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จัดพิมพ์โดยหน่วยซ่อมสร้างเครื่องอีเล็คทรอนิคส์ ภาควิชาสรีรวิทยา คณะแพทยศาสตร์
ศิริราชพยาบาล มหาวิทยาลัยมหิดล กรุงเทพมหานคร, พ.ศ.๒๕๒๔.

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Operational Amplifiers/Buffers

LM4250/LM4250C programmable operational amplifier

general description

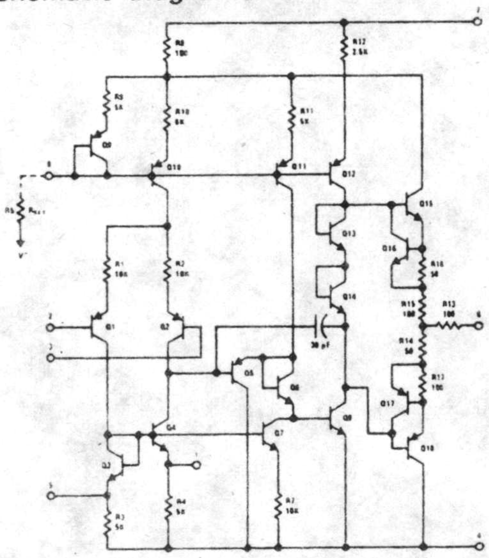
The LM4250 and LM4250C are extremely versatile programmable monolithic operational amplifiers. A single external master bias current setting resistor programs the input bias current, input offset current, quiescent power consumption, slew rate, input noise, and the gain-bandwidth product. The device is a truly general purpose operational amplifier.

features

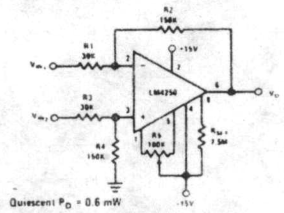
- ±1V to ±18V power supply operation
- 3 nA input offset current
- Standby power consumption as low as 500 nW
- No frequency compensation required
- Programmable electrical characteristics
- Offset Voltage nulling capability
- Can be powered by two flashlight batteries
- Short circuit protection

The LM4250C is identical to the LM4250 except that the LM4250C has its performance guaranteed over a 0°C to 70°C temperature range instead of the −55°C to +125°C temperature range of the LM4250.

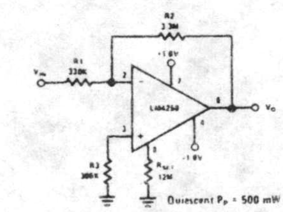
schematic diagrams



typical applications



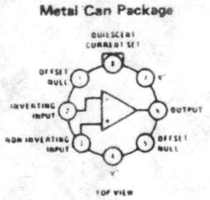
X5 Difference Amplifier



500 Nano-Watt X10 Amplifier

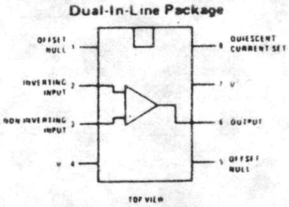
connection diagrams

Metal Can Package



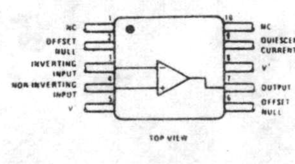
Order Number LM4250H or LM4250CH
See Package 11

Dual-In-Line Package



Order Number LM4250CN
See Package 20
Order Number LM4250J
or LM4250CJ
See Package 15

Flat Package



Order Number LM4250F
See Package 3

LM4250/LM4250C

absolute maximum ratings

Supply Voltage	±18V	Output Short-Circuit Duration		Indefinite
Power Dissipation (Note 1)	500 mW	Operating Temperature Range	LM4250	$-55^\circ C \le T_A \le 125^\circ C$
Differential Input Voltage	±30V		LM4250C	$0^\circ C \le T_A \le 70^\circ C$
Input Voltage (Note 2)	±15V	Storage Temperature Range		$-65^\circ C$ to $150^\circ C$
I_{SET} Current	150 µA	Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics LM4250 ($-55^\circ C \le T_A \le 125^\circ C$ unless otherwise specified)

PARAMETERS	CONDITIONS	$V_S = \pm 1.5V$			
		$I_{SET} = 1\ \mu A$		$I_{SET} = 10\ \mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25^\circ$ $R_S \le 100\ k\Omega$		3 mV		5 mV
I_{OS}	$T_A = 25^\circ$		3 nA		10 nA
I_{bias}	$T_A = 25^\circ$		7.5 nA		50 nA
Large Signal Voltage Gain	$T_A = 25^\circ$ $R_L = 100\ k\Omega$	40k			
	$V_O = \pm 0.6$, $R_L = 10\ k\Omega$			50k	
Supply Current	$T_A = 25^\circ C$		7.5 µA		80 µA
Power Consumption	$T_A = 25^\circ C$		23 µW		240 µW
V_{OS}	$R_S \le 100\ k\Omega$		4 mV		6 mV
I_{OS}	$T_A = 125^\circ C$		5 nA		10 nA
	$T_A = -55^\circ C$		3 nA		10 nA
I_{bias}			7.5 nA		50 nA
Input Voltage Range		±0.7V		±0.7V	
Large Signal Voltage Gain	$V_O = \pm 0.6V$ $R_L = 100\ k\Omega$	30k			
	$R_L = 10\ k\Omega$			30k	
Output Voltage Swing	$R_L = 100\ k\Omega$	±0.6V			
	$R_L = 10\ k\Omega$			±0.6V	
Common Mode Rejection Ratio	$R_S \le 10\ k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$	76 dB		76 dB	
Supply Current			8 µA		90 µA
Power Consumption			24 µW		270 µW

PARAMETERS	CONDITIONS	$V_S = \pm 15V$			
		$I_{SET} = 1\ \mu A$		$I_{SET} = 10\ \mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25^\circ C$ $R_S \le 100\ k\Omega$		3 mV		5 mV
I_{OS}	$T_A = 25^\circ C$		3 nA		10 nA
I_{bias}	$T_A = 25^\circ C$		7.5 nA		50 nA
Large Signal Voltage Gain	$T_A = 25^\circ C$ $R_L = 100\ k\Omega$	100k			
	$V_O = \pm 10V$ $R_L = 10\ k\Omega$			100k	
Supply Current	$T_A = 25^\circ C$		10 µA		90 µA
Power Consumption	$T_A = 25^\circ C$		300 µW		2.7 mW
V_{OS}	$R_S \le 100\ k\Omega$		4 mV		6 mV
I_{OS}	$T_A = 125^\circ C$		25 nA		25 nA
	$T_A = -55^\circ C$		3 nA		10 nA
I_{bias}			7.5 nA		50 nA
Input Voltage Range		±13.5V		±13.5V	
Large Signal Voltage Gain	$V_O = \pm 10V$ $R_L = 100\ k\Omega$	50k			
	$R_L = 10\ k\Omega$			50k	
Output Voltage Swing	$R_L = 100\ k\Omega$	±12V			
	$R_L = 10\ k\Omega$			±12V	
Common Mode Rejection Ratio	$R_S \le 10\ k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$	76 dB		76 dB	
Supply Current			11 µA		100 µA
Power Consumption			330 µW		3 mW

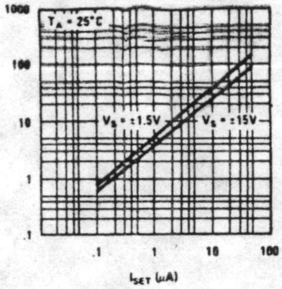
Note 1: The maximum junction temperature of the LM4250 is 150°C, while that of the LM4250C is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient, or 45°C/W junction to case. The thermal resistance of the dual-in-line package is 125°C/W.

Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

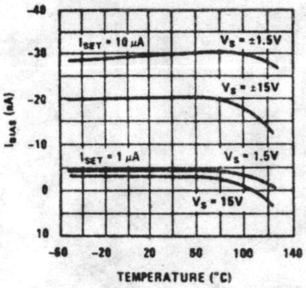
LM4250/LM4250C

typical performance characteristics

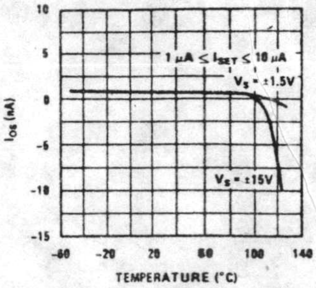
Input Bias Current vs I_{SET}



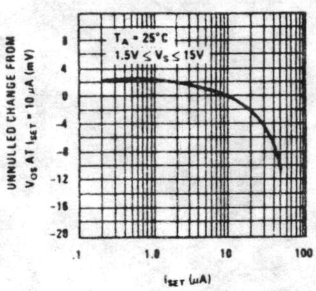
Input Bias Current vs Temperature



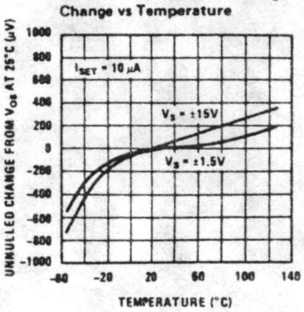
Input Offset Current vs Temperature



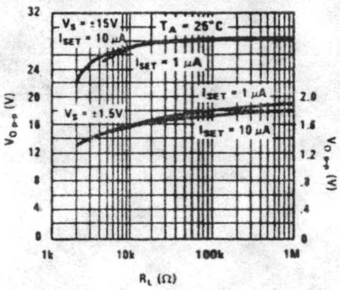
Unnulled Input Offset Voltage Change vs I_{SET}



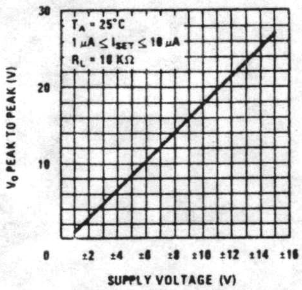
Unnulled Input Offset Voltage Change vs Temperature



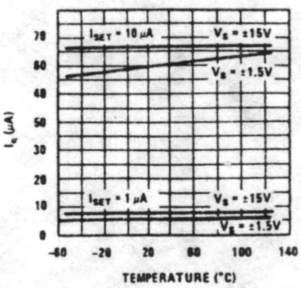
Peak to Peak Output Voltage Swing vs Load Resistance



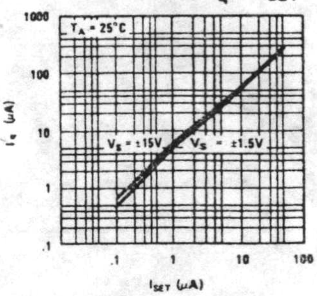
Peak to Peak Output Voltage Swing vs Supply Voltage



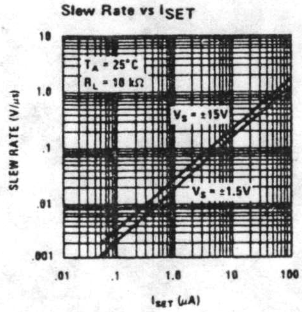
Quiescent Current (I_q) vs Temperature



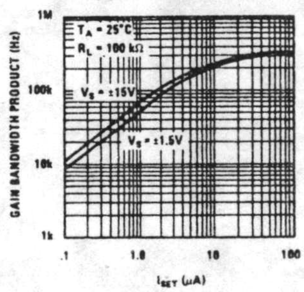
Quiescent Current (I_q) vs I_{SET}



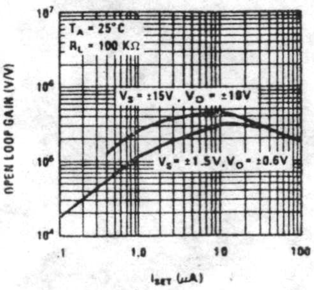
Slew Rate vs I_{SET}



Gain Bandwidth Product vs I_{SET}

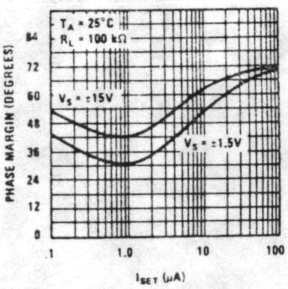


Open Loop Voltage Gain vs I_{SET}

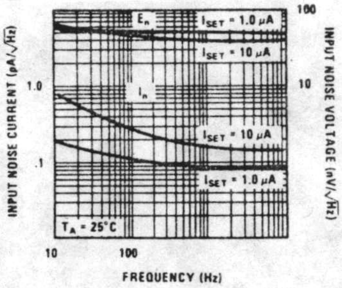


typical performance characteristics (con't)

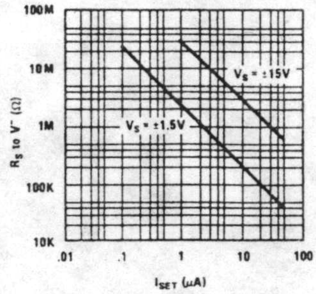
Phase Margin vs I_{SET}



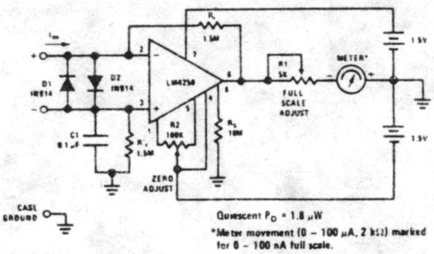
Input Noise Current (I_n) and Voltage (E_n) vs Frequency



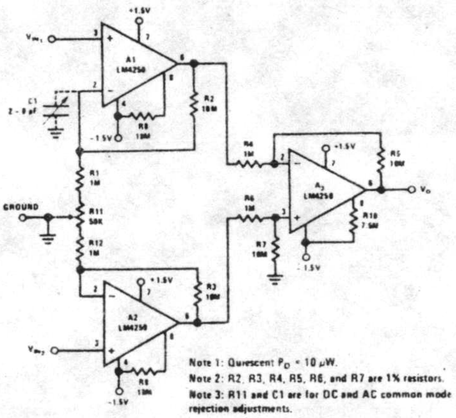
R_{SET} vs I_{SET}



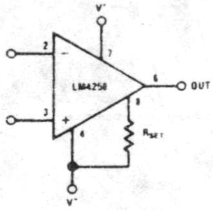
typical applications (con't)



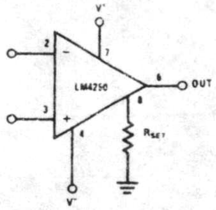
Floating Input Meter Amplifier
100 Nano-Ampere Full Scale



X100 Instrumentation Amplifier 10 μW



R_{SET} Connected to V^-

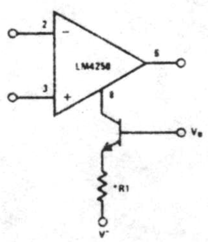


R_{SET} Connected to Ground

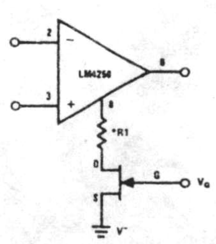
I_{SET} EQUATIONS:

$I_{SET} = \frac{V^+ + |V^-| - 0.5}{R_{SET}}$ where R_{SET} is connected to V^-.

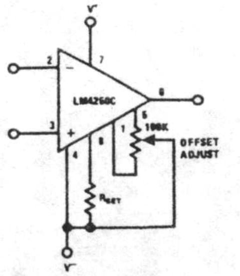
$I_{SET} = \frac{V^+ - 0.5}{R_{SET}}$ where R_{SET} is connected to ground.



