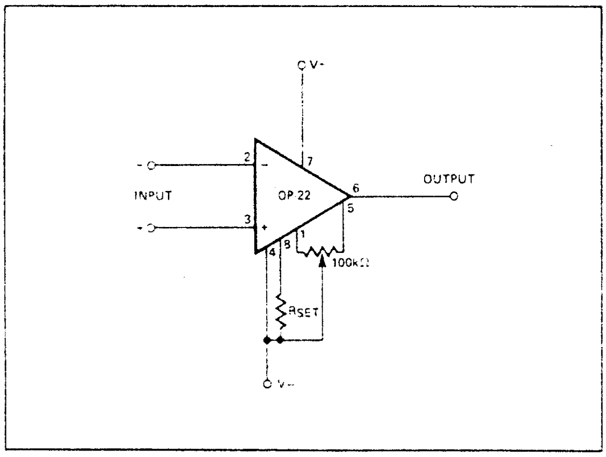
OFFSET VOLTAGE ADJUSTMENT

The offset voltage can be trimmed to zero using a 100kΩ potentiometer (see offset nulling circuit). Adjustment range is approximately ±5mV. Resolution of the nulling can be increased by using a smaller pot in conjunction with fixed resistors as shown below.

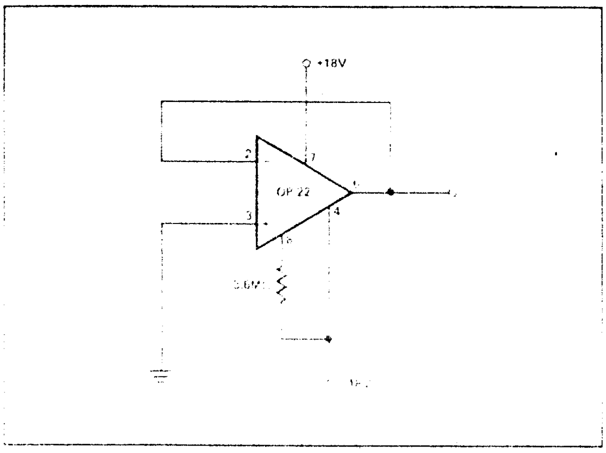


This arrangement has a ±500μV adjustment range. Offset nulling of the OP-22 has negligible effect on the value of TCV_{OS}.

OFFSET NULLING CIRCUIT



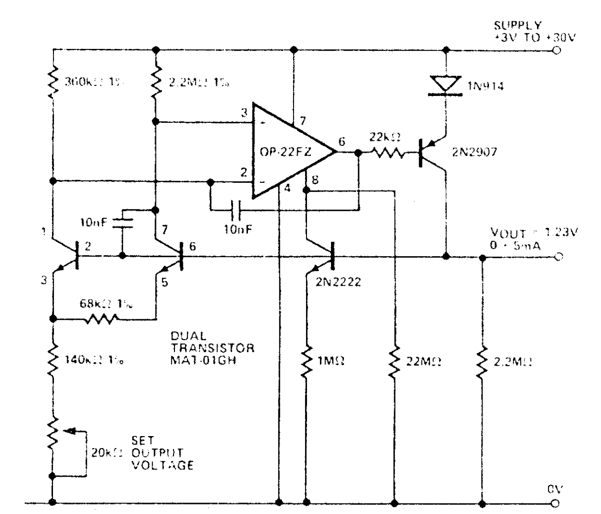
BURN-IN CIRCUIT



APPLICATIONS CIRCUITS

A micropower bandgap voltage reference operating at a quiescent current of 15μA may be constructed using an OP-22 and a MAT-01 dual transistor (see Figure 1). The circuit provides a 1.23V reference with better performance than micropower I.C. shunt regulators and has the advantages of being a series regulator.

MICROPOWER 1.23 VOLT BANDGAP REFERENCE



QUIESCENT CURRENT, 15μA AT 5V INCREASING TO 20μA AT 10V.
OUTPUT VOLTAGE TEMPERATURE COEFFICIENT (OVER 0° TO 70°C), 20ppm/°C TYP.
LINE REGULATION 0.01%/VOLT.
LOAD REGULATION, 0.001%/mA.

Figure 1

GATED MICROPOWER AMPLIFIER

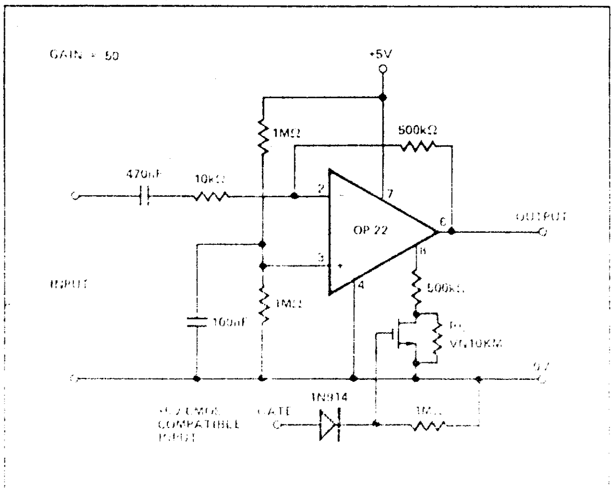


Figure 2

MICROPOWER INSTRUMENTATION AMPLIFIER

POWER DRAIN ≤ 3mW WITH ±5 VOLT SUPPLIES

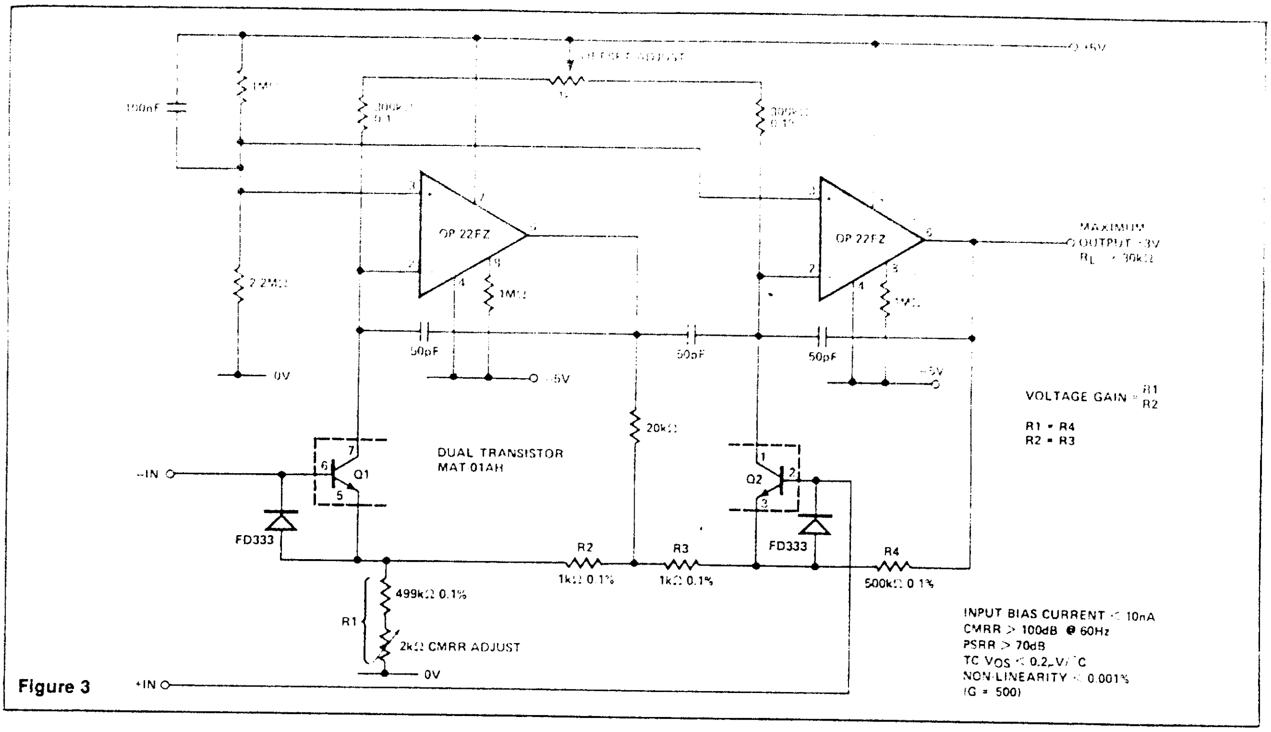


Figure 3

In Figure 2, the OP-22 is used as a gated amplifier where power consumption and bandwidth are controllable. R_S can be selected for a specific lower-power operation or omitted so the amplifier can be completely shut down.

A micropower instrumentation amplifier that consumes less than 3mW with ±5V supplies is shown in Figure 3. Offset voltage drift is better than 0.2μV/°C and common-mode input range is ±3V with CMRR of over 100dB at 60Hz.

Process control systems use two-wire 4-20mA current transmitters when sending analog signals through noisy environments. The "zero" or "offset" current of 4mA may be used to power the transmitter signal conditioning amplifiers and/or excite a d.c. transducer. This allows remote signal conditioning without having a remote power source. Power is provided at the receiving end where the signal current is monitored by a precision 50Ω resistor. The 4-20mA transmitter shown in Figure 4 has high stability, excellent linearity, and generates the 4-20mA current output. A 5V reference is available for powering transducers and micropower amplifiers at a maximum current of 2mA.

TWO TERMINAL 4-20mA TRANSMITTER

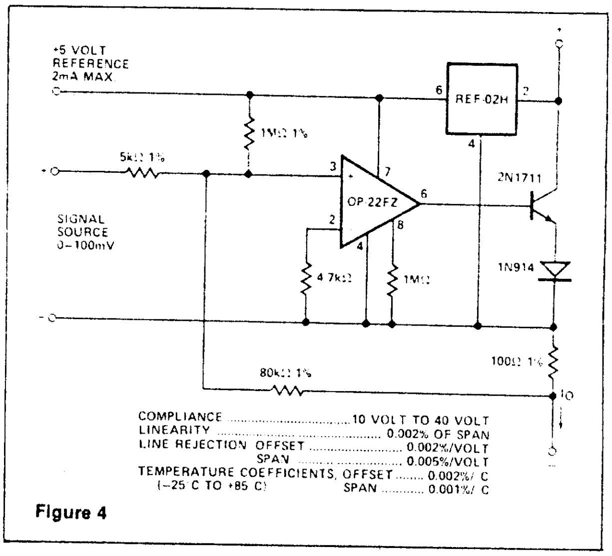


Figure 4

MICROPOWER WIEN-BRIDGE OSCILLATOR (P_d < 500μW)

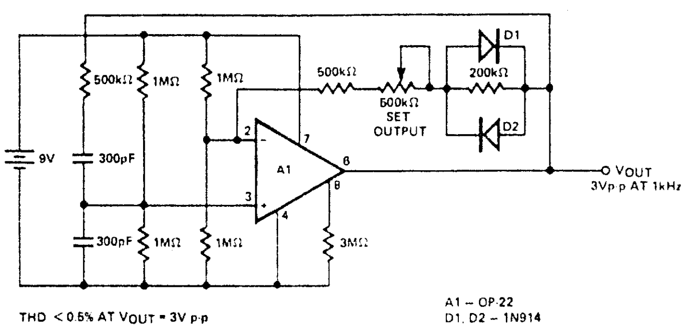


Figure 5

MICROPOWER 5 VOLT REGULATOR

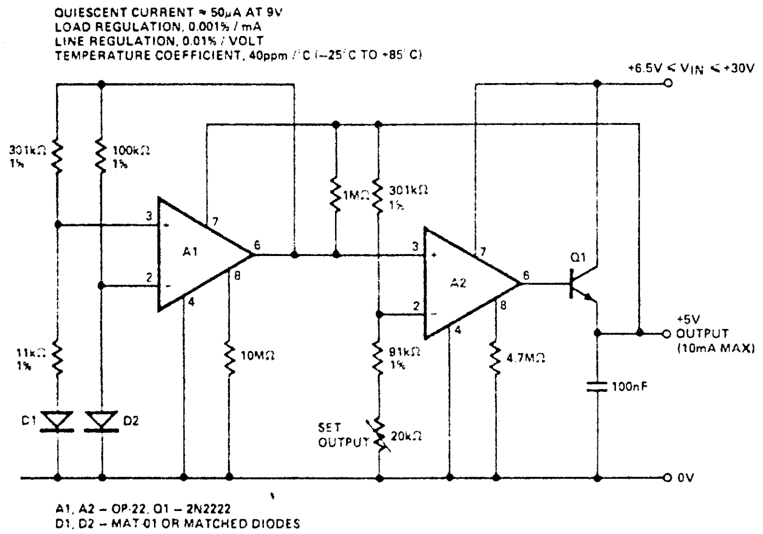


Figure 6

Figure 5 shows a micropower Wien-bridge oscillator designed for battery-powered instrumentation. Output level is controlled by nonlinear elements D1 and D2. When adjusted for 3V p-p output, the distortion level is below 0.5% at 1kHz.