Transistor Current Source Biasing



FET Current Source Biasing



Offset Null Circuit

*R1 limits I_{SET} maximum

electrical characteristics LM4250C ($0°C \le T_A \le 70°C$ unless otherwise specified)

PARAMETERS	CONDITIONS	$V_S = \pm 1.5V$			
		$I_{SET} = 1\,\mu A$		$I_{SET} = 10\,\mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25°C$ $R_S \le 100\,k\Omega$		5 mV		6 mV
I_{OS}	$T_A = 25°C$		6 nA		20 nA
I_{bias}	$T_A = 25°C$		10 nA		75 nA
Large Signal Voltage Gain	$T_A = 25°C$ $R_L = 100\,k\Omega$	25k			
	$V_O = \pm 0.6V$ $R_L = 10\,k\Omega$			25k	
Supply Current	$T_A = 25°C$		8 µA		90 µA
Power Consumption	$T_A = 25°C$		24 µW		270 µW
V_{OS}	$R_S \le 10\,k\Omega$		6.5 mV		7.5 mV
I_{OS}			8 nA		25 nA
I_{bias}			10 nA		80 nA
Input Voltage Range		±0.6V		±0.6V	
Large Signal Voltage Gain	$V_O = \pm 0.6V$ $R_L = 100\,k\Omega$	25k			
	$R_L = 10\,k\Omega$			25k	
Output Voltage Swing	$R_L = 100\,k\Omega$	±0.6V			
	$R_L = 10\,k\Omega$			±0.6V	
Common Mode Rejection Ratio	$R_S \le 10\,k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \le 10\,k\Omega$	74 dB		74 dB	
Supply Current			8 µA		90 uA
Power Consumption			24 µW		270 uW

PARAMETERS	CONDITIONS	$V_S = \pm 15V$			
		$I_{SET} = 1\,\mu A$		$I_{SET} = 10\,\mu A$	
		MIN	MAX	MIN	MAX
V_{OS}	$T_A = 25°C$ $R_S \le 100\,k\Omega$		5 mV		6 mV
I_{OS}	$T_A = 25°C$		6 nA		20 nA
I_{bias}	$T_A = 25°C$		10 nA		75 nA
Large Signal Voltage Gain	$T_A = 25°C$ $R_L = 100\,k\Omega$	60k			
	$V_O = \pm 10V$ $R_L = 10\,k\Omega$			60k	
Supply Current	$T_A = 25°C$		11 µA		100 µA
Power Consumption	$T_A = 25°C$		330 µW		3 mW
V_{OS}	$R_S \le 10\,k\Omega$		6.5 mV		7.5 mV
I_{OS}			8 nA		25 nA
I_{bias}			10 nA		80 nA
Input Voltage Range		±13.5V		±13.5V	
Large Signal Voltage Gain	$V_O = \pm 10V$ $R_L = 100\,k\Omega$	50k			
	$R_L = 10\,k\Omega$			50k	
Output Voltage Swing	$R_L = 100\,k\Omega$	±12V			
	$R_L = 10\,k\Omega$			±12V	
Common Mode Rejection Ratio	$R_S \le 10\,k\Omega$	70 dB		70 dB	
Supply Voltage Rejection Ratio	$R_S \le 10\,k\Omega$	74 dB		74 dB	
Supply Current			11 uA		100 uA
Power Consumption			300 uW		3 mW

resistor biasing

Set Current Setting Resistor to V^-

	I_{SET}				
V_S	0.1 µA	0.5 µA	1.0 µA	5 µA	10 µA
±1.5V	25.6 MΩ	5.04 MΩ	2.5 MΩ.	492 kΩ	244 kΩ
±3.0V	55.6 MΩ	11.0 MΩ	5.5 MΩ	1.09 MΩ	544 kΩ
±6.0V	116 MΩ	23.0 MΩ	11.5 MΩ	2.29 MΩ	1.14 MΩ
±9.0V	176 MΩ	35.0 MΩ	17.5 MΩ	3.49 MΩ	1.74 MΩ
±12.0V	236 MΩ	47.0 MΩ	23.5 MΩ	4.69 MΩ	2.34 MΩ
±15.0V	296 MΩ	59.0 MΩ	29.5 MΩ	5.89 MΩ	2.94 MΩ

3

ข้อมูลทางไฟฟ้าของทรานซิสเตอร์

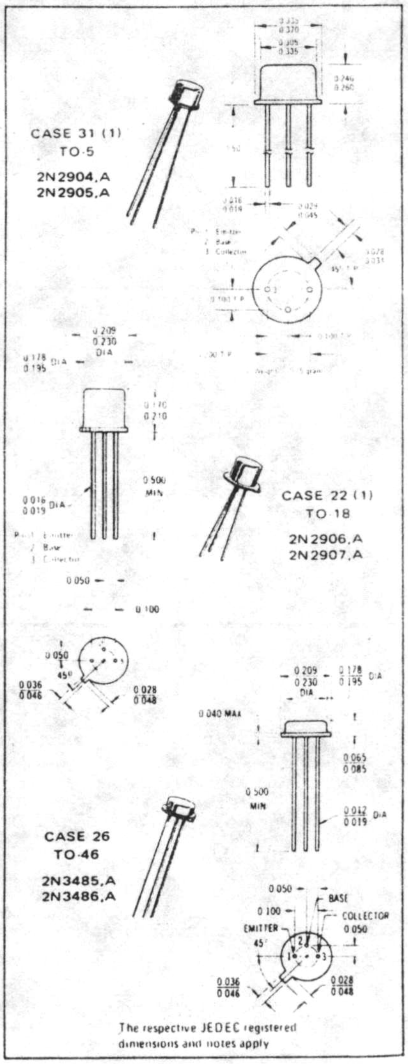
2N2904,A thru 2N2907,A (SILICON)
2N3485,A, 2N3486,A

PNP SILICON ANNULAR HERMETIC TRANSISTORS

. . . designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry.

- High DC Current Gain Specified – 0.1 to 500 mAdc
- High Current-Gain–Bandwidth Product – f_T = 200 MHz (Min) @ I_C = 50 mAdc
- Low Collector-Emitter Saturation Voltage – $V_{CE(sat)}$ = 0.4 Vdc (Max) @ I_C = 150 mAdc
- 2N2904,A thru 2N2907,A Complement to NPN 2N2218,A, 2N2219,A, 2N2221,A, 2N2222,A
- JAN/JTX Available, Except 2N3485 and 2N3486.

PNP SILICON SWITCHING AND AMPLIFIER TRANSISTORS



SELECTOR GUIDE

Device Type	Characteristic				Package
	BV_{CEO} I_C = 10 mAdc Volts	h_{FE} I_C = 1.0 mAdc Min	I_C = 150 mAdc Min	I_C = 500 mAdc Min	
2N2904	40	25	40	20	TO-5
2N2905		50	100	30	
2N2906		25	40	20	TO-18
2N2907		50	100	30	
2N3485		25	40	20	TO-46
2N3486		50	100	30	
2N2904A	60	40	40	40	TO-5
2N2905A		100	100	50	
2N2906A		40	40	40	TO-18
2N2907A		100	100	50	
2N3485A		40	40	40	TO-46
2N3486A		100	100	50	

*MAXIMUM RATINGS

Rating	Symbol	Non-A Suffix	A-Suffix	Unit
Collector-Emitter Voltage	V_{CEO}	40	60	Vdc
Collector-Base Voltage	V_{CB}	60		Vdc
Emitter-Base Voltage	V_{EB}	5.0		Vdc
Collector Current – Continuous	I_C	600		mAdc

Rating	Symbol	2N2904,A 2N2905,A	2N2906,A 2N2907,A	2N3485,A 2N3486,A	Unit
Total Device Dissipation @ T_A = 25°C	P_D	600	400	400	mW
Derate above 25°C		3.43	2.28	2.28	mW/°C
Total Device Dissipation @ T_C = 25°C	P_D	3.0	1.8	2.0	Watts
Derate above 25°C		17.2	10.3	11.43	mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-65 to +200			°C

2N2904,A thru 2N2907,A/2N3485,A, 2N3486,A (continued)

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

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector-Emitter Breakdown Voltage(1) (I_C = 10 mAdc, I_B = 0)	Non-A Suffix A-Suffix	BV_{CEO}	40 60	– –	– –	Vdc
Collector-Base Breakdown Voltage (I_C = 10 μAdc, I_E = 0)		BV_{CBO}	60	–	–	Vdc
Emitter-Base Breakdown Voltage (I_E = 10 μAdc, I_C = 0)		BV_{EBO}	5.0	–	–	Vdc
Collector Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)		I_{CEX}	–	–	50	nAdc
Collector Cutoff Current (V_{CB} = 50 Vdc, I_E = 0)	Non-A Suffix A-Suffix	I_{CBO}	– –	– –	0.020 0.010	μAdc
(V_{CB} = 50 Vdc, I_E = 0, T_A = 150°C)	Non-A Suffix A-Suffix		– –	– –	20 10	
Base Cutoff Current (V_{CE} = 30 Vdc, V_{BE} = 0.5 Vdc)		I_B	–	–	50	nAdc
ON CHARACTERISTICS						
DC Current Gain (I_C = 0.1 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485 2N2905,2N2907,2N3486 2N2904A,2N2906A,2N3485A 2N2905A,2N2907A,2N3486A	h_{FE}	20 35 40 75	– – – –	– – – –	–
(I_C = 1.0 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485 2N2905,2N2907,2N3486 2N2904A,2N2906A,2N3485A 2N2905A,2N2907A,2N3486A		25 50 40 100	– – – –	– – – –	
(I_C = 10 mAdc, V_{CE} = 10 Vdc)	2N2904,2N2906,2N3485 2N2905,2N2907,2N3486 2N2904A,2N2906A,2N3485A 2N2905A,2N2907A,2N3486A		35 75 40 100	– – – –	– – – –	
(I_C = 150 mAdc, V_{CE} = 10 Vdc)(1)	2N2904,A,2N2906,A,2N3485,A 2N2905,A,2N2907,A,2N3486,A		40 100	– –	120 300	
(I_C = 500 mAdc, V_{CE} = 10 Vdc)(1)	2N2904,2N2906,2N3485 2N2905,2N2907,2N3486 2N2904A,2N2906A,2N3485A 2N2905A,2N2907A,2N3486A		20 30 40 50	– – – –	– – – –	
Collector-Emitter Saturation Voltage(1) (I_C = 150 mAdc, I_B = 15 mAdc) (I_C = 500 mAdc, I_B = 50 mAdc)		$V_{CE(sat)}$	– –	– –	0.4 1.6	Vdc
Base-Emitter Saturation Voltage (I_C = 150 mAdc, I_B = 15 mAdc)(1) (I_C = 500 mAdc, I_B = 50 mAdc)		$V_{BE(sat)}$	– –	– –	1.3 2.6	Vdc
DYNAMIC CHARACTERISTICS						
Current-Gain—Bandwidth Product(2) (I_C = 50 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)		f_T	200	–	–	MHz
Output Capacitance (V_{CB} = 10 Vdc, I_E = 0, f = 100 kHz)		C_{ob}	–	–	8.0	pF
Input Capacitance (V_{BE} = 2.0 Vdc, I_C = 0, f = 100 kHz)		C_{ib}	–	–	30	pF
SWITCHING CHARACTERISTICS						
Turn-On Time	(V_{CC} = 30 Vdc, I_C = 150 mAdc, I_{B1} = 15 mAdc) (Figure 15a)	t_{on}	–	26	45	ns
Delay Time		t_d	–	6.0	10	ns
Rise Time		t_r	–	20	40	ns
Turn-Off Time	(V_{CC} = 6.0 Vdc, I_C = 150 mAdc, I_{B1} = I_{B2} = 15 mAdc) (Figure 15b)	t_{off}	–	70	100	ns
Storage Time		t_s	–	50	80	ns
Fall Time		t_f	–	20	30	ns

*Indicates JEDEC Registered Data.
(1)Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.
(2)f_T is defined as the frequency at which $|h_{fe}|$ extrapolates to unity.

2N2904,A thru 2N2907,A/2N3485,A, 2N3486,A (continued)

FIGURE 1 – NORMALIZED DC CURRENT GAIN

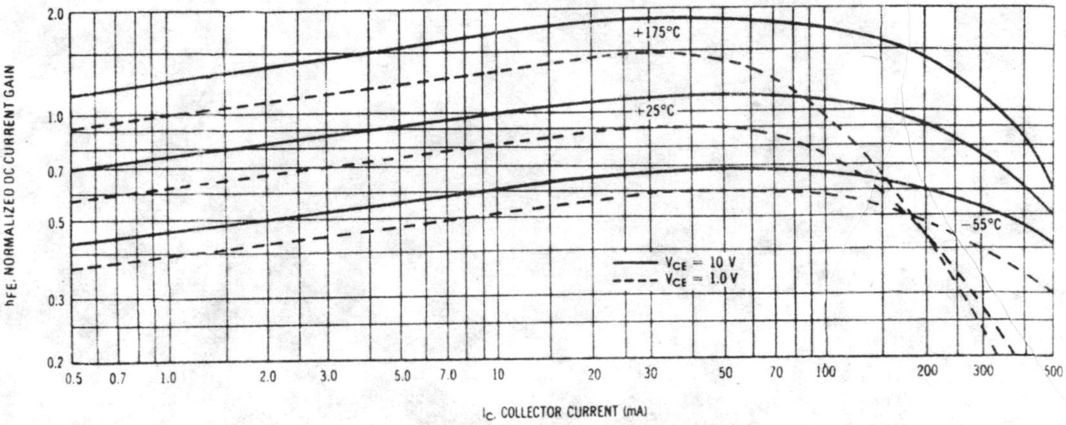
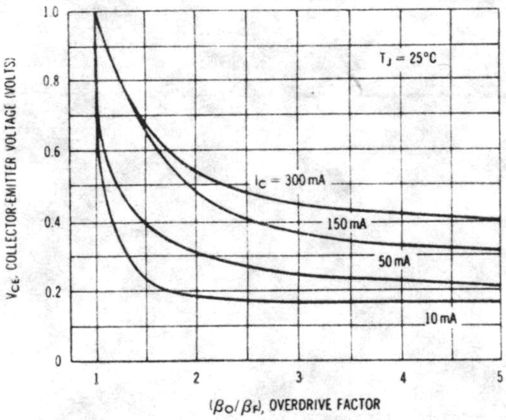


FIGURE 2 – NORMALIZED COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current. β_O (current gain at edge of saturation) is the current gain of the transistor at 1 volt, and β_F (forced gain) is the ratio of I_C/I_{BF} in a circuit.

EXAMPLE: For type 2N2905, estimate a base current (I_{BF}) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at $I_C = 150$ mA an overdrive factor of at least 3 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that h_{FE} @ 1 volt is approximately 0.60 of h_{FE} @ 10 volts. Using the guaranteed minimum of 100 @ 150 mA and 10 V, $\beta_O = 60$ and substituting values in the overdrive equation, we find:

$$\frac{\beta_O}{\beta_F} = \frac{h_{FE} @ 1\ V}{I_C/I_{BF}} \qquad 3 = \frac{60}{150/I_{BF}} \qquad I_{BF} \approx 7.5\ mA$$

FIGURE 3 – "ON" VOLTAGES

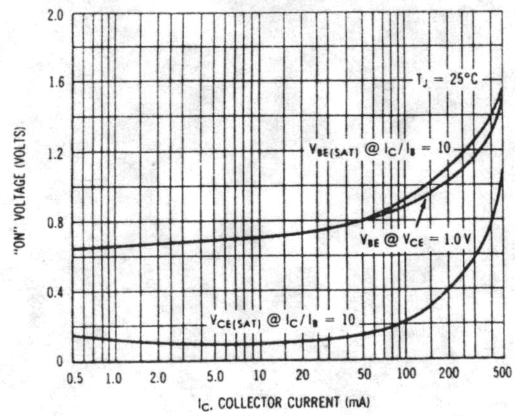
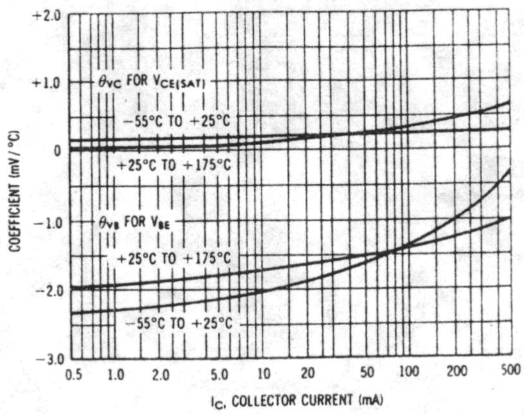


FIGURE 4 – TEMPERATURE COEFFICIENTS



2N2904,A thru 2N2907,A/2N3485,A, 2N3486,A (continued)

SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE

V_{CE} = 10 V, T_A = 25°C

FIGURE 5 – FREQUENCY EFFECTS

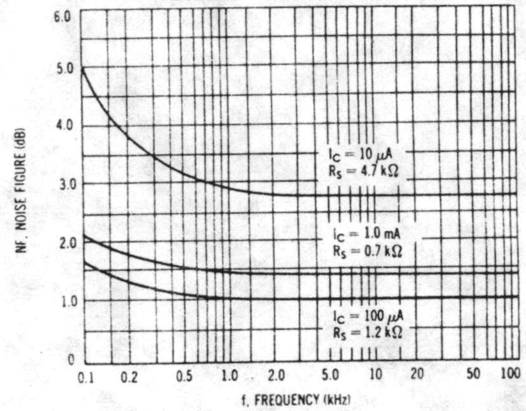
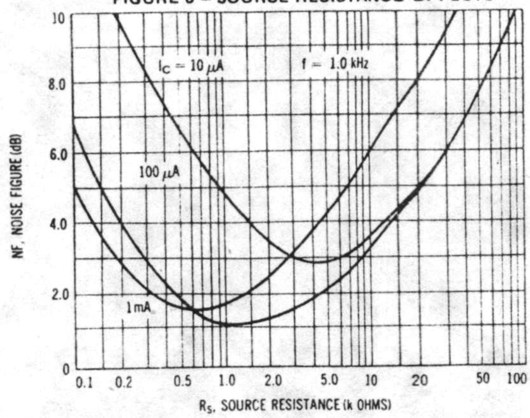