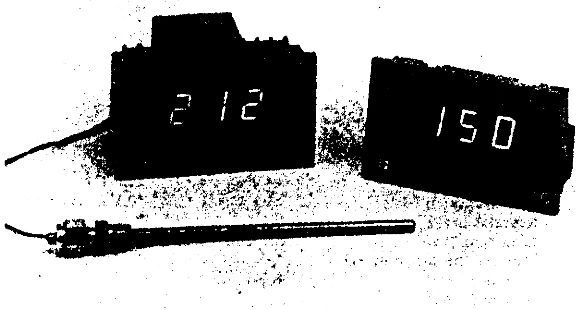
The 5 volt regulator in Figure 6 is intended for instrumentation requiring good power efficiency. Low-power 3-terminal IC regulators typically draw 2mA to 5mA quiescent current compared to only 50μA with this discrete implementation. Maximum load current is 10mA as shown, and can be increased by changing Q1 to a power transistor and proportionately increasing the set current of A2.

ANALOG DEVICES

General Purpose Temperature Probe

AC2626

FEATURES
- Linear Current Output: 1μA/K
- Wide Range: -55°C to +150°C
- Laser Trimmed Sensor (AD590) to ±1.0°C Calibration Accuracy (AC2626L)
- Excellent Linearity: ±0.4°C Over Full Range (AC2626L)
- 6 Inch or 4 Inch Standard, Stainless Steel Sheath
- 3/16 Inch in Outside Diameter
- 3 Feet Teflon Coated Lead Wire
- Wide Power Supply Range +4V to +30V
- Low Cost
- Fast Response: 2 Seconds (In Stirred Water)
- Sensor Isolated From Sheath



PRODUCT DESCRIPTION
The AC2626 is a stainless steel tubular probe measuring 3/16 inch (4.76mm) in outside diameter and is available in 6 inch (152.4mm) or 4-inch (101.6mm) lengths. The probe is available in linearity grades of 0.3°C, 0.4°C, 0.8°C or 1.5°C.

The probe is designed for both liquid and gaseous immersion applications as well as temperature measurements in refrigeration or any general temperature monitoring application.

For taking measurements in pipes or other closed vessels, the AC2629 compression fitting is available. The AC2629 may be applied anywhere along the probe and is supplied in two materials. The low cost AC2629B is constructed of brass and the higher priced AC2629SS is made of stainless steel.

PRODUCT HIGHLIGHTS
The AC2626 is based on the AD590 temperature transducer, a two terminal integrated circuit which produces an output current linearly proportional to absolute temperature.

Costly linearization circuitry, precision voltage amplifiers, resistance measuring circuitry and cold junction compensation are not needed in applying the AC2626.

Due to the high impedance current output of the AD590, the AC2626 is particularly useful in remote sensing applications, because of its insensitivity to voltage drops over lines. The output characteristics also make the AC2626 easy to multiplex.

In addition to temperature measurement, applications include temperature compensation, biasing proportional to absolute temperature, flow rate measurement, level detection of fluids and anemometry.

DIRECT INTERFACE PRODUCTS
For display and/or control applications, two companion products are available. The AD2038, 6 channel digital thermometer, and the AD2040, low cost temperature indicator, were designed to be used in conjunction with the AC2626.

1. The AD2038 is a low cost, ac line powered 6 channel digital scanning thermometer designed to interface to printers, computers, serial data transmitters, etc., for display, control, logging or transmission of multi-point temperature data. Channel selection is made via three methods: manual, using the switch provided on the front; auto/scan, where the AD2038 cycling on an internal clock can continually scan the six input channels or external selection, where control inputs provided on the rear connector enable channel selection via external BCD coding.
2. The AD2040 is a low cost, 3 digit temperature indicator. An internal precision voltage reference, resistor network and span and zero adjusts allow the AD2040 to read out directly in °C, °F, K or R. User selectable readout as well as all other connections, i.e., +5V dc power and AC2626 interface are all made via the terminal block on the rear.

APPLICATION HINTS
1. Under all operating conditions, a minimum 4V dc must be present across the AC2626.
2. Use of twisted pair wiring is recommended, particularly for remote applications or in high noise environments. Shielded wire is desirable in severe noise environments.
3. For the lowest cost, the J and K grades are recommended. Where probe interchangeability is desired, grade L is recommended.

SPECIFICATIONS (typical @ +25°C and +5V unless otherwise specified)

MODEL	AC2626J	AC2626K	AC2626L	AC2626M
ABSOLUTE MAXIMUM RATINGS[1]				
Forward Voltage (V_S)	+44V	*	*	*
Reverse Voltage (V_S)	-20V	*	*	*
Breakdown Voltage (Case to Leads)	±200V	*	*	*
Rated Performance Temp. Range	-55°C to +150°C	*	*	*
Storage Temperature Range	-60°C to +160°C	*	*	*
POWER SUPPLY				
Operating Voltage Range	+4V to +30V	*	*	*
OUTPUT				
Nominal Current Output @ +25°C (298.2°K)	298.2µA	*	*	*
Nominal Temperature Coefficient	1µA/°C	*	*	*
Calibration Error @ +25°C	±5.0°C max	±2.5°C max	±1.0°C max	±0.5°C max
Absolute Error (over rated performance temperature range)				
Without External Calibration Adjustment	±10.0°C max	±5.5°C max	±3.0°C max	±1.7°C max
With +25°C Calibration Error Set to Zero	±3.0°C max	±2.0°C max	±1.6°C max	±1.0°C max
Nonlinearity	±1.5°C max	±0.8°C max	±0.4°C max	±0.3°C max
Repeatability[2]	0.1°C	*	*	*
Long Term Drift[3]	0.1°C max/month	*	*	*
Time Constant[4] (in stirred water)	2 sec.	*	*	*
Current Noise	40pA/$\sqrt{Hz}$	*	*	*
Power Supply Rejection				
$+4V \leq V_S \leq +5V$	0.5µA/V	*	*	*
$+5V \leq V_S \leq +15V$	0.2µA/V	*	*	*
$+15V \leq V_S \leq +30V$	0.1µA/V	*	*	*
Electrical Turn-On Time	20µs	*	*	*
+ Lead Color	yellow	orange	blue	green

ORDERING GUIDE

AC2626 □ □

GRADE J, K, L — ENTER (first box)

LENGTH 4, 6 — ENTER (second box)

AC2629 □

BRASS B, TYPE 316 STAINLESS SS — ENTER

NOTES

[1] Maximum safe recommended pressure: 7500psi (5.17 × 10^4 Kpa).

[2] Maximum deviation between +25°C readings after temperature cycling between -55°C and +150°C; guaranteed, not tested.

[3] Conditions. constant +5V, constant +125°C; guaranteed, not tested.

[4] The time constant is defined as the time required to reach 63.2% of an instantaneous temperature change.

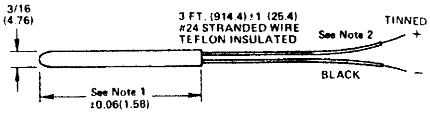
*Specifications same as AC2626J.

Specifications subject to change without notice.

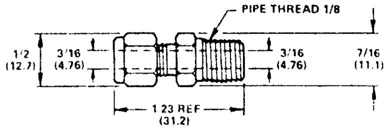
MECHANICAL OUTLINE

Dimensions shown in inches and (mm).

AC2626



AC2629

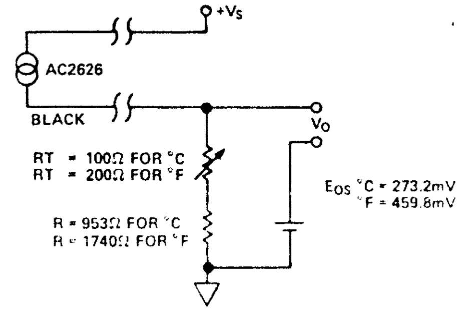


NOTE 1 Probes are available in 4-inch or 6-inch lengths

NOTE 2 + lead wire is color coded: J, yellow; K, orange; L, blue.

NOTE 3 When assembling compression fitting (AC2629) to probe, tighten the 1/2" nut 3/4's of a turn from finger tight.

CALIBRATION



For most applications, a single point calibration is sufficient. With the probe at a known temperature, adjust R_T so that V_O corresponds to the known temperature.

If more detailed information is desired, see the AD590 data sheet and application note.

ICL7660
CMOS Voltage Converter

INTERSIL

GENERAL DESCRIPTION

The Intersil ICL7660 is a monolithic CMOS power supply circuit which offers unique performance advantages over previously available devices. The ICL7660 performs supply voltage conversion from positive to negative for an input range of +1.5V to +10.0V, resulting in complementary output voltages of −1.5V to −10.0V. Only 2 non-critical external capacitors are needed for the charge pump and charge reservoir functions. The ICL7660 can also be connected to function as a voltage doubler and will generate output voltages up to +18.6V with a +10V input. Note that an additional diode is required for $V_{SUPPLY} > 6.5V$.

Contained on chip are a series DC power supply regulator, RC oscillator, voltage level translator, and four output power MOS switches. A unique logic element senses the most negative voltage in the device and ensures that the output N-channel switch source-substrate junctions are not forward biased. This assures latchup free operation.

The oscillator, when unloaded, oscillates at a nominal frequency of 10kHz for an input supply voltage of 5.0 volts. This frequency can be lowered by the addition of an external capacitor to the "OSC" terminal, or the oscillator may be overdriven by an external clock.

The "LV" terminal may be tied to GROUND to bypass the internal series regulator and improve low voltage (LV) operation. At medium to high voltages (+3.5 to +10.0 volts), the LV pin is left floating to prevent device latchup.

An enhanced direct replacement for this part called ICL7660S will become available shortly and will be more appropriate for new designs.