FIGURE 6 – SOURCE RESISTANCE EFFECTS



h PARAMETERS

V_{CE} = 10 Vdc, f = 1.0 kHz, T_A = 25°C

This group of graphs illustrates the relationship between h_{fe} and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 7 – INPUT IMPEDANCE

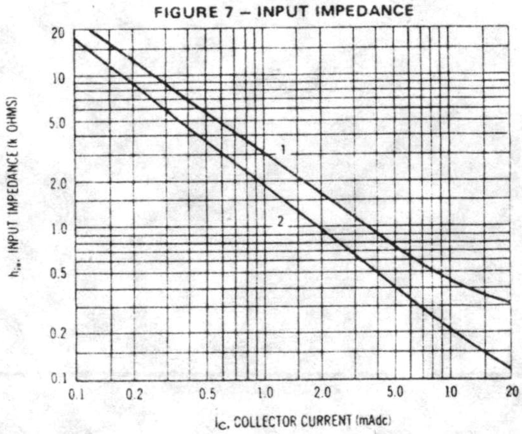


FIGURE 8 – VOLTAGE FEEDBACK RATIO

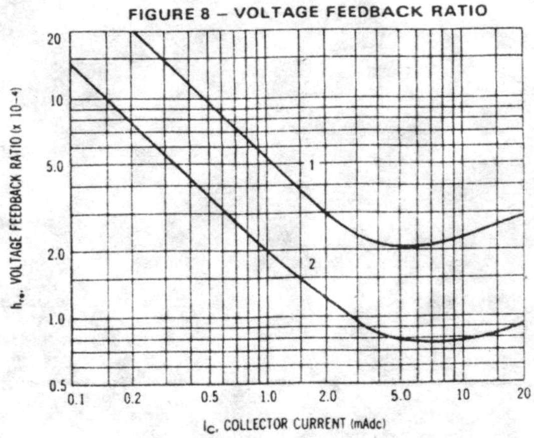


FIGURE 9 – CURRENT GAIN

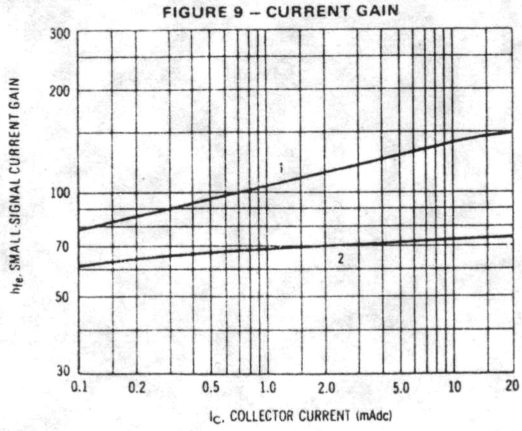
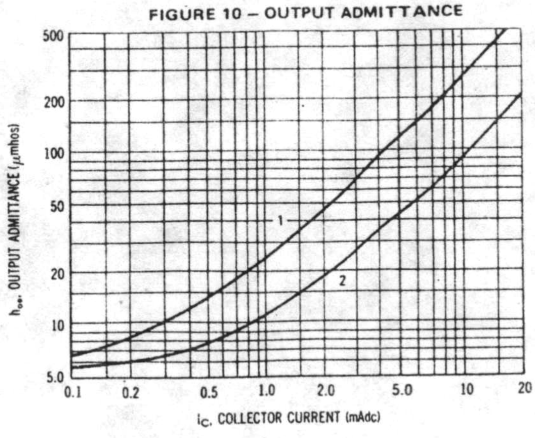


FIGURE 10 – OUTPUT ADMITTANCE



2N2904,A thru 2N2907,A/2N3485,A, 2N3486,A (continued)

FIGURE 11 – TURN ON TIME

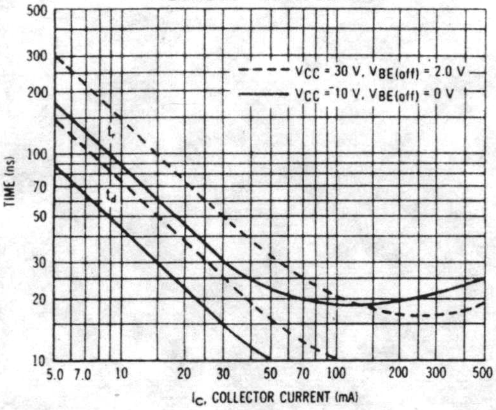


FIGURE 12 – CHARGE DATA

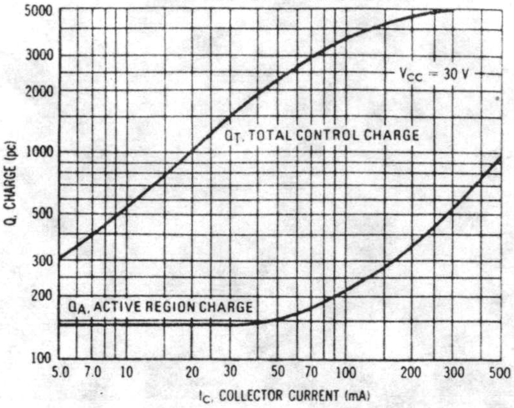


FIGURE 13 – STORAGE TIME

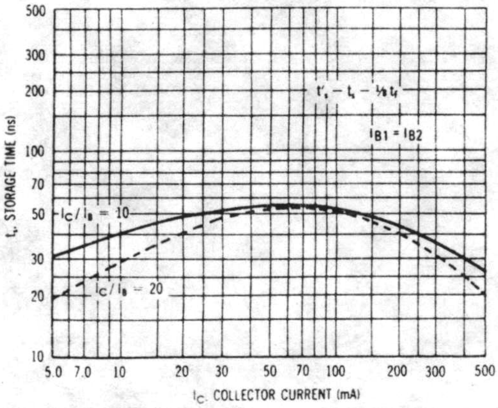


FIGURE 14 – FALL TIME

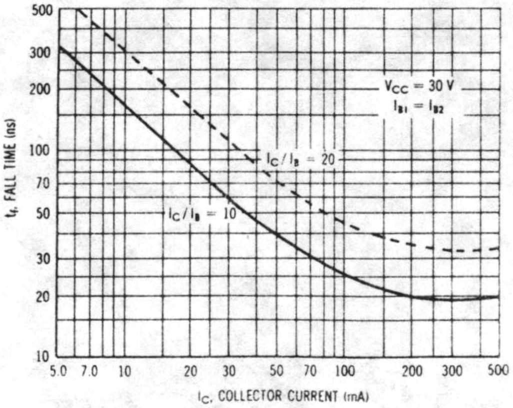


FIGURE 15a – DELAY AND RISE TIME TEST CIRCUIT

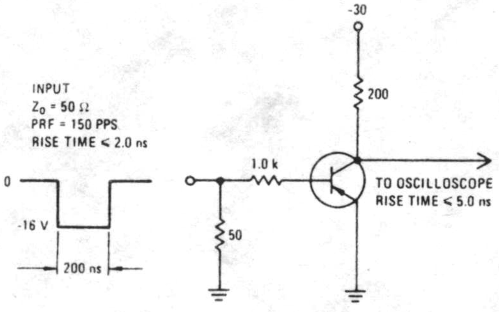
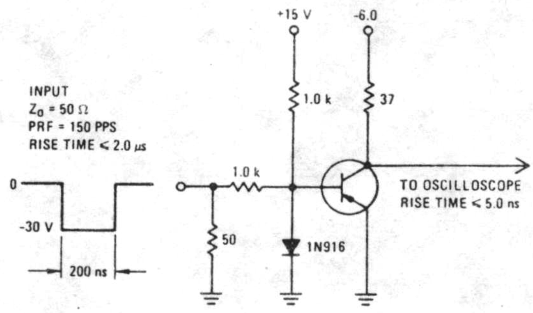


FIGURE 15b – STORAGE AND FALL TIME TEST CIRCUIT



2N2904,A thru 2N2907,A/2N3485,A, 2N3486,A (continued)

FIGURE 16 – CURRENT-GAIN–BANDWIDTH PRODUCT

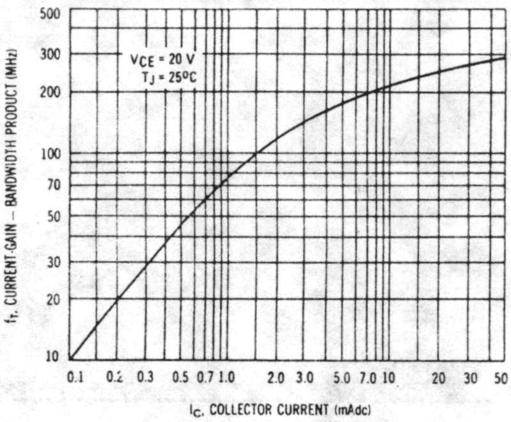


FIGURE 17 – CAPACITANCES

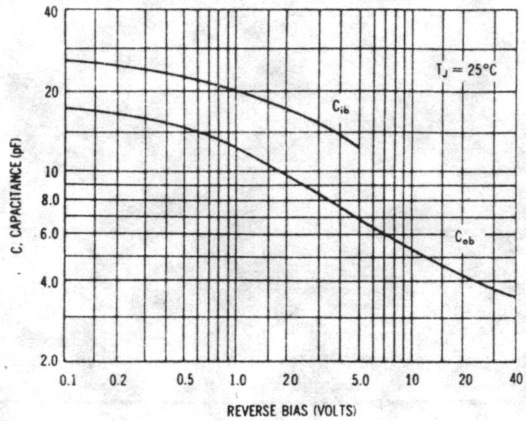
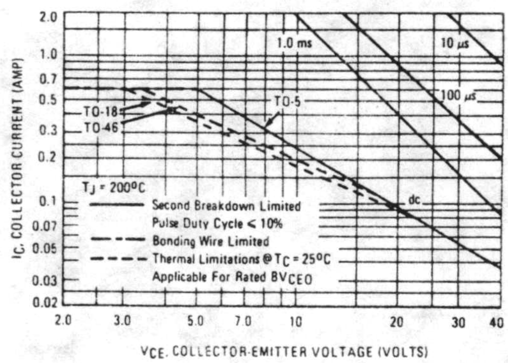


FIGURE 18 – ACTIVE REGION SAFE OPERATING AREAS

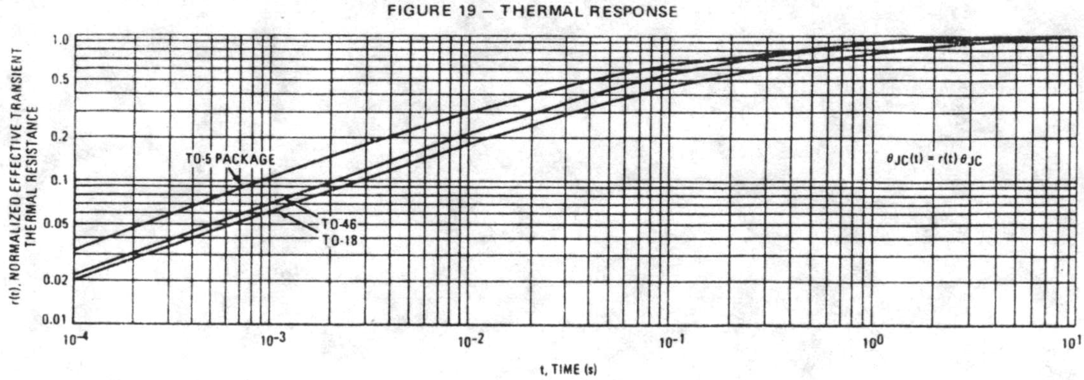


This graph shows the maximum I_C-V_{CE} limits of the device both from the standpoint of thermal dissipation (at 25°C case temperature), and secondary breakdown. For case temperatures other than 25°C, the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

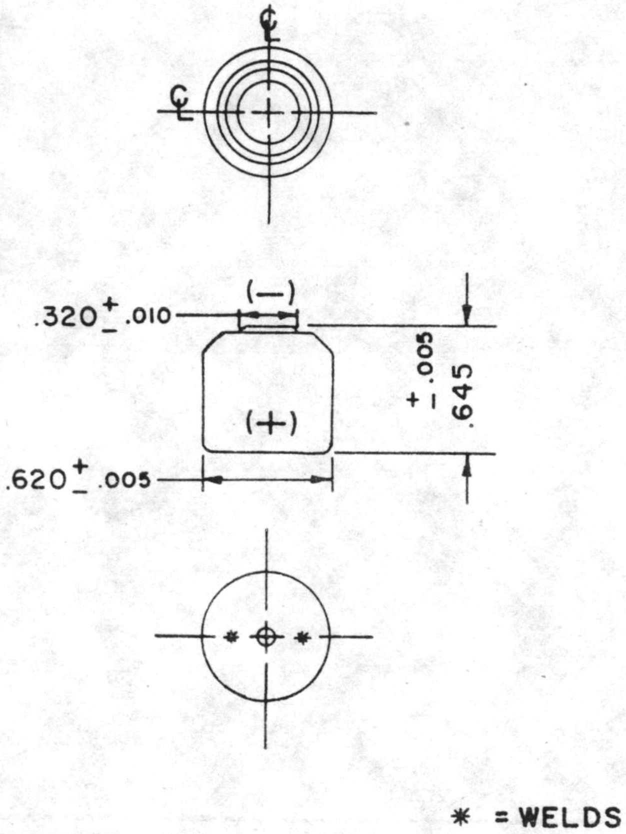
For pulse applications, the maximum I_C-V_{CE} product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

FIGURE 19 – THERMAL RESPONSE



MALLORY
MALLORY BATTERY COMPANY
a division of P. R. MALLORY & CO. INC.
S. Broadway, Tarrytown, New York, 10591; Telephone: 914-591-7000

CERTIFIED CELL [redacted] 317937



INCHES DEC.	M.M.
.005	.13
.010	.25
.320	8.13
.620	15.75
.645	16.38

SPECIFICATIONS

TYPE _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ MERCURIC OXIDE SILVER
NOMINAL VOLTAGE _ _ _ _ _ _ _ _ _ _ 1.38 ± .03 VOLTS
SHORT CIRCUIT CURRENT _ _ _ _ 100 MA. MIN.
SERVICE CAPACITY (AT 98.6° F. TO 0.9 VOLTS) 1,000 MAH
(RATED CAPACITY AT 1330 ± 1% OHMS)
AVERAGE WEIGHT _ _ _ _ _ _ _ _ _ _ 13.6 GMS (.48 OZ)
VOLUME _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ 3.28 C.C. (.20 CU. IN.)
WELDED INNER & OUTER CANS

ภาคผนวก ค. (ต่อ)