FEATURES

- **Simple Conversion of +5V Logic Supply to ±5V Supplies**
- **Simple Voltage Multiplication ($V_{OUT} = (-)\ nV_{IN}$)**
- **99.9% Typical Open Circuit Voltage Conversion Efficiency**
- **98% Typical Power Efficiency**
- **Wide Operating Voltage Range 1.5V to 10.0V**
- **Easy to Use — Requires Only 2 External Non-Critical Passive Components**

APPLICATIONS

- **On Board Negative Supply for Dynamic RAMs**
- **Localized μ-Processor (8080 Type) Negative Supplies**
- **Inexpensive Negative Supplies**
- **Data Acquisition Systems**

ORDERING INFORMATION

Part Number	Temp. Range	Package
ICL7660CTV	0° to +70°C	TO-99
ICL7660CBA	0°C to +70°C	8 PIN SOIC
ICL7660CPA	0° to +70°C	8 PIN MINI DIP
ICL7660MTV*	−55° to +125°C	TO-99

*Add /883B to part number if 883B processing is required.

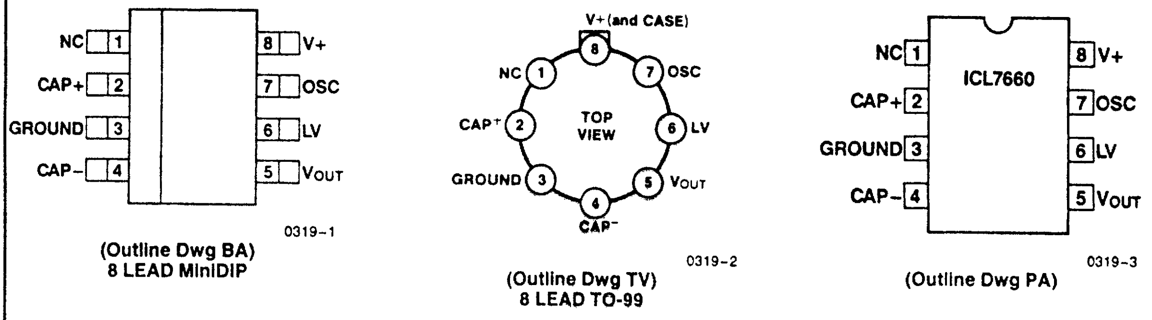


Figure 1: Pin Configurations

302063-004

NOTE: All typical values have been characterized but are not tested.

ICL7660

ABSOLUTE MAXIMUM RATINGS

Supply Voltage 10.5V
LV and OSC Input Voltage
(Note 1) .... −0.3V to (V± +0.3V) for $V^+ < 5.5V$
(V^+ −5.5V) to (V^+ +0.3V) for $V^+ > 5.5V$
Current into LV (Note 1) .... 20μA for V+ >3.5V
Output Short Duration ($V_{SUPPLY} \leq 5.5V$) .... Continuous
Power Dissipation (Note 2)
ICL7660CTV 500mW
ICL7660CPA 300mW
ICL7660MTV 500mW

Operating Temperature Range
ICL7660M .... −55°C to +125°C
ICL7660C .... 0°C to +70°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature
(Soldering, 10sec) .... 300°C

NOTE: *Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

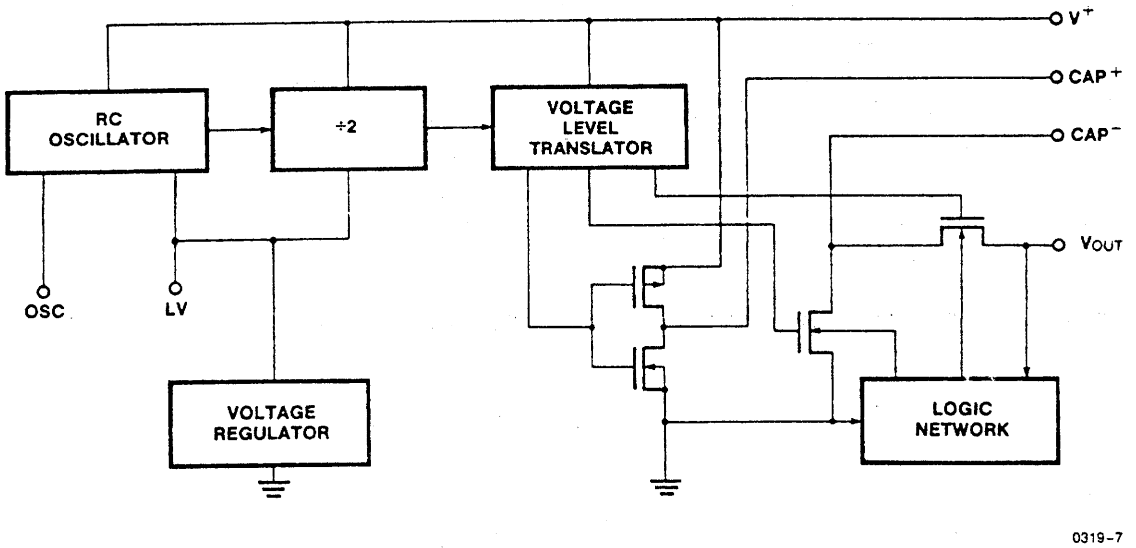


Figure 2: Functional Diagram

OPERATING CHARACTERISTICS

$V^+ = 5V$, $T_A = 25°C$, $C_{OSC} = 0$, Test Circuit Figure 3 (unless otherwise specified)

Symbol	Parameter	Test Conditions	Limits Min	Limits Typ	Limits Max	Units
I^+	Supply Current	$R_L = \infty$		170	500	μA
V^+_{H1}	Supply Voltage Range − Hi (D_X out of circuit) (Note 3)	$0°C \leq T_A \leq 70°C$, $R_L = 10k\Omega$, LV Open	3.0		6.5	V
		$-55°C \leq T_A \leq 125°C$, $R_L = 10k\Omega$, LV Open	3.0		5.0	V
V^+_{L1}	Supply Voltage Range − Lo (D_X out of circuit)	$MIN \leq T_A \leq MAX$, $R_L = 10k\Omega$, LV to GROUND	1.5		3.5	V
V^+_{H2}	Supply Voltage Range − Hi (D_X in circuit)	$MIN \leq T_A \leq MAX$, $R_L = 10k\Omega$, LV Open	3.0		10.0	V
V^+_{L2}	Supply Voltage Range − Lo (D_X in circuit)	$MIN \leq T_A \leq MAX$, $R_L = 10k\Omega$, LV to GROUND	1.5		3.5	V

NOTE: All typical values have been characterized but are not tested.

ICL7660

OPERATING CHARACTERISTICS

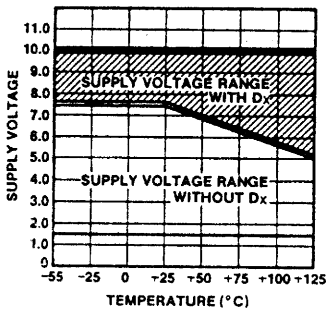
$V^{+} = 5V$, $T_A = 25°C$, $C_{OSC} = 0$, Test Circuit Figure 3 (unless otherwise specified) (Continued)

Symbol	Parameter	Test Conditions	Limits			Units
			Min	Typ	Max	
R_{OUT}	Output Source Resistance	$I_{OUT} = 20mA$, $T_A = 25°C$		55	100	Ω
		$I_{OUT} = 20mA$, $0°C \leq T_A \leq +70°C$			120	Ω
		$I_{OUT} = 20mA$, $-55°C \leq T_A \leq +125°C$ (Note 3)			150	Ω
		$V^{+} = 2V$, $I_{OUT} = 3mA$, LV to GROUND $0°C \leq T_A \leq +70°C$			300	Ω
		$V^{+} = 2V$, $I_{OUT} = 3mA$, LV to GROUND, $-55°C \leq T_A \leq +125°C$, D_X in circuit (Note 3)			400	Ω
f_{OSC}	Oscillator Frequency			10		kHz
P_{Ef}	Power Efficiency	$R_L = 5k\Omega$	95	98		%
$V_{OUT\ Ef}$	Voltage Conversion Efficiency	$R_L = \infty$	97	99.9		%
Z_{OSC}	Oscillator Impedance	$V^{+} = 2$ Volts		1.0		MΩ
		$V = 5$ Volts		100		kΩ

Notes: 1. Connecting any input terminal to voltages greater than V+ or less than GROUND may cause destructive latchup. It is recommended that no inputs from sources operating from external supplies be applied prior to "power up" of the ICL7660.
2. Derate linearly above 50°C by 5.5mW/°C.
3. ICL7660M only.

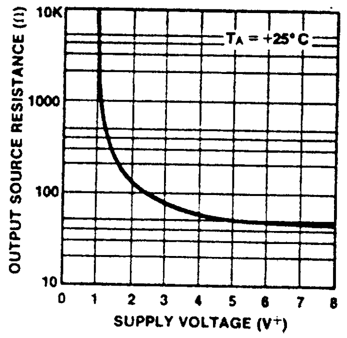
TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 3)

OPERATING VOLTAGE AS A FUNCTION OF TEMPERATURE



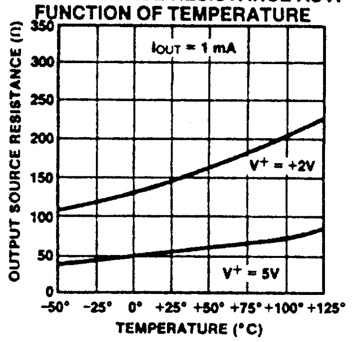
0319-8

OUTPUT SOURCE RESISTANCE AS A FUNCTION OF SUPPLY VOLTAGE



0319-9

OUTPUT SOURCE RESISTANCE AS A FUNCTION OF TEMPERATURE



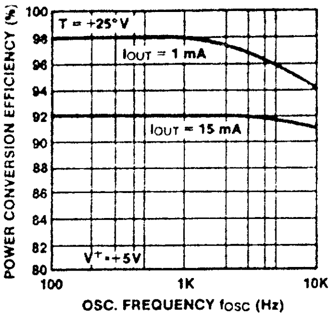
0319-10

NOTE: All typical values have been characterized but are not tested.

ICL7660

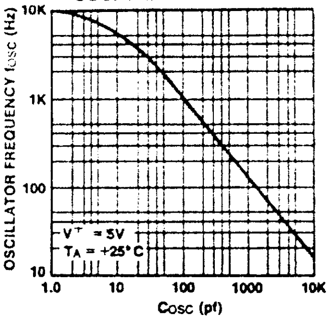
TYPICAL PERFORMANCE CHARACTERISTICS (Circuit of Figure 3) (Continued)