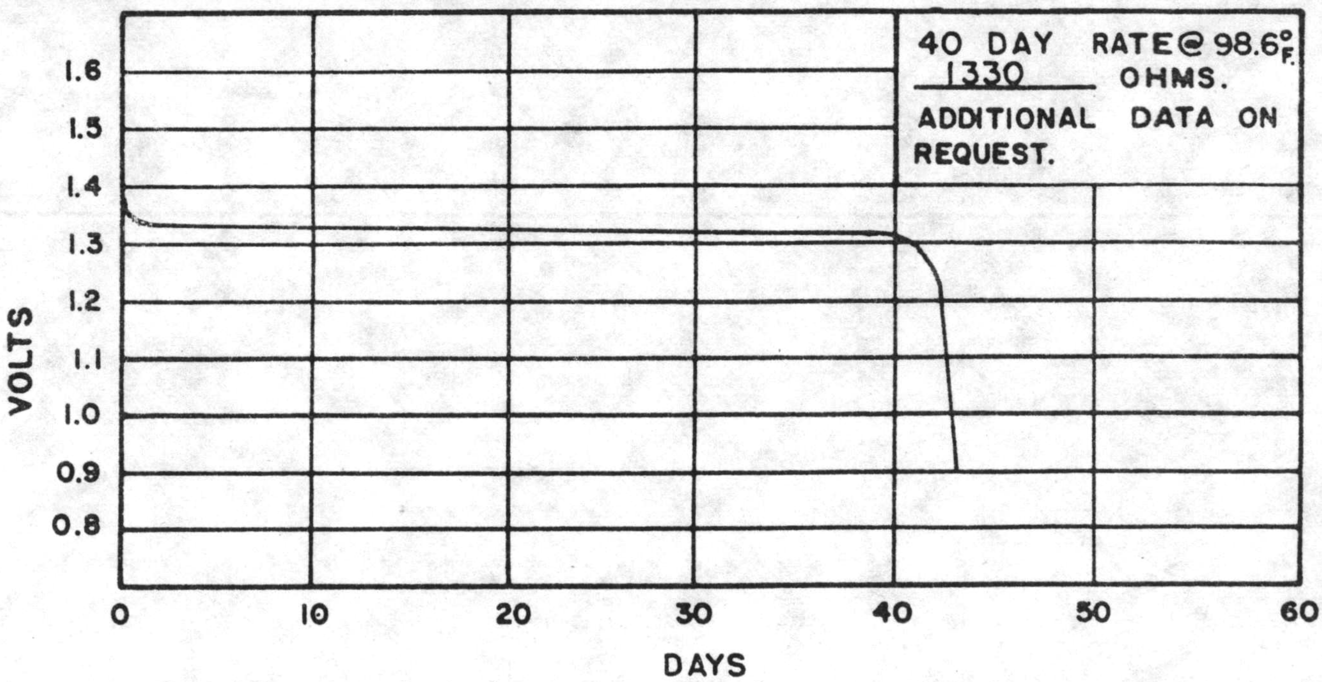
CELL TYPE — 317937 [redacted] **RATED CAPACITY — 1000 MA**

DISCHARGE DATA —

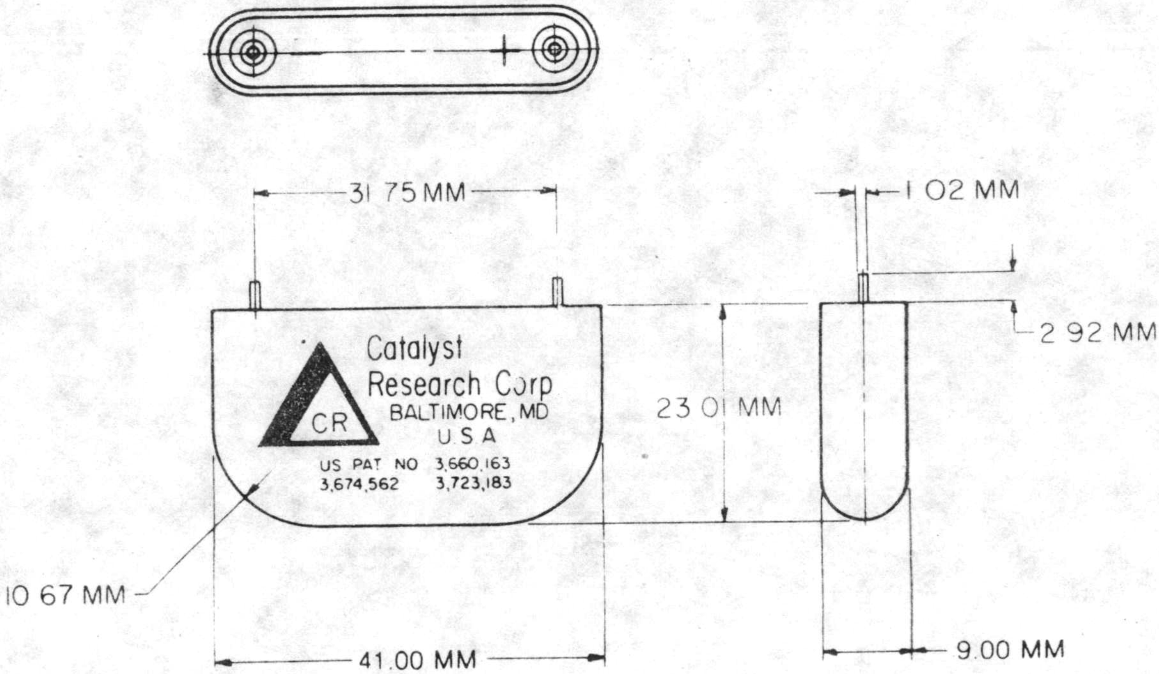
DUTY CYCLE	STARTING DRAIN IN MILLIAMPERES	LOAD	TIME TO END-POINT VOLTAGE .9
CONTINUOUS 24 HRS/ DAY AT 98.6° F.	1.0	1330 ± 1% OHMS	40 DAYS MIN.

THIS CELL IS DESIGNED FOR HIGH RELIABILITY MEDICAL APPLICATIONS REQUIRING EXTENDED SERVICE AT MICROAMPERE CURRENTS AND BODY TEMPERATURES. FOR DETAILED DISCHARGE INFORMATION CONTACT MALLORY BATTERY CO.

TYPICAL DISCHARGE (VOLTAGE VS. TIME)



Model 804B/23 SOLID LITHIUM IODINE CELL

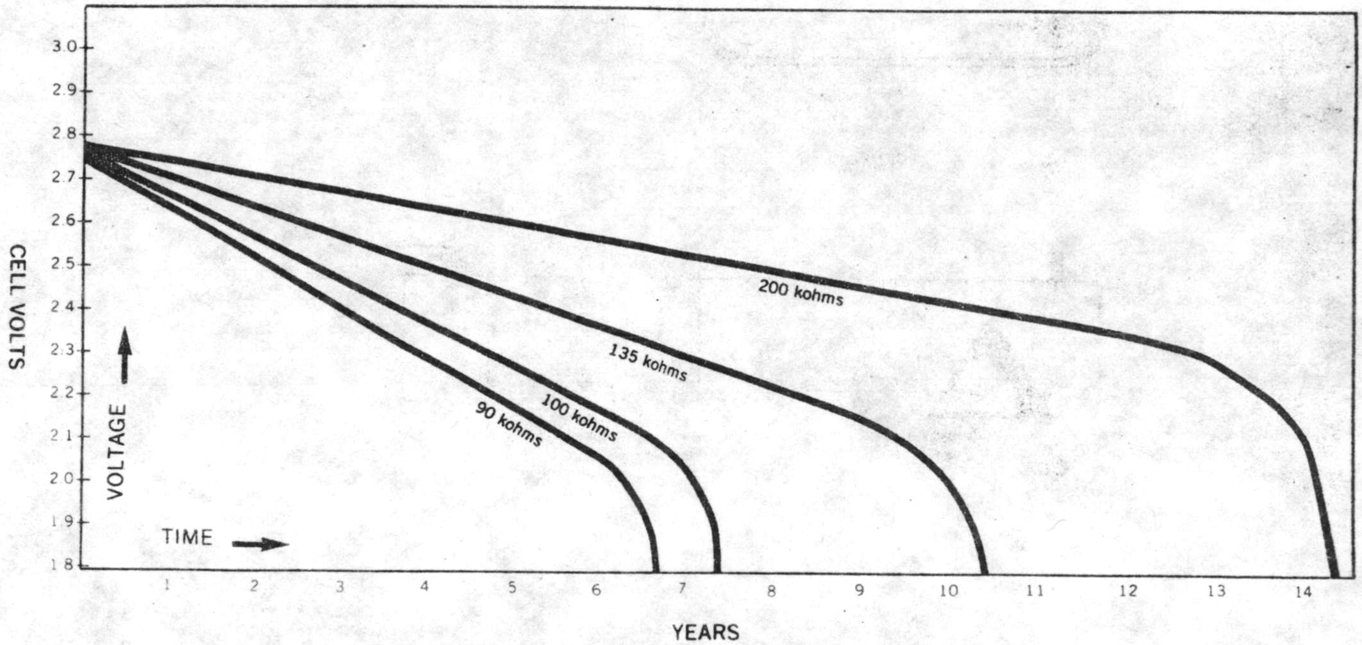


Volume	7.34 cm^3
Weight	20.5 grams
Lithium Area	14.22 cm^2
Voltage	2.80 volts under no load
Recommended Currents	1 to 50 microamperes at 37°C
Nominal Capacity	1.7 ampere-hours
Energy	4.1 watt-hours
Energy Density	0.56 watt-hours/cm^3 0.20 watt-hours/gram
Self-Discharge	Less than 5% in 10 years
Seal	Heliarc welded with glass/metal hermetic seals. Less than 4.6 x 10^8 max helium leak, by helium back fill method
Insulation Resistance	Greater than 10^{10} ohms from either pin to case
Storage Temp	-40°C to 50°C with brief excursions to 60°C

The capacities shown are based upon average fill weights. Standard deviation of capacity from battery to battery is approximately .03 ampere-hours.