POWER CONVERSION EFFICIENCY AS A FUNCTION OF OSC. FREQUENCY



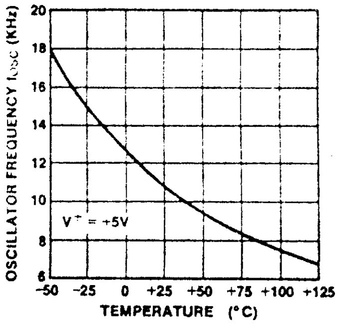
0319-11

FREQUENCY OF OSCILLATION AS A FUNCTION OF EXTERNAL OSC. CAPACITANCE



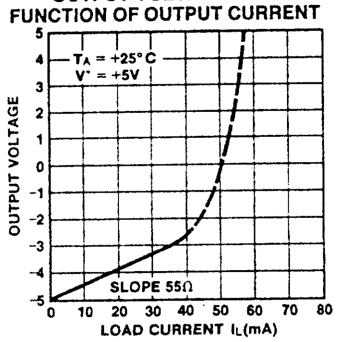
0319-12

UNLOADED OSCILLATOR FREQUENCY AS A FUNCTION OF TEMPERATURE



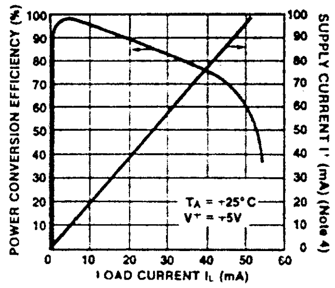
0319-13

OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



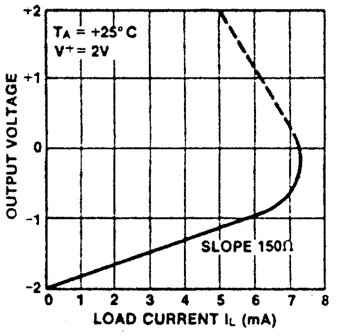
0319-14

SUPPLY CURRENT & POWER CONVERSION EFFICIENCY AS A FUNCTION OF LOAD CURRENT



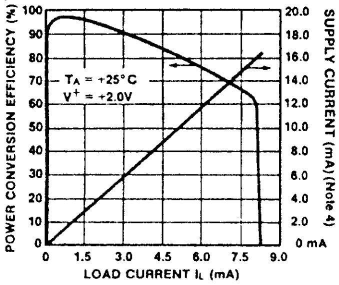
0319-15

OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT CURRENT



0319-16

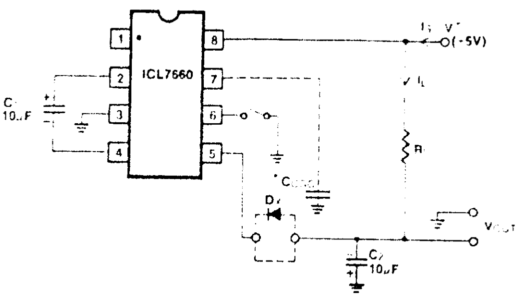
SUPPLY CURRENT & POWER CONVERSION EFFICIENCY AS A FUNCTION OF LOAD CURRENT



0319-17

NOTE 4. These curves include in the supply current that current fed directly into the load R_L from V^+ (see Figure 3). Thus, approximately half the supply current goes directly to the positive side of the load, and the other half, through the ICL7660, to the negative side of the load. Ideally, $V_{OUT} \cong 2 V_{IN}$, $I_S \cong 2 I_L$, so $V_{IN} \bullet I_S \cong V_{OUT} \bullet I_L$.

NOTE: All typical values have been characterized but are not tested.



0319-18

NOTES: 1. For large values of C_{OSC} (>1000pF) the values of C_1 and C_2 should be increased to 100µF.

2. D_X is required for supply voltages greater than 6.5V @ $-55°C \le T_A \le +70°C$; refer to performance curves for additional information.

Figure 3: ICL7660 Test Circuit

DETAILED DESCRIPTION

The ICL7660 contains all the necessary circuitry to complete a negative voltage converter, with the exception of 2 external capacitors which may be inexpensive 10µF polarized electrolytic types. The mode of operation of the device may be best understood by considering Figure 4, which shows an idealized negative voltage converter. Capacitor C_1 is charged to a voltage, V+, for the half cycle when switches S_1 and S_3 are closed. (Note: Switches S_2 and S_4 are open during this half cycle.) During the second half cycle of operation, switches S_2 and S_4 are closed, with S_1 and S_3 open, thereby shifting capacitor C_1 negatively by V+ volts. Charge is then transferred from C_1 to C_2 such that the voltage on C_2 is exactly V+, assuming ideal switches and no load on C_2. The ICL7660 approaches this ideal situation more closely than existing non-mechanical circuits.

In the ICL7660, the 4 switches of Figure 4 are MOS power switches; S_1 is a P-channel device and S_2, S_3 & S_4 are N-channel devices. The main difficulty with this approach is that in integrating the switches, the substrates of S_3 & S_4 must always remain reverse biased with respect to their sources, but not so much as to degrade their "ON" resistances. In addition, at circuit startup, and under output short circuit conditions ($V_{OUT}=V+$), the output voltage must be sensed and the substrate bias adjusted accordingly. Failure to accomplish this would result in high power losses and probable device latchup.

This problem is eliminated in the ICL7660 by a logic network which senses the output voltage (V_{OUT}) together with the level translators, and switches the substrates of S_3 & S_4 to the correct level to maintain necessary reverse bias.

The voltage regulator portion of the ICL7660 is an integral part of the anti-latchup circuitry, however its inherent voltage drop can degrade operation at low voltages. Therefore, to improve low voltage operation the "LV" pin should be connected to GROUND, disabling the regulator. For supply voltages greater than 3.5 volts the LV terminal must be left open to insure latchup proof operation, and prevent device damage.

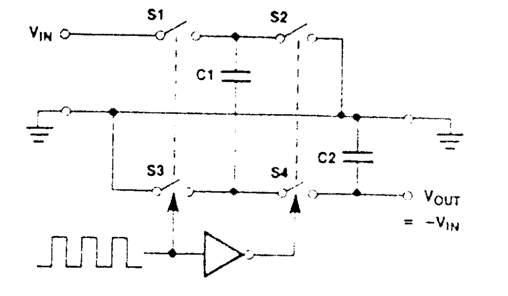


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Figure 4: Idealized Negative Voltage Converter

THEORETICAL POWER EFFICIENCY CONSIDERATIONS

In theory a voltage converter can approach 100% efficiency if certain conditions are met:

A The drive circuitry consumes minimal power.

B The output switches have extremely low ON resistance and virtually no offset.

C The impedances of the pump and reservoir capacitors are negligible at the pump frequency.

The ICL7660 approaches these conditions for negative voltage conversion if large values of C_1 and C_2 are used. **ENERGY IS LOST ONLY IN THE TRANSFER OF CHARGE BETWEEN CAPACITORS IF A CHANGE IN VOLTAGE OCCURS.** The energy lost is defined by:

$$E = \frac{1}{2} C_1 (V_1{}^2 - V_2{}^2)$$

where V_1 and V_2 are the voltages on C_1 during the pump and transfer cycles. If the impedances of C_1 and C_2 are relatively high at the pump frequency (refer to Figure 4) compared to the value of R_L, there will be a substantial difference in the voltages V_1 and V_2. Therefore it is not only desirable to make C_2 as large as possible to eliminate output voltage ripple, but also to employ a correspondingly large value for C_1 in order to achieve maximum efficiency of operation.

DO'S AND DON'TS

1. Do not exceed maximum supply voltages.
2. Do not connect LV terminal to GROUND for supply voltages greater than 3.5 volts.
3. Do not short circuit the output to V+ supply for supply voltages above 5.5 volts for extended periods, however, transient conditions including startup are okay.
4. When using polarized capacitors, the + terminal of C_1 must be connected to pin 2 of the ICL7660 and the + terminal of C_2 must be connected to GROUND.
5. Add diode D_X as shown in Figure 3 for high-voltage, elevated temperature applications.
6. Add capacitor (~ 0.1µF, disc) from pin 8 to ground to limit rate of rise of input voltage to approximately 2V/µs.

NOTE: All typical values have been characterized but are not tested.

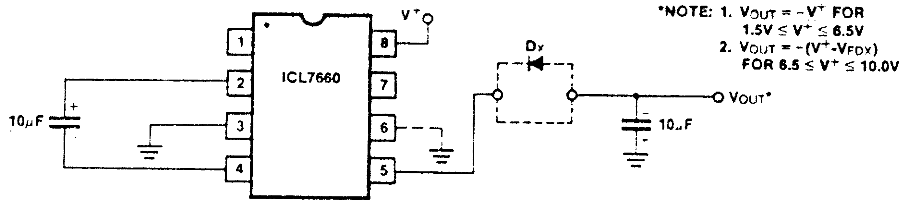

Figure 5: Simple Negative Converter

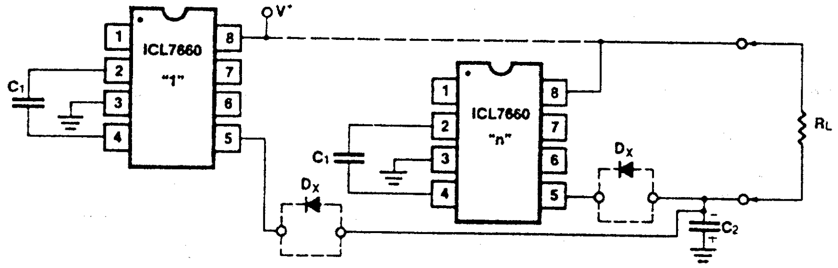

Figure 6: Paralleling Devices

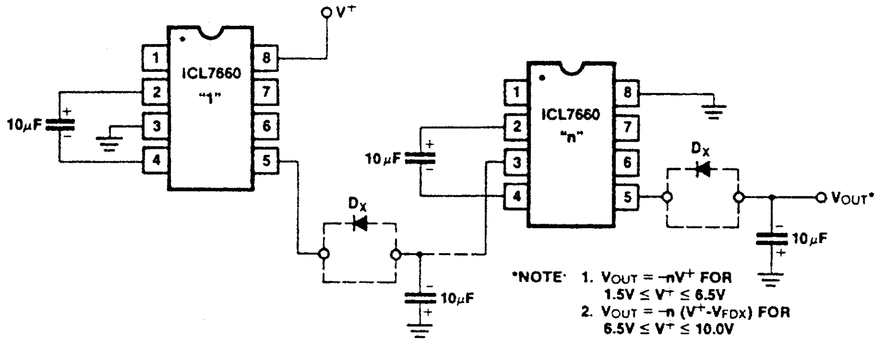

Figure 7: Cascading Devices for Increased Output Voltage

NOTE: All typical values have been characterized but are not tested.

CONSIDERATIONS FOR HIGH VOLTAGE & ELEVATED TEMPERATURE

The ICL7660 will operate efficiently over its specified temperature range with only 2 external passive components (storage & pump capacitors), provided the operating supply voltage does not exceed 6.5 volts at +70°C and 5.0 volts at +125°C. Exceeding these maximums at the temperatures indicated may result in destructive latchup of the ICL7660. (Ref: Graph "Operating Voltage Vs. Temperature")

Operation at supply voltages of up to 10.0 volts over the full temperature range without danger of latchup can be achieved by adding a general purpose diode in series with the ICL7660 output, as shown by "D_X" in the circuit diagrams. The effect of this diode on overall circuit performance is the reduction of output voltage by one diode drop (approximately 0.6 volts).

TYPICAL APPLICATIONS

Simple Negative Voltage Converter

The majority of applications will undoubtedly utilize the ICL7660 for generation of negative supply voltages. Figure 5 shows typical connections to provide a negative supply where a positive supply of +1.5V to +10.0 volts is available. Keep in mind that pin 6 (LV) is tied to the supply negative (GND) for supply voltages below 3.5 volts, and that diode D_X must be included for proper operation at higher voltages and/or elevated temperatures.

The output characteristics of the circuit in Figure 5 are those of a nearly ideal voltage source in series with 55 ohms. Thus for a load current of −10mA and a supply voltage of +5 volts, the output voltage will be −4.3 volts. The dynamic output impedance due to the capacitor impedances is approximately $1/\omega C$, where:

$$C = C_1 = C_2$$

$$\text{which gives } \frac{1}{\omega C} = \frac{1}{2\pi f_{PUMP} \times 10^{-5}} \cong 3 \text{ ohms}$$

for $C = 10\mu F$ and $f_{PUMP} = 5kHz$ (½ of oscillator frequency)

Paralleling Devices

Any number of ICL7660 voltage converters may be paralleled to reduce output resistance. The reservoir capacitor, C_2, serves all devices while each device requires its own pump capacitor, C_1. The resultant output resistance would be approximately:

$$R_{OUT} = \frac{R_{OUT} \text{ (of ICL7660)}}{n \text{ (number of devices)}}$$

Cascading Devices

The ICL7660 may be cascaded as shown to produce larger negative multiplication of the initial supply voltage. However, due to the finite efficiency of each device, the practical limit is 10 devices for light loads. The output voltage is defined by:

$$V_{OUT} = -n\,(V_{IN}),$$

where n is an integer representing the number of devices cascaded. The resulting output resistance would be approximately the weighted sum of the individual ICL7660 R_{OUT} values.

Changing the ICL7660 Oscillator Frequency

It may be desirable in some applications, due to noise or other considerations, to increase the oscillator frequency. This is achieved by overdriving the oscillator from an external clock, as shown in Figure 8. In order to prevent possible device latchup, a 100kΩ resistor must be used in series with the clock output. In a situation where the designer has generated the external clock frequency using TTL logic, the addition of a 10kΩ pullup resistor to V^+ supply is required. Note that the pump frequency with external clocking, as with internal clocking, will be ½ of the clock frequency. Output transitions occur on the positive-going edge of the clock.

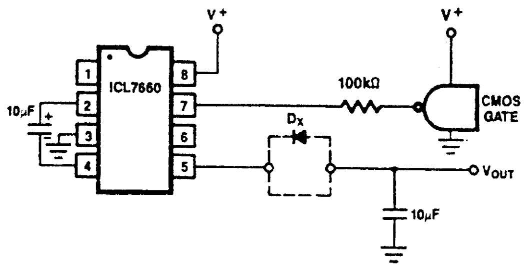

Figure 8: External Clocking 0319-23

It is also possible to increase the conversion efficiency of the ICL7660 at low load levels by lowering the oscillator frequency. This reduces the switching losses, and is shown in Figure 9. However, lowering the oscillator frequency will cause an undesirable increase in the impedance of the pump (C_1) and reservoir (C_2) capacitors; this is overcome by increasing the values of C_1 and C_2 by the same factor that the frequency has been reduced. For example, the addition of a 100pF capacitor between pin 7 (Osc) and V^+ will lower the oscillator frequency to 1kHz from its nominal frequency of 10kHz (a multiple of 10), and thereby necessitate a corresponding increase in the value of C_1 and C_2 (from 10μF to 100μF).

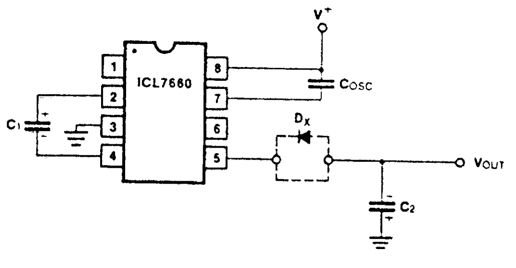

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Figure 9: Lowering Oscillator Frequency

NOTE: All typical values have been characterized but are not tested.

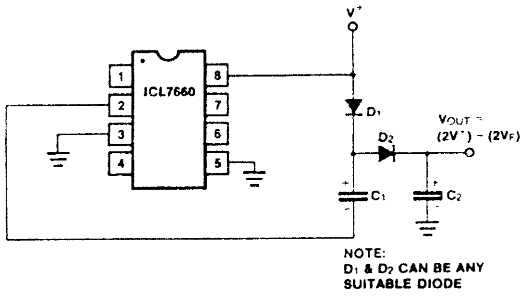

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Figure 10: Positive Voltage Doubler

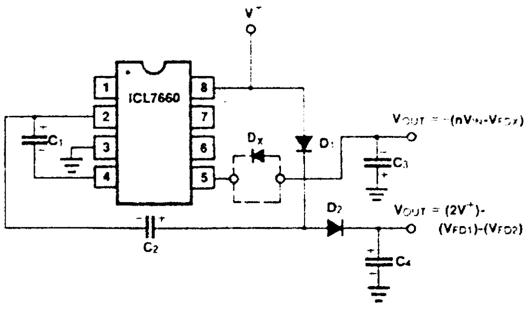

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Figure 11: Combined Negative Voltage Converter and Positive Doubler

Positive Voltage Doubling

The ICL7660 may be employed to achieve positive voltage doubling using the circuit shown in Figure 10. In this application, the pump inverter switches of the ICL7660 are used to charge C_1 to a voltage level of $V^+ - V_F$ (where V^+ is the supply voltage and V_F is the forward voltage drop of diode D_1). On the transfer cycle, the voltage on C_1 plus the supply voltage (V^+) is applied through diode D_2 to capacitor C_2. The voltage thus created on C_2 becomes $(2V^+) - (2V_F)$ or twice the supply voltage minus the combined forward voltage drops of diodes D_1 and D_2.

The source impedance of the output (V_{OUT}) will depend on the output current, but for $V^+ = 5$ volts and an output current of 10mA it will be approximately 60 ohms.

Combined Negative Voltage Conversion and Positive Supply Doubling

Figure 11 combines the functions shown in Figures 5 and 10 to provide negative voltage conversion and positive voltage doubling simultaneously. This approach would be, for example, suitable for generating +9 volts and −5 volts from an existing +5 volt supply. In this instance capacitors C_1 and C_3 perform the pump and reservoir functions respectively for the generation of the negative voltage, while capacitors C_2 and C_4 are pump and reservoir respectively for the doubled positive voltage. There is a penalty in this configuration which combines both functions, however, in that the source impedances of the generated supplies will be somewhat higher due to the finite impedance of the common charge pump driver at pin 2 of the device.

Voltage Splitting

The bidirectional characteristics can also be used to split a higher supply in half, as shown in Figure 12. The combined load will be evenly shared between the two sides. Because the switches share the load in parallel, the output impedance is much lower than in the standard circuits, and higher currents can be drawn from the device. By using this circuit, and then the circuit of Figure 7, +15V can be converted (via +7.5, and −7.5) to a nominal −15V, although with rather high series output resistance (~250Ω).

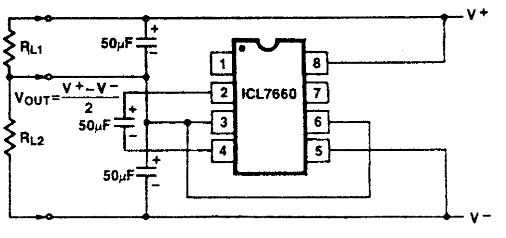

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Figure 12: Splitting A Supply In Half

NOTE: All typical values have been characterized but are not tested.

Regulated Negative Voltage Supply

In some cases, the output impedance of the ICL7660 can be a problem, particularly if the load current varies substantially. The circuit of Figure 13 can be used to overcome this by controlling the input voltage, via an ICL7611 low-power CMOS op amp, in such a way as to maintain a nearly constant output voltage. Direct feedback is inadvisable, since the ICL7660's output does not respond instantaneously to change in input, but only after the switching delay. The circuit shown supplies enough delay to accommodate the 7660, while maintaining adequate feedback. An increase in pump and storage capacitors is desirable, and the values shown provides an output impedance of less than 5Ω to a load of 10mA.

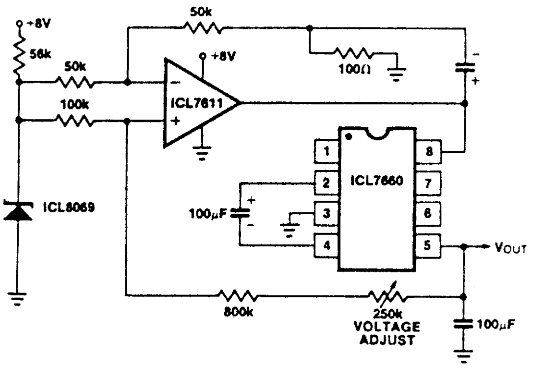

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Figure 13: Regulating the Output Voltage

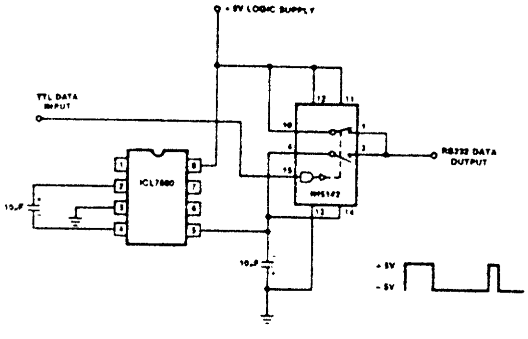

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Figure 14: RS232 Levels From A Single 5V Supply

OTHER APPLICATIONS

Further information on the operation and use of the ICL7660 may be found in A051 "Principals and Applications of the ICL7660 CMOS Voltage Converter".

NOTE: All typical values have been characterized but are not tested.

ICL8069
Low Voltage Reference

INTERSIL

GENERAL DESCRIPTION

The ICL8069 is a 1.2V temperature compensated voltage reference. It uses the band-gap principle to achieve excellent stability and low noise at reverse currents down to 50μA. Applications include analog-to-digital converters, digital-to-analog converters, threshold detectors, and voltage regulators. Its low power consumption makes it especially suitable for battery operated equipment.

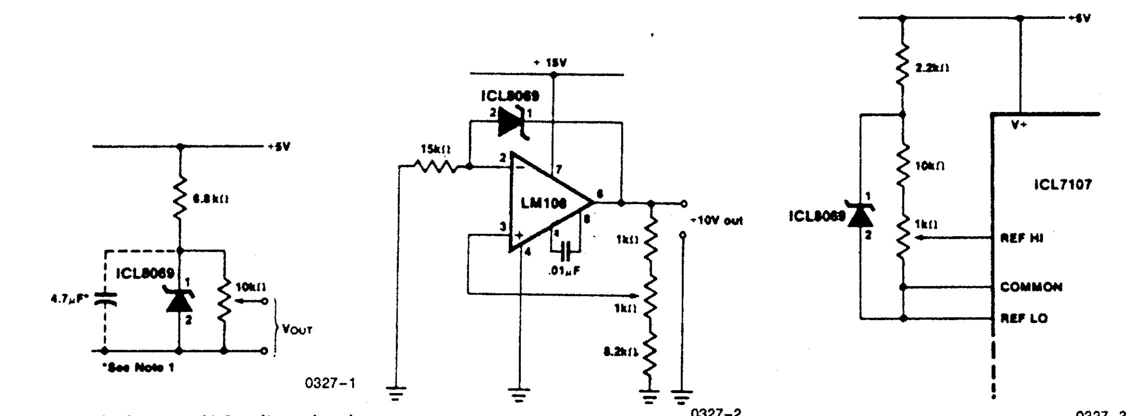
FEATURES

- **Low Bias Current — 50μA Min**
- **Low Dynamic Impedance**
- **Low Reverse Voltage**
- **Low Cost**

ORDERING INFORMATION

Order P/N TO-92	Order P/N TO-52	Temperature Range	Max. Temp. Coeff. of V_{REF}
ICL8069CCZR	ICL8069CCSQ	0°C to +70°C	0.005%/°C
—	ICL8069CMSQ	−55°C to +125°C	0.005%/°C
ICL8089DCZR	ICL8069DCSQ	0°C to +70°C	0.01%/°C
—	ICL8069DMSQ	−55°C to +125°C	0.01%/°C

**Parameter Min/Max Limits guaranteed at 25°C only for DICE orders.



(a) Simple Reference (1.2 volts or less)

(b) Buffered 10V Reference using a single supply.

(c) Double regulated 100mV reference for ICL7107 one-chip DPM circuit.

Figure 1: Functional Diagrams

Figure 2: Pin Configurations

INTERSIL'S SOLE AND EXCLUSIVE WARRANTY OBLIGATION WITH RESPECT TO THIS PRODUCT SHALL BE THAT STATED IN THE WARRANTY ARTICLE OF THE CONDITION OF SALE. THE WARRANTY SHALL BE EXCLUSIVE AND SHALL BE IN LIEU OF ALL OTHER WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, INCLUDING THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR USE.

303120-003

NOTE: All typical values have been characterized but are not tested.

ICL8069

INTERSIL

ABSOLUTE MAXIMUM RATINGS

Reverse Voltage .... See Note 2
Forward Current 10mA
Reverse Current 10mA
Power Dissipation .... Limited by max forward/reverse current

Storage Temperature .... −65°C to +150°C
Operating Temperature
ICL8069C .... 0°C to +70°C
ICL8069M .... −55°C to +125°C
Lead Temperature (Soldering, 10sec) .... 300°C

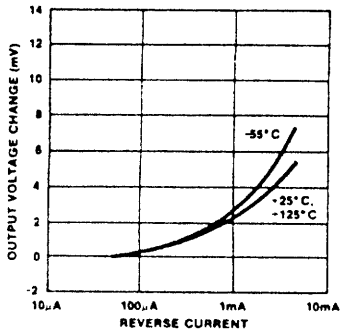
NOTE: *Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions above those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristics	Test Conditions	Min	Typ	Max	Units
Reverse breakdown Voltage	$I_R = 500\mu A$	1.20	1.23	1.25	V
Reverse breakdown Voltage change	$50\mu A \leq I_R \leq 5mA$		15	20	mV
Reverse dynamic impedance	$I_R = 50\mu A$ $I_R = 500\mu A$		1 1	2 2	Ω
Forward Voltage Drop	$I_F = 500\mu A$		0.7	1	V
RMS Noise Voltage	$10Hz \leq f \leq 10kHz$ $I_R = 500\mu A$		5		μV
Long Term Stability	$I_R = 4.75mA$ $T_A = 25°C$		1		ppm/kHR
Breakdown voltage Temperature coefficient ICL8069C ICL8069D	$I_R = 500\mu A$ T_A = operating Temperature range (Note 3)			.005 .01	%/°C
Reverse Current Range		0.050		5	mA

TYPICAL PERFORMANCE CHARACTERISTICS

VOLTAGE CHANGE AS A FUNCTION OF REVERSE CURRENT



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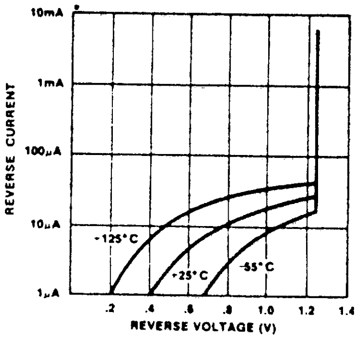
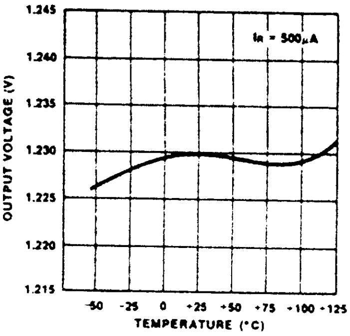
REVERSE VOLTAGE AS A FUNCTION OF CURRENT



0327-7

REVERSE VOLTAGE AS A FUNCTION OF TEMPERATURE



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Notes: 1) If circuit strays in excess of 200pF are anticipated, a 4.7μF shunt capacitor will ensure stability under all operating conditions.

2) In normal use, the reverse voltage cannot exceed the reference voltage. However when plugging units into a powered-up test fixture, an instantaneous voltage equal to the compliance of the test circuit will be seen. This should not exceed 20V.

3) For the military part, measurements are made at 25°C, −55°C, and +125°C. The unit is then classified as a function of the worst case T.C. from 25°C to −55°C, or 25°C to +125°C.

NOTE: All typical values have been characterized but are not tested.

Issued November 1986 **7023**

RS Data Library

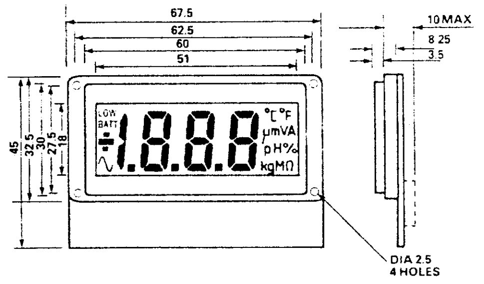
Single rail supply LCD DVM module

Stock number 257-852

A very low profile, d.v.m. module especially designed for single rail power supply working. This enables the power supply 0V to be connected to the signal 0V and allows a flexibility in system design not usually associated with this style of module. The 3½ digit clear LCD display is further enhanced by an extensive set of user-selectable legends as shown. A particularly useful feature is the solder pads on the rear of the module that allow very easy linking of connections to bring up the desired legends on the display. All the usual features such as auto-zero, auto-polarity, overrange and low battery indicator are present. Digit height is 15mm (0.6in). Maximum display is 1999, giving an effective 'full scale deflection' of 200mV. Accuracy is 0.05% of input ±1 count. Current consumption is typically 1mA. An internal bandgap reference assures excellent stability of the reading.

Features

- System flexibility – module 'ground' can also be signal 'ground'
- Extensive set of display annunciators (legends)
- Auto-zero
- Auto-polarity
- Overrange and low battery indications
- 15mm (0.6in) digit height
- 199.9mV basic fsd
- Bandgap reference for stability



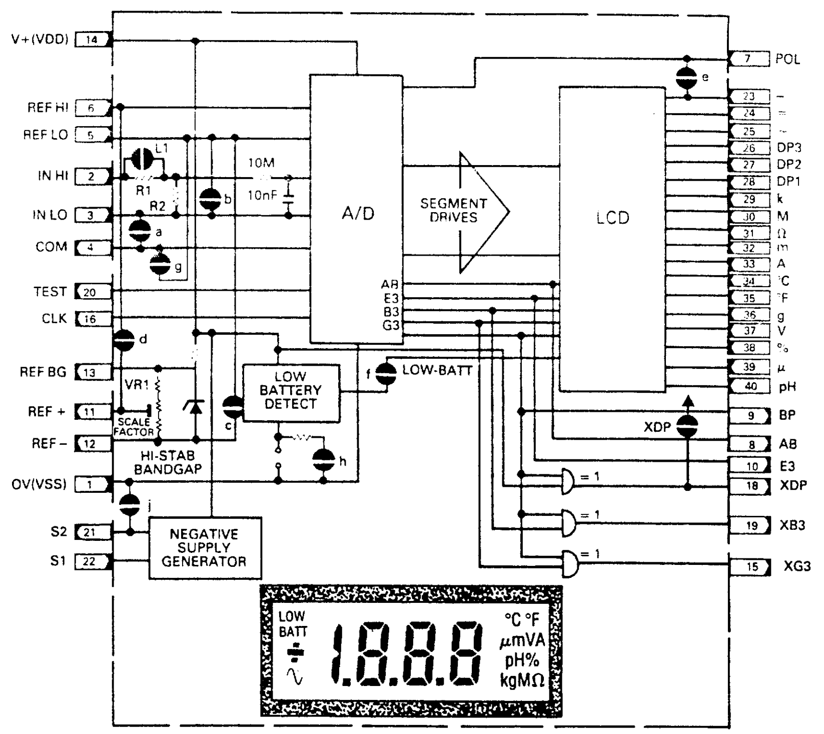
Electrical characteristics $T_A = 25°C$

Parameter		Value (typical)
Power supply voltage, V_{SS} to V_{DD}	Single ended mode (Figure 4)	2.5 to 7.5 Vdc
	Conventional connection (Figure 6)	5 to 15 Vdc
Supply current (excluding common current)		1mA
Display resolution		1999, 1 count = 100µV (without attenuators)
Input impedance (See note 1)		>1000MΩ
Error		0.05% of input ± 1 count
Range temperature coefficient		50ppm/°C
Input leakage current		1pA
Common mode rejection ratio		86dB
Sample rate		3/sec

Operating temperature 0°C to +50°C
Storage temperature −20°C to +60°C

Note 1: Operations under many practical conditions ie. facilitated by connection of a 10MΩ resistor across the input.

Figure 1 **Schematic diagram**



Note: Pad j **must** be linked for single-ended operation.

Circuit notes

The module incorporates a dual-slope-integration analogue-to-digital converter which consumes typically 50μA from the power supply.

The converter functions ratiometrically and has fully differential analogue signal and reference inputs.

An RC network provides signal input filtering and overload protection.

Internally, the converter operates with 200mV full scale although a hermetically sealed trimmer is provided to facilitate display adjustment for individual sensor scaling. For larger changes in scaling, input voltage attenuators or current shunts may easily be added to the instrument. A high stability bandgap voltage reference ic produces 100mV reference, or an external voltage may be applied to the reference input. The display reading
= (Signal Input ÷ Reference Input) x 1000.

Standard features include autozero circuitry, automatic polarity, and overrange indication of a 1 displayed in the most significant digit position and remaining digits blanked. Correct autozero operation is facilitated by connection of 10MΩ resistor across the input terminals. The autopolarity circuitry functions at zero signal voltage for precise null detection.

An internal RC oscillator provides a reading rate of approximately 3 per second.

Low battery detection circuitry provides advance warning of battery failure directly on the display. The value of R10 may be altered, if required, by adding a resistor at the rear of the pcb and splitting pad h to isolate the internal resistor. Resistors in the range 100k to 200k are usually required.

The differential analogue inputs may be operated within 0.5V below the positive supply (V_{DD}) and 1V above the negative supply (V_{SS}). A common mode reference point (COM) is provided to enable measurement of signals fully floating with respect to the power supply. The single-ended operation facility removes the restriction with respect to negative supply, which may then be connected direct to signal low.

The TEST output may be used as a negative supply for external integrated circuits with a maximum load of 1mA. If TEST is connected to V+ the L.C.D. segments will be turned on and the display will read as shown in Figure 3. (This mode should not be used for extended periods, to avoid damage to the L.C.D.) Note that – 1888 is not precisely indicated, two segments being 'missing'. This occurs as an unavoidable consequence of using the B3 and G3 outputs to feed one of the internal integrated circuits.

Connections

The module is extremely versatile and the connections are listed below.

Pin 1 Supply negative 0V (V_{SS})
Pin 2 Analogue signal HI input (IN HI)
Pin 3 Analogue signal LO input (IN LO)
Pin 4 Analogue common (COM)
Internally derived common mode reference point established approximately 3V below V+, for use with signals floating with respect to supply.
Pin 5 Reference LO input (Ref LO)
Pin 6 Reference HI input (Ref HI)

Differential reference voltage inputs, against which the input signal is compared and displayed ratiometrically.

Pin 7 Polarity output (POL)

The polarity output signal is in antiphase to the backplane signal when IN HI is negative with respect to IN LO. Connecting POL to – provides automatic indication of negative inputs and positive inputs are implied by lack of the – legend. To obtain + and – indication connect POL to: via a FET inverter and connect – to XDP.

Pin 8 AB output for use in autoranging circuits

Pin 9 Backplane (BP)

Square wave signal derived from internal oscillator, to which all LCD symbol drives are referred. Symbols are turned on when driven by a signal in antiphase to BP.

Pin 10 E3 output for use in autoranging circuits

Pin 11 Reference HI output (REF +)

Pin 12 Reference LO output (REF –)

Adjustable 100mV reference voltage provided when REF – correctly terminated (usually to COM).

Pin 13 Bandgap reference (REF BG)

High-stability output from bandgap voltage reference, typically 1.2V wrt REF – when the latter is correctly terminated.

Pin 14 Supply positive V+ (V_{DD})

Pin 15 XG3 Output for use in autoranging circuits

Pin 16 Clock (CLK)

Internal RC oscillator of approximately 48kHz providing 3 readings per second. An external oscillator or capacitor may be applied between CLK and TEST to alter the timing.

Connecting CLK to TEST implements elementary form of display hold function by stopping the clock and preventing information update. Prolonged use may damage the LCD due to steady DC levels being present in this mode.

Pin 17 Not used

Pin 18 LCD symbol drive output (XDP)

Square wave in antiphase to BP, may be connected to any combination of LCD symbols or decimal points for indication.

Pin 19 XB3 Output for use in autoranging circuits

Pin 20 TEST Internal digital ground which may be used as the negative supply for external circuits, subject to 1mA maximum load.

When TEST is connected to V+ the main LCD digits will be turned on, with the test pattern shown in Figure 3. (If POL is connected to polarity bar–, this will also be turned on). The display test should not be activated for extended periods.

Pin 21 S2
Pin 22 S1 — Negative Supply Generator

Auxiliary power supply connections to enable the instrument to measure true single ended signal with IN LO connected to SUPPLY V_{SS}.

Pin LMP2
Pin LMP1 — Not used

Pins 23-40 LCD annunciators

–, :, ~, DP3, DP2, DP1, k, M, Ω, m, A, °C, °F, g, V, %, μ, pH

Direct connections to the LCD segments, any combination of which may be turned on by connecting to XDP. Connection to BP permanently turns off the segments.

Solder pads are provided at strategic points on the module which may be bridged to eliminate wiring otherwise required to establish a particular mode of operation.

Solder pads function

- a COM to IN LO
- b REF LO to IN LO
- c REF– to REF LO
- d REF+ to REF HI
- e POL to –
- f Automatic LOW BATT indication is provided by a normally bridged pad which may be cut if not required or the indication may be controlled by external circuitry.
- g Com to REF LO.
- h For modifying R10 value - see text.
- j V_{SS} to S2. Link for single-ended operation.
- XDP In addition to the output at the main edge connector, XDP annunciator drive pads are provided between alternate pairs of annunciator connections, for convenient commitment of them by solder bridging if required.
- L1 IN HI signal input link on reverse side of pcb.

Figure 2 **Pcb pin connection diagram**

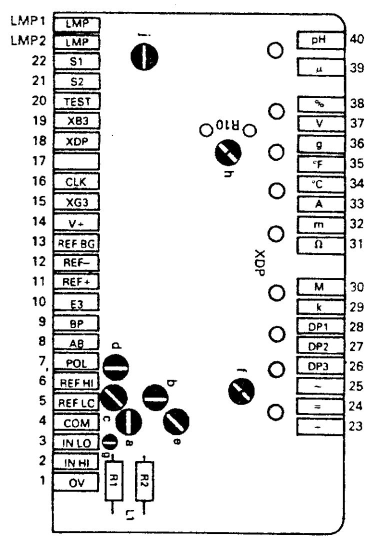
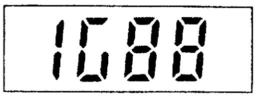
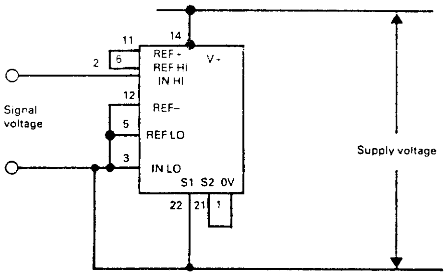


Figure 3 **Display in 'TEST' condition**



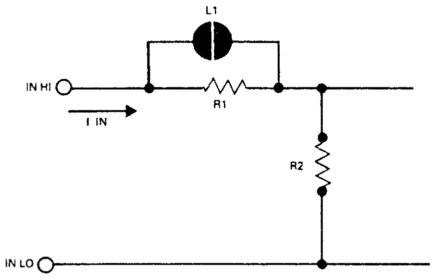
Application circuits

Figure 4 **Measurement of single-ended inputs**



All links may be achieved using the pads provided.

Figure 5 **Alternative full scale reading**



Voltage attenuator or current shunt components may be added as shown to alter the full scale reading. (10M value may be used for R1 with adjustment of the trimmer provided.)

Full scale	L1/R1	R2
200mV	LINK	-
2V	9M	1M
20V	9M9	100K
200V	9M99	10K
2000V	9M999	1K
200uA	LINK	1K
2mA	LINK	100R
20mA	LINK	10R
200mA	LINK	1R
2A	LINK	OR1

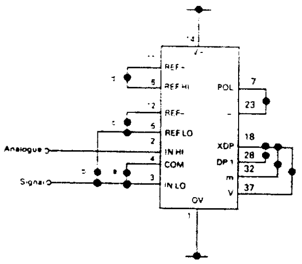
Voltage Input:

$$\text{Full scale} = 2000 \times \frac{R1 + R2}{R2} \text{ mV}$$

Current input:

Meter input voltage = $I_{IN} \times R_2$

Figure 6 **Measurement of floating voltage with 200mV full scale and annunciators**



Using the solder-bridge connections only four wires are required for signal and supply.

Issued July 1986 **6660**

RS Data Library

LCD panel meter module with annunciators

Stock number 257-846

A low profile digital panel meter module with a 3½ digit liquid crystal display incorporating a wide range of commonly employed symbols. A high-contrast display combined with a wide viewing angle results in excellent clarity. Very low current consumption allows long battery life to be obtained: especially useful in portable equipment. Typical applications include digital thermometers, pH meters, and multimeters. Supplied complete with mounting clips.

Absolute maximum ratings

Supply voltage ___ +15V d.c. max
Operating temperature ___ 0°C to +50°C
Storage temperature ___ −20°C to +60°C
Pin soldering temperature ___ 250°C for 8 secs max

Module operation

The L.C.D. panel meter module is centred around the 7126 integrated circuit which is a complete dual-slope-integration analogue-digital convertor which consumes typically only 50μA and drives the custom L.C.D. direct. The circuit diagram of the module is shown in Figure 1.

Components R3, R4 and C1 determine the integrator time constant and C2 reduces the susceptibility to noise of the auto-zero-circuitry. The display is guaranteed to read zero when the analogue input is zero volts.

An input filter is formed by R5 and C3 and assists with overload protection of the 7126. The input voltage may exceed the supply voltage provided the input current does not exceed 100μA.

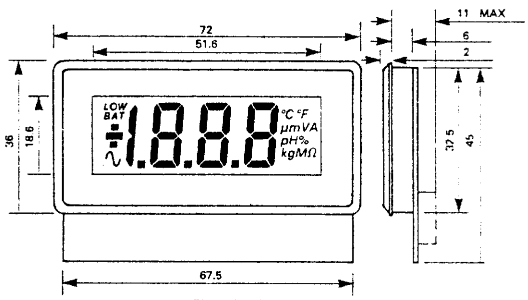
The frequency of the internal oscillator is determined by C5 and R6 and provides typically three samples per second.

As supplied the module is calibrated by means of VR1 for a full scale reading of 200mV with link L1 in circuit and resistor R2 omitted. Figure 2 shows how the input sensitivity may be altered and how the module may be converted for current measurement.

Features

- 15mm high digits
- Auto-zero and auto-polarity
- Programmable decimal points
- 200mV 'full-scale deflection'
- Accuracy is 0.05% of reading (± 1 digit)
- Current consumption typically 100μA at 9V
- Variable threshold low battery warning indicator
- Internal bandgap reference for excellent stability.

Panel cut-out: 68 × 33



Dimensions in mm

Handling precautions

The DPM module contains CMOS devices and must be handled correctly to prevent damage. Input pins should be shorted with conductive foil. Do not make any circuit changes under 'Power On' conditions as high transients may cause permanent damage.

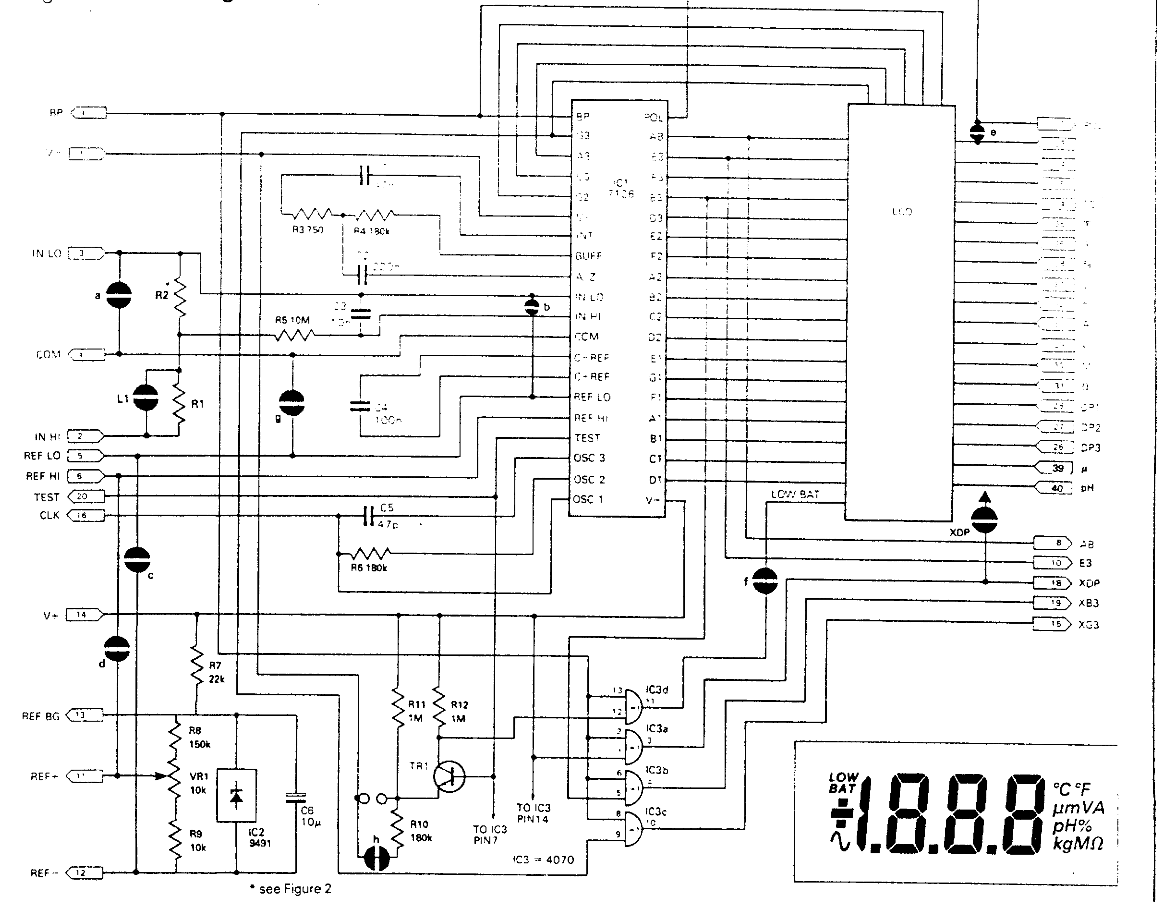
The 7126 has its own internal voltage reference in so far as common is maintained at approximately 2.8V below the positive supply with a temperature coefficient of typically 80ppm/°C. A potential divider could be formed across the internal reference in order to derive the voltage required for the convertor reference input. The convertor operates in ratiometric mode such that the digital display is 1000 V_{IN}/V_{ref} and V_{ref} is normally 100mV.

Electrical characteristics $T_A = 25°C$

Note 1: Accuracy is 0.05% of reading ±1 digit.
Note 2: Also see text 'Module operation'.

Parameter	Symbol	Condition	Min	Typ	Max	Units
Supply voltage	V_{CC}		5	9	15	V dc
Input impedance	R_{in}		100			MΩ
Accuracy		dc voltage: see note 1	0.05			%
Current consumption	I_{CC}	See note 2		100		μA
Sample rate					3	s^{-1}
Reading stability				50		ppm/°C
Low battery warning threshold				6.4		V dc
Battery life		PP3 battery		2000		hours

Figure 1 **Circuit diagram of the DPM module**



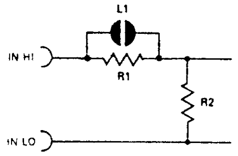
* see Figure 2

In order to obtain higher stability of reading a bandgap reference integrated circuit (IC2) type 9491 is used which relies upon the bulk properties and doping levels of the silicon. The bandgap reference does however require at least 50μA additional current to remain correctly biased. If minimum module consumption is the main requirement the i.c. reference should be used and R7 should be removed to isolate the bandgap reference from the supply. A potential divider across IC2 produces a 100mV output at REF+.

When using the i.c. reference the module may be operated down to 7 volts, whereas when the bandgap reference is used operation down to 5 volts is possible.

A low-battery detection circuit is included in the module to provide advance warning of battery failure directly on the display. A potential divider is formed across the supply by R11 and R10 and when the voltage falls below the threshold set by R10, the collector TR1 changes to a high level. Exclusive - OR gate IC3d then acts as an inverter to provide an output in anti-phase to the backplane input and so provide the required L.C.D. drive signal for the LOW BAT warning. The 180k value fitted for R10 provides advance battery low warning at typically 6.4V. The value of R10 may be altered, if required, by adding a resistor at the rear of the p.c.b. and splitting pad h to isolate the internal resistor. Resistors in the range 100k to 200k are usually required.

Figure 2 **Method of altering the full scale reading of the DPM module**



Required Full Scale	L1/R1	R2
2V	10M	1M
20V	10M	100k
200V	10M	10k
2000V	10M	1k
200μA	LINK	1k
2mA	LINK	100Ω
20mA	LINK	10Ω
200mA	LINK	1Ω

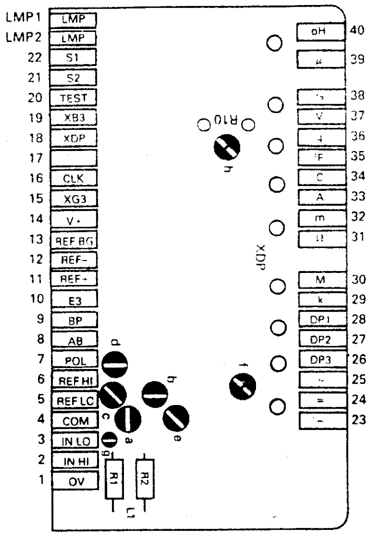
Exclusive −OR gate IC3a inverts the backplane signal and may be used to activate any multiple of the auxiliary L.C.D. symbols or decimal points by direct connection to those required. Gates IC3b and IC3c provide outputs which are useful in auto-ranging applications.

Connection notes

The pin connection diagram for the p.c.b. is shown in Figure 3. The analogue inputs are truly differential and may be operated to within 0.5V below the positive supply and 1V above the negative supply. Common mode rejection ratio within this range is typically 86dB. The COM (common) pin is a convenient method of establishing the correct common mode voltage since it is set approximately 2.8V below the positive supply.

Reference inputs are differential and may be anywhere within the power supply voltage range of the module.

Figure 3 **P.c.b. pin connection diagram**



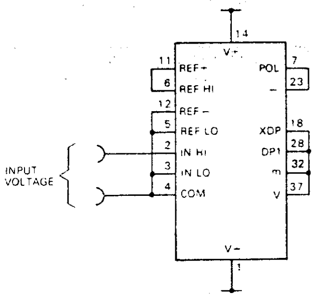
The Polarity output is a square wave in-phase with the backplane signal when the analogue input has positive polarity and in anti-phase when the input has negative polarity.

Four outputs are provided for use in auto-ranging applications, these are AB, E3, XG3 and XB3 – see Figure 4d.

Output REF+ is 100mV with respect to REF– when the latter is correctly terminated. REF BG is 1.2V with respect to REF–.

Figure 4a **Module connections for measuring a floating voltage source with 200mV full scale**

Autopolarity indication is implemented together with the decimal point and 'mV' annunciation.



Note that the linking is achieved by the use of the solder pads, not wire links.

The Clock output may be used for systems timing or as an input to over-ride the internal oscillator and control the sample rate. If CLK is connected to V+ (or TEST) the display may be held at a particular value, but this should not be connected for extended periods as the steady d.c. potential applied to the L.C.D. may cause the segments to 'burn'.

The TEST output may be used as a negative supply for external integrated circuits with a maximum load of 1mA. If TEST is connected to V+ the L.C.D. segments will be turned on and the display will read as shown in Figure 5. (This mode should not be used for extended periods, to avoid damage to the L.C.D.) Note that – 1888 is not precisely indicated, two segments being 'missing'. This occurs as an unavoidable consequence of using the B3 and G3 outputs to feed IC3 – see Figure 2.

Figure 4b **Basic arrangement for measuring the ratio of two voltages**

The display = 1000 V2/V1. Maximum input voltage is ± 2V with a [illegible] supply

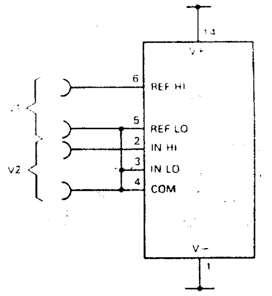


Figure 4c

If a zero display is required when the applied input is not zero volts the offset voltage should be connected between the IN LO and COM, while the input voltage is connected between the COM and IN HI.

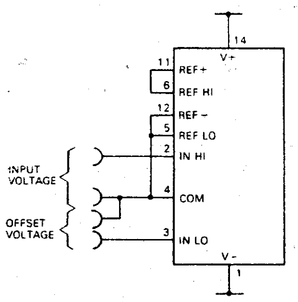


Figure 4d **Generation of signals for use in auto-ranging applications**

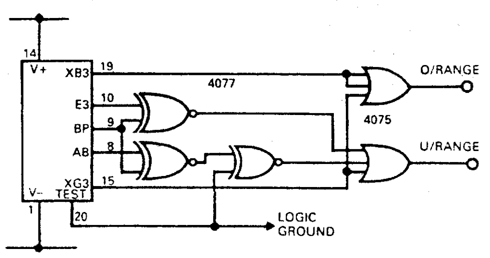
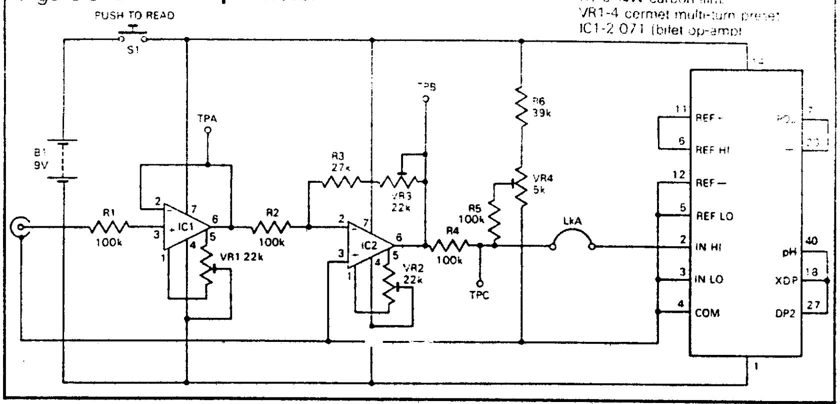


Figure 5 **Display in 'TEST' condition.**

Applications

The L.C.D. DPM may form the basis of many instruments. The circuits on page 3 give the basic connection data, along with the Figure 2 on page 2. Further circuits are suggested here, although some experimentation may be required to optimise these for particular applications.

Figure 6 **Circuit for pH Meter**



pH Meter

'pH' is essentially a measure of the acidity of a solution and as such is useful in many industrial and organic processes. The value is in fact defined as:

$$pH = \log_{10}(1 \div [H+])$$

A 'neutral' solution (e.g. pure water) has a pH of 7. Acidity is indicated by values between 0 and 7, and alkalinity by values between 7 and 14.

pH probes produce very small voltages and required amplification by high impedance amplifiers to drive a suitable meter. Figure 6 shows a suitable circuit.

Operational amplifier IC1 forms a unity-gain voltage follower, with a very high input impedance. Amplification is provided by IC2 and is set by VR3. A reference voltage is adjusted by VR4, such that with zero input from the probe a reading of 7.00 is obtained on the panel meter.

Calibration

1. Remove link LK A.
2. Connect battery.
3. Connect 150mm of wire (insulated) to the meter side of LK A position. Bare the other end – this acts as a 'test prod'.
4. Touch 'prod' on the 'earthy' side of the coaxial input socket. A reading of 0.00 should be obtained.
5. Connect a shorting link to the coaxial socket and touch the 'prod' on TP A. Adjust VR1 for a zero reading.
6. Touch 'prod' on TP B and adjust VR2 for zero reading.
7. Touch 'prod' on TP C and adjust VR4 for a reading of 7.00.
8. Remove the lead and insert LK A. Remove the socket link and insert the pH probe.
9. Place the pH probe into distilled water (pH 7) and adjust VR1 for a reading of 7.00.
10. Place the probe into an acid solution of pH 4. Adjust VR3 for a reading of 4.00. Calibration is now complete.

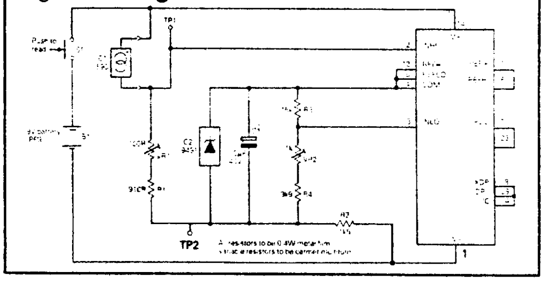
Digital Thermometer

The circuit of a digital thermometer is shown in Figure 7. This has been designed to operate with the **590** type of temperature sensor (RS Stock No. 308-809).

Calibration of the circuit is easily performed with the aid of a digital voltmeter. Connect the voltmeter across TP1 and TP2 and, with the 590 sensor at 0°C, adjust VR1 for a voltmeter reading of 273mV. With the 590 sensor still held at 0°C, adjust VR2 for a digital display of 0.0°C.

Calibration can be effected at ambient temperature if a calibrated thermometer is available. VR1 may be adjusted so that the voltage across TP1 and TP2, equals 1mV/°K at that temperature. VR2 can then be adjusted until the digital display indicates the correct temperature.

Figure 7 **Digital thermometer**



Multi-meter circuits

The meter module is ideally suited as a basis of a high grade multi-meter. Figure 2 outlines the method of use for d.c. voltage and current ranges. For a.c. a precision rectifier, using an operational amplifier, can be located after the attenuator stages. Resistance ranges are fairly readily incorporated in the normal manner. Input protection can also be arranged in a conventional way. Since, however, some specialized components (close tolerance resistors) are required, an actual circuit is not offered.