Model 804B/23 SOLID LITHIUM IODINE CELL

PROJECTED PERFORMANCE
CONSTANT CURRENT DISCHARGE



GROSS CAPACITY ABOVE 2.0 VOLTS

LOAD (in kohms)	50	90	100	135	200
CAPACITY (in amp. hrs.)	1.35	1.57	1.60	1.67	1.71

PROJECTED PERFORMANCE
CONSTANT CURRENT DISCHARGE

CONSTANT CURRENT = 15 MICROAMPS

AMP HRS EXPENDED	TIME YEARS	CELL VOLTS	IMPEDANCE KOHMS
00	00	2.79	39
13	83	2.75	3.01
26	1.79	2.71	6.01
40	2.74	2.66	9.00
53	3.69	2.62	12.00
66	4.64	2.57	15.01
78	5.59	2.53	18.01
91	6.54	2.48	21.00
1.04	7.49	2.44	24.01
1.17	8.43	2.39	27.00
1.30	9.38	2.35	30.01
1.43	10.32	2.30	33.01
1.55	11.26	2.26	36.01
1.65	11.96	2.21	39.01
1.69	12.27	2.17	42.07

CONSTANT CURRENT = 25 MICROAMPS

AMP. HRS. EXPENDED	TIME YEARS	CELL VOLTS	IMPEDANCE KOHMS
.00	.00	2.79	.40
.15	.62	2.72	3.01
.32	1.33	2.65	6.02
.48	2.04	2.57	9.01
.64	2.74	2.50	12.02
.79	3.45	2.42	15.02
.95	4.15	2.35	18.01
1.11	4.85	2.27	21.02
1.27	5.55	2.20	24.01
1.42	6.26	2.12	27.02
1.58	6.94	2.05	30.02
1.66	7.33	1.97	33.02
1.70	7.47	1.90	36.00
1.71	7.54	1.82	39.27

CONSTANT CURRENT = 30 MICROAMPS

AMP. HRS. EXPENDED	TIME YEARS	CELL VOLTS	IMPEDANCE KOHMS
.00	.00	2.79	.40
.16	.56	2.71	3.02
.34	1.20	2.62	6.02
.51	1.83	2.53	9.02
.68	2.46	2.44	12.00
.85	3.10	2.35	1501
1.02	3.73	2.26	18.01
1.19	4.36	2.17	21.02
1.36	4.99	2.08	24.02
1.53	5.62	1.99	27.01
1.65	6.07	1.90	30.04
1.69	6.23	1.81	33.14
1.71	6.29	1.71	36.21
1.72	6.33	1.62	39.35
1.72	6.35	1.53	42.18

ภาคผนวก ง.

ราคาอุปกรณ์อีเล็คทรอนิคส์และวัสดุที่ใช้ประกอบในเครื่องควบคุมจังหวะการเต้นของหัวใจ แบบให้อัตราเต้นคงที่ต้นแบบ

๑)	ตัวความต้านทาน ๕%	๗ ตัว	ตัวละ	.๒๕ บาท	=	๑.๗๕	บาท
๒)	ตัวเก็บประจุไฟฟ้า ๑๐%	๒ ตัว	ตัวละ	๓.๕๐ บาท	=	๗	บาท
๓)	LM4250	๑ ตัว	ตัวละ	๑๔๐ บาท	=	๑๔๐	บาท
๔)	2N2907	๑ ตัว	ตัวละ	๒๐ บาท	=	๒๐	บาท
๕)	เซลเมอคิวรี่	๔ ก้อน	ก้อนละ	๗๐ บาท	=	๒๘๐	บาท
๖)	แผ่นวงจรพิมพ์หน้าเดียว	๑ แผ่น			=	๒๐	บาท
๗)	1N4148	๒ ตัว	ตัวละ	๑ บาท	=	๒	บาท
๘)	ขั้วต่อ แหวนยาง สกรู				=	๑๐๐	บาท
๙)	แท่นใส่เซลเมอคิวรี่				=	๕๐	บาท
๑๐)	กาว Silver epoxy				=	๕๐	บาท
๑๑)	กาว Epoxy แข็ง				=	๕๐	บาท
๑๒)	ยางซีลีโคน อีลาสโตเมอร์				=	๑๐๐	บาท
๑๓)	ค่าแรงงานประกอบ				=	๒๕๐	บาท
			รวมราคาทั้งสิ้น		=	๑๐๗๗.๗๕	บาท

ภาคผนวก ง. (ต่อ)

ราคาอุปกรณ์อีเล็คทรอนิคส์และวัสดุที่ใช้ประกอบในเครื่องควบคุมจังหวะการเต้นของหัวใจ แบบให้อัตราเต้นเมื่อต้องการต้นแบบ

๑)	ตัวความต้านทาน ๕%	๓๓ ตัว	ตัวละ	.๒๕ บาท	=	๘.๒๕	บาท
๒)	ตัวเก็บประจุ ๑๐%	๑๔ ตัว	ตัวละ	๓.๕๐ บาท	=	๔๙	บาท
๓)	คอยล์	๒ ตัว	ตัวละ	๒๐ บาท	=	๔๐	บาท
๔)	LM4250	๕ ตัว	ตัวละ	๑๔๐ บาท	=	๗๐๐	บาท
๕)	BC109	๑ ตัว	ตัวละ	๑๕ บาท	=	๑๕	บาท
๖)	2N2906	๑ ตัว	ตัวละ	๑๕ บาท	=	๑๕	บาท
๗)	เซลลิเธียม	๒ ก้อน	ก้อนละ	๓๐๐ บาท	=	๖๐๐	บาท
๘)	แผ่นวงจรพิมพ์หน้าเดียว	๑ แผ่น			=	๔๐	บาท
๙)	1N4148	๘ ตัว	ตัวละ	๑ บาท	=	๘	บาท
๑๐)	ซีเนอร์ไดโอด	๒ ตัว	ตัวละ	๔.๕๐ บาท	=	๙	บาท
๑๑)	หรีด สวิสช์	๑ ตัว	ตัวละ	๒๕ บาท	=	๒๕	บาท
๑๒)	ขั้วต่อ แหวนยาง สกรู				=	๑๐๐	บาท
๑๓)	แท่นใส่เซลลิเธียม				=	๕๐	บาท
๑๔)	กาว Epoxy แข็ง				=	๕๐	บาท
๑๕)	ยางซีลีโคน อีลาสโตเมอร์				=	๑๐๐	บาท
๑๖)	ค่าแรงงานประกอบ				=	๕๐๐	บาท
			รวมราคาทั้งสิ้น		=	๒๓๐๙.๒๕	บาท

ประวัติผู้เขียน

นายครรชิต โขมพัตร เกิดเมื่อวันที่ ๓๑ พฤษภาคม พ.ศ.๒๔๙๗ ณ จังหวัดเชียงใหม่ จบการศึกษาชั้นมัธยมศึกษาตอนปลายชั้นปีที่ ๕ จากโรงเรียน ภ.ป.ร.ราชวิทยาลัย สามพราน นครปฐม สำเร็จการศึกษาวิศวกรรมศาสตร์บัณฑิต สาขาวิศวกรรมไฟฟ้า (อีเล็คทรอนิคส์) จากคณะวิศวกรรมศาสตร์ สถาบันเทคโนโลยีพระจอมเกล้าวิทยาเขตธนบุรี เมื่อ พ.ศ.๒๕๑๙ เคยเป็นอาจารย์ผู้ช่วยที่คณะวิศวกรรมไฟฟ้า จุฬาลงกรณมหาวิทยาลัยเมื่อ พ.ศ.๒๕๒๐ ได้เสนอบทความทางวิชาการในการประชุมทางวิชาการวิศวกรรมไฟฟ้า ครั้งที่ ๔ ที่สถาบันเทคโนโลยีพระจอมเกล้า วิทยาเขตเจ้าคุณทหาร ลาดกระบัง เมื่อ พ.ศ.๒๕๒๔

ปัจจุบันรับราชการตำแหน่งวิศวกร ๔ ประจำหน่วยซ่อมสร้างเครื่องอีเล็คทรอนิคส์ ภาควิชาสรีรวิทยา คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล