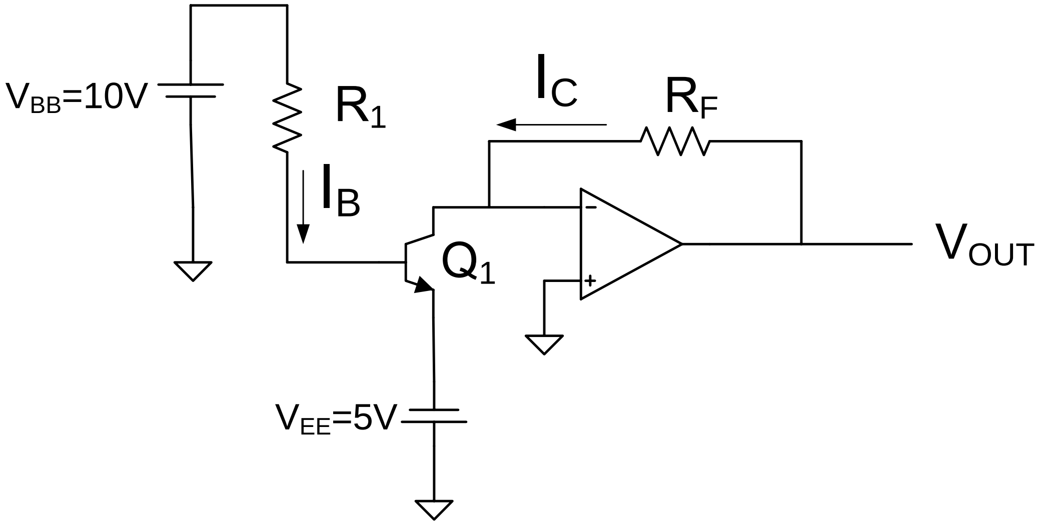
EE 330
Laboratory 10
Spring 2007
Bipolar Devices and Applications

Objective: The objective of this laboratory is to develop measurement methods for extracting device parameters of the Bipolar Junction Transistor (BJT), to extract device parameters of the BJT, and to investigate applications of discrete BJTs

Discussion: The measurement of parameters of devices is often facilitated with the use of simple op amp circuits. The circuit shown below is useful for measuring some parameters of the bipolar transistor. Although configured to facilitate measurement of parameters of npn transistors, some straightforward modifications can be used to make measurements of parameters of pnp transistors as well.



In this circuit the voltage V_{EE} is used to create a positive value for V_{CE}. The base current is given by

$$\mathbf{I_B \cong \frac{V_{BB} + V_{EE} - 0.6}{R_1}}$$

The collector current is proportional to I_C. The component values R_1 and R_F can be chosen to establish the desired base current level and the desired output voltage level respectively.

Datasheets for discrete transistors were very complete 25 years ago but with the limited use of discrete bipolar transistors today, details provided in the datasheets are often sketchy. In textbooks of the 60s and 70s, the small-signal parameters of the bipolar transistor were generally expressed in terms of h-parameters (hybrid parameters) rather than in terms of the conductance parameters that are more commonly used today. This is still reflected in the datasheets today. The relationship between the conductance parameters and the h-parameters are

$\beta = h_{fe}$
$g_\pi = h_{ie}$
$g_0 = h_{oe}$

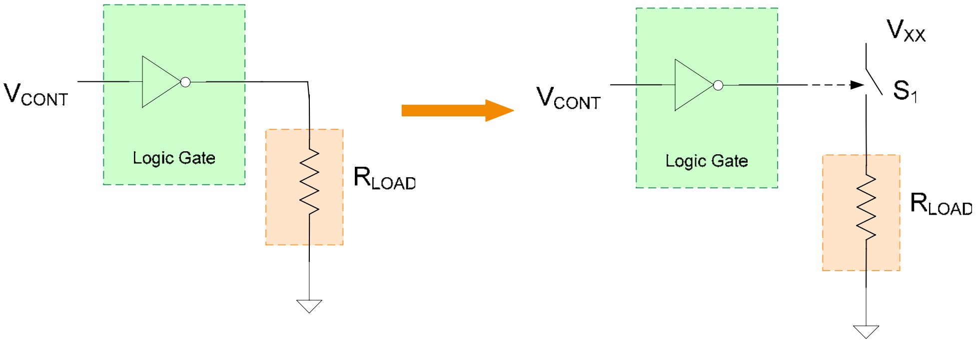
The key parameter g_m is generally not given directly in a datasheet but

$g_m = \beta g_\pi = h_{fe} h_{ie}$

There is one other small-signal parameter that is given in some of the datasheets, h_{re}. This parameter was not discussed in class and characterizes the small amount of feedback that exists I the bipolar transistor form the collector to the base. By assuming the BJT is unilateral, we have neglected this effect.

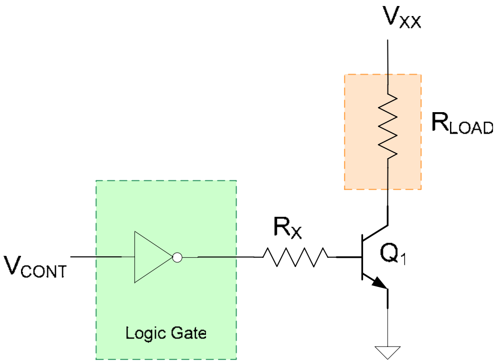
It was shown in the device models that the small signal parameters go, gm, and gπ are strongly operating point dependent. Unfortunately, most manufacturer's datasheets do not directly reflect this dependence and simply give the small-signal h-parameters at a single operating point. This limits the usefulness of the small-signal model parameters that are given.

One common task of an electronic circuit is to drive a rather large load (a load that requires a large current) based upon the Boolean status of a logic gate or based upon the output level of a comparator or an operational amplifier. Conceptually, a logic gate is depicted driving a load in the following figure.



Concept of driving load based upon condition of Boolean Variable

Although there are a small number of applications where this load can be driven directly as indicated, there are two major limitations that preclude this approach in most applications. The first is the voltage level that will be supplied to the load with this approach is the same as the high Boolean logic level which may not be the desired voltage that is to be applied to the load. The second is the current drive limitations of the Boolean gate or the comparator or op amp. The BJT is often used to serve as a switch when a large load needs to be driven and this is one of the most common applications of discrete BJTs today is as a switch. The use of a BJT as a switch is shown in the following figure.

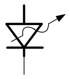


Use of a BJT as a switch

Because of the high current gain of the BJT, a small amount of dc current can be used to control a large amount of current in the collector. When used as a switch, the base current drive should be sufficiently strong so that the transistor will operate in cutoff when in the "OFF" state and in saturation when in the "ON" state. If the base current drive is not sufficiently strong to drive the transistor into the saturation region in the "ON" state, it will generally end up in the forward active region. Although the forward active region is widely used when building an amplifier, it is generally avoided when using the BJT as a switch. If insufficient base drive is not provided, two undesirable effects will be observed. First, the voltage at the load will not be at the desired level. And, second, since the CE voltage will not be small, excessive power dissipation will occur in the BJT and, depending upon the application, this could cause so much heating that the BJT will be destroyed.

Many applications of transistors and diodes are in the greater optoelectronics area whereby light energy is emitted from semiconductor devices or whereby incident light is detected by semiconductor devices. Light emitting diodes (LEDs) and laser diodes are widely used as sources of light and photodiodes, photo-transistors and Darlington photo-transistors are widely used as light detectors. Invariably the light sources will emit energy over a rather narrow spectral range and invariably photo-detectors will respond optimally over a limited spectrum and often little if at all at to other wavelengths of light. When transmitting light and detecting light, it is important that the spectral response of the transmitter and detectors be compatible. Optoelectronic devices operate over a wide frequency spectrum with some operating at speed up to 1GHz or higher thus making them useful for very high speed data communications.

The symbols for a LED, photo-diode, photo-transistor, and a photo-Darlington transistor are shown below. In the LED, the light emitted increases with the current flowing in the device. In a photo-diode, the reverse biased diode current increases with light intensity and in the photo-transistor and photo-Darlington structures, the collector current increases with light intensity. The photo-transistors can be used with our without a connection to the base lead and in some photo-transistors, the base lead is not even available. If a base current is input to a photo-transistor, the collector current is that sum of that due to photons entering the base region and that due to the base current.


LED

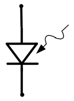


Photo Diode

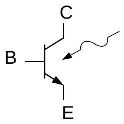


Photo Transistor

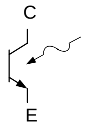


Photo Transistor w/o Base Terminal

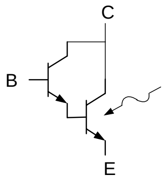


Photo Darlington

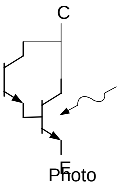
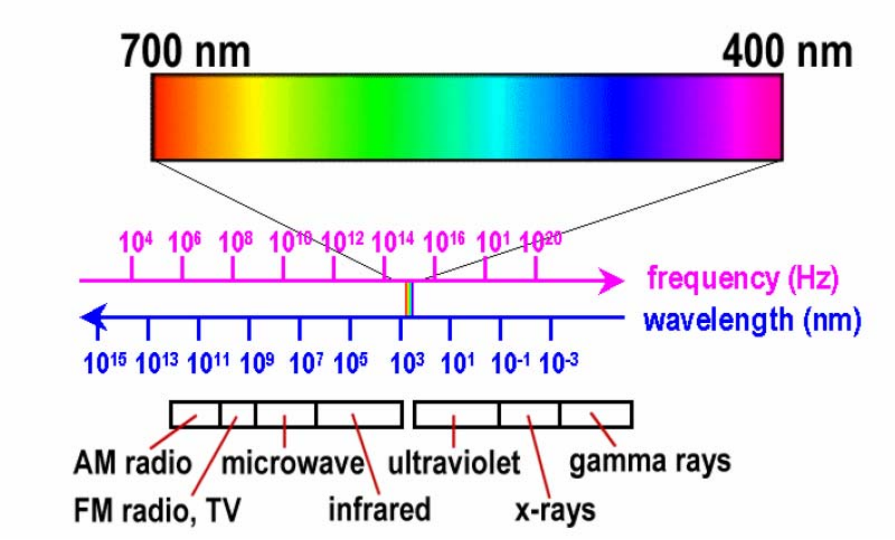


Photo Darlington w/o Base Terminal

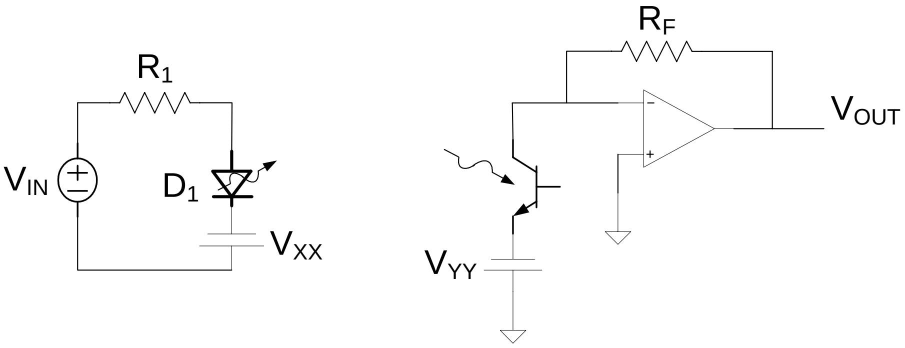
Many light sources operate in the visible region with wavelengths between 400nm and 700nm whereas others operate in the much broader infrared region which is not visible to the human eye. The spectral bands of light are shown in the figure below.



Spectral Bands of Light (obtained from WWB as site http://groups.csail.mit.edu/graphics/classes/6.837/F01/Lecture02/sp)

Some applications of optoelectronics include essentially all communitcations over fiber optic networks, the remote controllers used for TVs, CD players, etc, the detectors in scanners, and imagers that are used in digital cameras and cell phone.

One application that will be considered in this experiment is an optical wireless link. Such a link can be used to transmit an audio signal over an air channel. A block diagram of one possible implementation of an audio link is shown below.



Optical Link

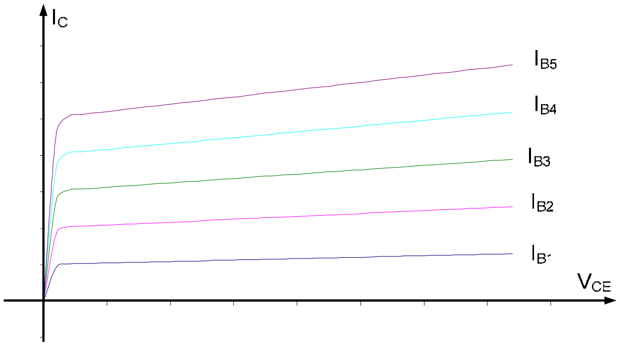
In these structures, a quiescent bias is maintained on both the photo-diode and the photo-transistor so that reasonably linear operation is obtained when a small-signal input is present. The amount of light emitted from the photo-diode and the amount of light received form the phototransistor is strongly a function of the orientation of the devices and the radiation pattern for the device.

Part 1 Measure the parameters I_S , β, and V_{AF} for the 2N4400 Bipolar Junction Transistor at a collector current of approximately 15mA and compare with the values in the data sheet. You can get reasonably good results by ignoring the effects of V_{AF} when making these measurements.
(Remember the model for the BJT in the Forward Active Region)☺

$$\left.\begin{aligned} I_C &= I_S e^{\frac{V_{BE}}{V_t}}\left(1+\frac{V_{CE}}{V_{AF}}\right) \\ I_B &= \frac{I_S}{\beta} e^{\frac{V_{BE}}{V_t}} \end{aligned}\right\} \qquad V_{BE} > 0.4V, \quad V_{BC} < 0$$

Part 2 Compare the small-signal model parameters g_m, g_o, and g_π with those given in one of the attached data sheets. Remember you have to relate them through the h-parameters and can only make a comparison at one operating point since the parameters are only given at one operating point.

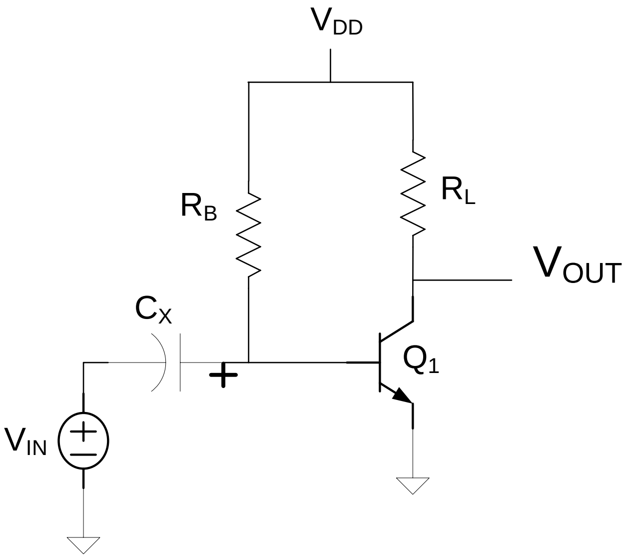
Part 3 Using Signal Express, plot the output characteristics for the 2N4400 BJT. Specifically, plot I_C versus V_{CE} for values of I_B between .4mA and 1.4mA with .2mA steps. Compare the output characteristics with those in the manufacturer's datasheet.



Functional Form of Output Charactristics

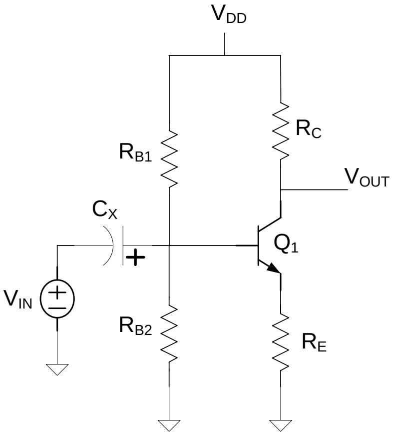
Part 4 A Common-Emitter amplifier is shown. Based upon the value of β that you measured, determine the value of R_B necessary to establish a quiescent collector current of 1mA. Set V_{DD}=12V and R_L to 5KΩ when doing this calculation. The coupling capacitor should be large, in the 1uF range or larger. Note the polarity of the electrolytic coupling capacitor is critical.

a) Build this circuit and verify that the desired collector current is obtained.
b) Compare the theoretical small-signal voltage gain with what is measured for this circuit.
c) What is the maximum output signal swing that you can obtain with this amplifier and how does that compare to the theoretical maximum signal swing?



Capacitor Coupled Common Emitter Amplifier

Part 5 Build and test a small-signal voltage amplifier using the BJT as the active device with a small signal gain of -10 that can drive a 5K load resistor. The CE amplifier with an emitter resistor is one circuit that works well for achieving this design requirement. The CE amplifier with an emitter resistor along with a popular biasing scheme is shown below. In this structure, the resistor R_C can be considered as the load.



Common Emitter Amplifier with Emitter Resistor

Make comments about the effort and performance of the bipolar amplifier you build compared to that required for using operational amplifiers as the active device to achieve the same gain when driving the same load.

Part 6 Using an inverter or multiple inverters in the 74HC04 array, design and test an incandescent lamp driver using a BJT as a switch that will turn on a 300mA, 6V incandescent lamp if the Boolean Input to the inverter is low and turn it off if the input to the inverter is high. Be sure to drive the BJT in saturation when turning on the lamp and into cutoff when turning off the BJT. Terminate all unused inputs in the 75HC04. Read the data sheet for the 74HC04 to be sure that you do not exceed the supply ratings of this device.

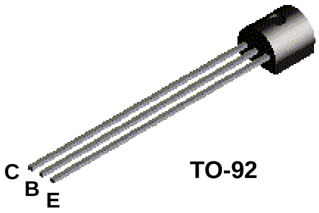
Part 7 Determine the range of wavelengths over which the L14C1 photo transistor will respond. Determine the output current of the L14C1 under ambient light and from a RED LED that is 6 inches away when the LED is biased with a current of about 10mA. It may be necessary to shield the LED from ambient light when measuring the output from an LED. A straw with electricians tape around it makes a pretty good shield.

Part 8 Design and test an optical detector that will turn an incandescent lamp on when a light beam is broken and off when the light bean is intact. The optical detector should operate over a minimum distance between the source and detector of 6 inches.

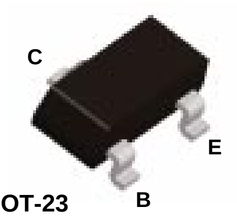
Part 9 Design and test a wireless optical link that will transmit an audio signal over at least 6 inches. The test should include applying the received signal to a speaker so that the audio signal can be verified.

FAIRCHILD
SEMICONDUCTOR TM

2N4400 MMBT4400



TO-92



SOT-23
Mark: 83

NPN General Purpose Amplifier

This device is designed for use as general purpose amplifiers and switches requiring collector currents to 500 mA.

Absolute Maximum Ratings*

TA = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	40	V
V_{CBO}	Collector-Base Voltage	60	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector Current - Continuous	600	mA
T_J, T_{stg}	Operating and Storage Junction Temperature Range	-55 to +150	°C

*These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:
1) These ratings are based on a maximum junction temperature of 150 degrees C.
2) These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics

TA = 25°C unless otherwise noted

Symbol	Characteristic	Max		Units
		2N4400	*MMBT4400	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	mW mW/°C
$R_{\theta JC}$	Thermal Resistance, Junction to Case	83.3		°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	°C/W

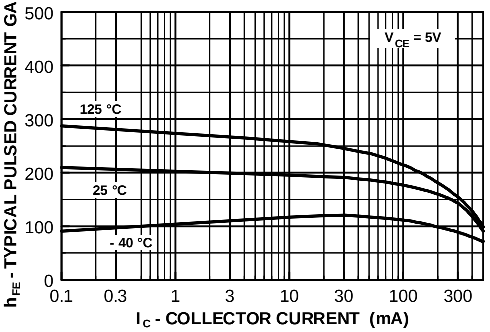
Electrical Characteristics

TA = 25°C unless otherwise noted

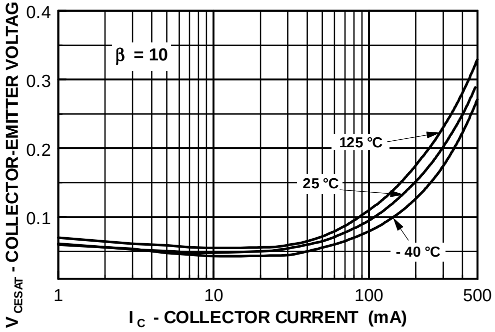
Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage*	I_C = 1.0 mA, I_B = 0	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	I_C = 100 μA, I_E = 0	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	I_E = 100 μA, I_C = 0	6.0		V
I_{CEX}	Collector Cutoff Current	V_{CE} = 35 V, V_{EB} = 0.4 V		0.1	μA
I_{BL}	Emitter Cutoff Current	V_{CE} = 35 V, V_{EB} = 0.4 V		0.1	μA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	V_{CE} = 1.0 V, I_C = 1.0 mA	20		
		V_{CE} = 1.0 V, I_C = 10 mA	40		
		V_{CE} = 1.0 V, I_C = 150 mA	50	150	
		V_{CE} = 2.0 V, I_C = 500 mA	20		
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	I_C = 150 mA, I_B =15 mA		0.40	V
		I_C = 500 mA, I_B = 50 mA		0.75	V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	I_C = 150 mA, I_B =15 mA	0.75	0.95	V
		I_C = 500 mA, I_B = 50 mA		1.2	V
SMALL SIGNAL CHARACTERISTICS					
C_{ob}	Output Capacitance	V_{CB} = 5.0 V, f = 140 kHz		6.5	pF
C_{ib}	Input Capacitance	V_{EB} = 0.5 V, f = 140 kHz		30	pF
h_{fe}	Small-Signal Current Gain	I_C = 20 mA, V_{CE} = 10 V, f = 100 MHz	2.0		
h_{fe}	Small-Signal Current Gain	V_{CE} = 10 V, I_C = 1.0 mA, f = 1.0 kHz	20	250	
h_{ie}	Input Impedance		0.5	7.5	KΩ
h_{re}	Voltage Feedback Ratio		0.1	8.0	x 10^{-4}
h_{oe}	Output Admittance		1.0	30	μmhos
SWITCHING CHARACTERISTICS					
t_d	Delay Time	V_{CC} = 30 V, I_C = 150 mA, I_{B1} = 15 mA ,V_{EB} = 2 V		15	ns
t_r	Rise Time			20	ns
t_s	Storage Time	V_{CC} = 30 V, I_C = 150 mA I_{B1} = I_{B2} = 15 mA		225	ns
t_f	Fall Time			30	ns

*Pulse Test: Pulse Width £ 300 ms, Duty Cycle £ 2.0%

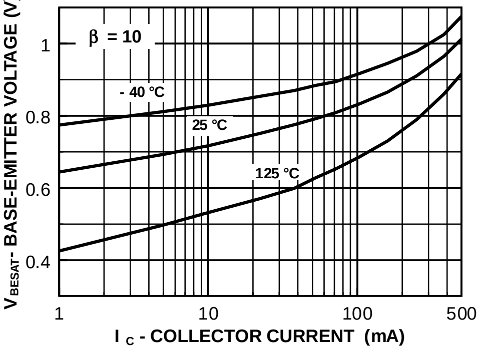
Typical Characteristics



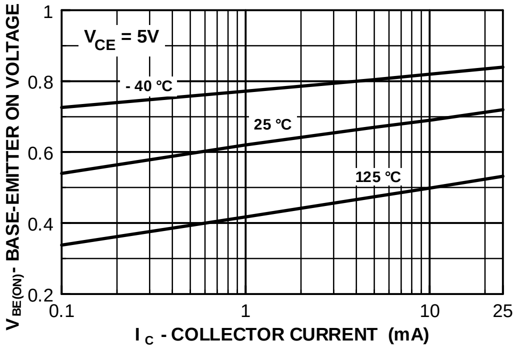
Typical Pulsed Current Gain vs Collector Current



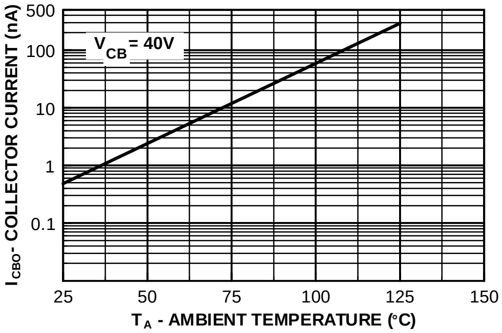
Collector-Emitter Saturation Voltage vs Collector Current



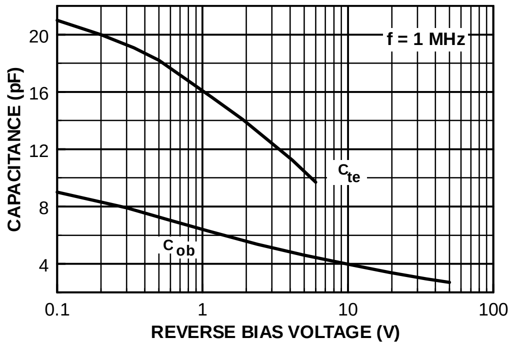
Base-Emitter Saturation Voltage vs Collector Current



Base-Emitter ON Voltage vs Collector Current

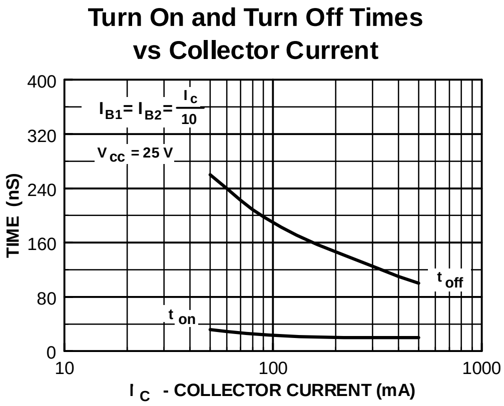


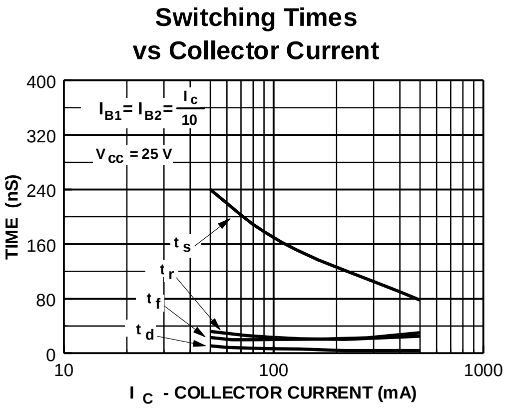
Collector-Cutoff Current vs Ambient Temperature

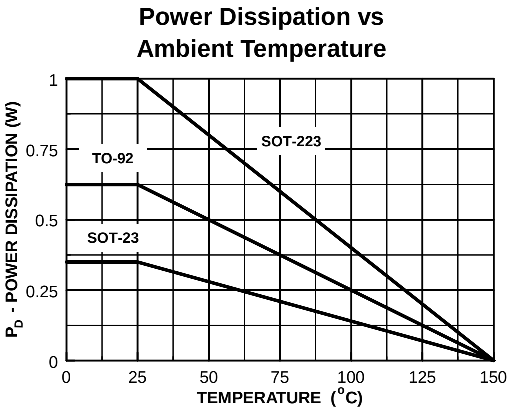


Emitter Transition and Output Capacitance vs Reverse Bias Voltage

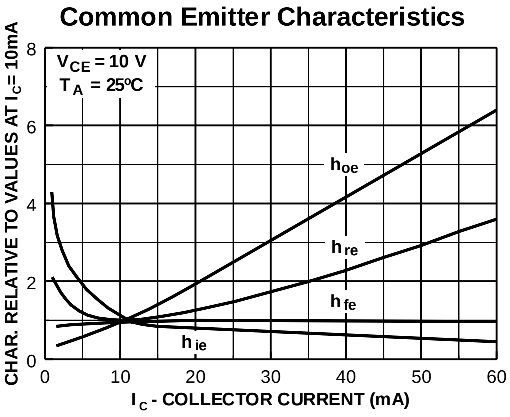
Typical Characteristics (continued)

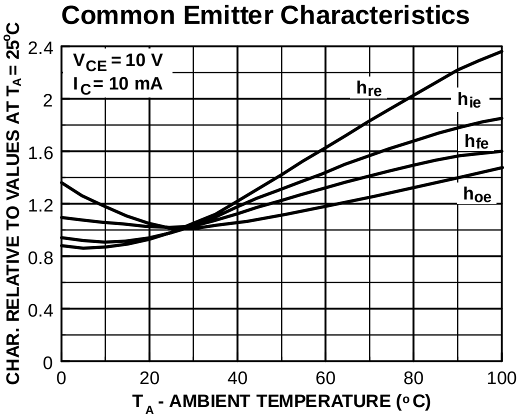


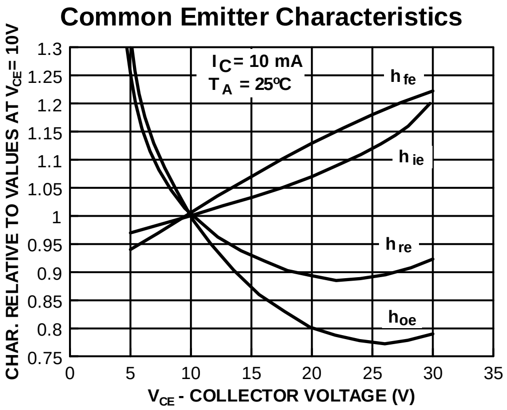




Typical Common Emitter Characteristics (f = 1.0kHz)







Test Circuits

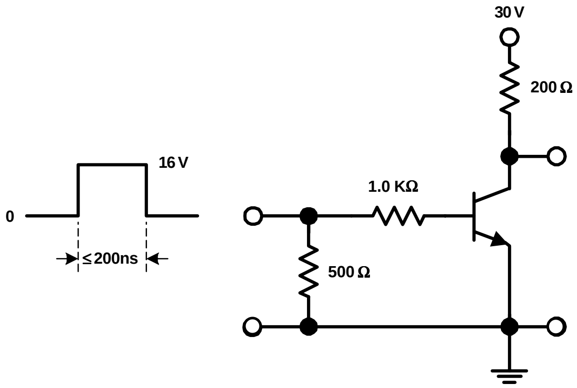


FIGURE 1: Saturated Turn-On Switching Timer

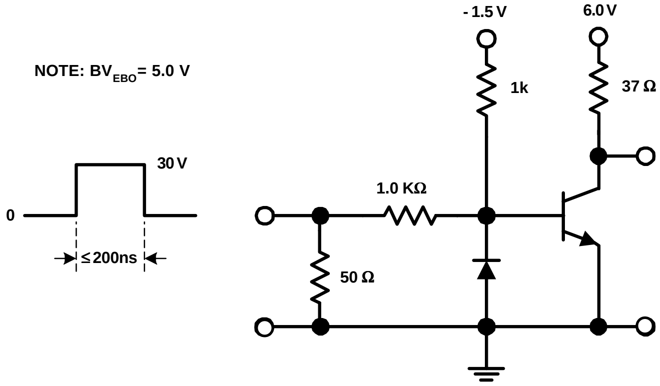


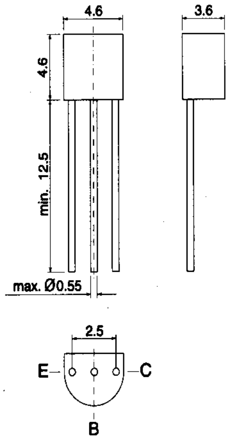
FIGURE 2: Saturated Turn-Off Switching Time

HN / 2N 4400/4401
NPN EPITAXIAL SILICON TRANSISTOR

General purpose transistor

Collector Emitter Voltage: V_{CEO} = 40V
Collector Dissipation: P_C (max) = 625mW

On special request, these transistors can be manufactured in different pin configurations. Please refer to the "TO-92 TRANSISTOR PACKAGE OUTLINE" on page 80 for the available pin options.



TO-92 Plastic Package
Weight approx. 0.18 g
Dimensions in mm

Absolute Maximum Ratings (T_a = 25°C)

Characteristic	Symbol	Value	Unit
Collector-Base Voltage	V_{CBO}	60	V
Collector-Emitter Voltage	V_{CEO}	40	V
Emitter-Base Voltage	V_{EBO}	6	V
Collector Current	I_C	600	mA
Collector Dissipation	P_C	625	mW
Junction Temperature	T_j	150	°C
Storage Temperature Range	T_S	-55 to + 150	°C

G S P FORM A AVAILABLE

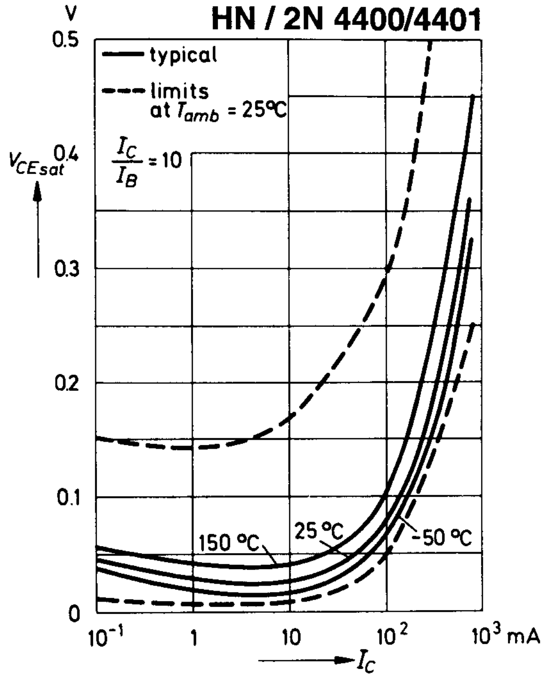
HN / 2N 4400/4401
NPN EPITAXIAL SILICON TRANSISTOR

Characteristics at T_{amb} =25 °C

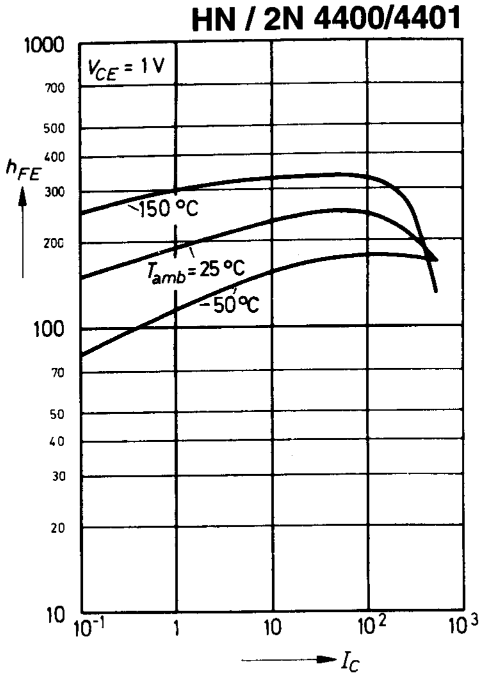
	Symbol	Min.	Typ.	Max.	Unit
DC Current Gain.					
at V_{CE} = 1V, I_C = 0.1 mA					
HN / 2N 4401	h_{FE}	20	-		-
at V_{CE} = 1V, I_C = 1 mA					
HN / 2N 4400	h_{FE}	20	-		-
HN / 2N 4401	h_{FE}	40	-		-
at V_{CE} = 1V, I_C = 10 mA					
HN / 2N 4400	h_{FE}	40	-		-
HN / 2N 4401	h_{FE}	80	-		-
at V_{CE} = 1V, I_C = 150 mA					
HN / 2N 4400	h_{FE}	50	-	150	-
HN / 2N 4401	h_{FE}	100	-	300	-
at V_{CE} = 2V, I_C = 500 mA					
HN / 2N 4400	h_{FE}	20	-		-
HN / 2N 4401	h_{FE}	40	-		-
Collector Cutoff Current at V_{CE} = 35 V, at V_{EB} = 0.4V	I_{CEX}	-	-	100	nA
Collector Emitter Breakdown Voltage at I_C = 1 mA, I_B = 0	$V_{(BR)CEO}$	40	-	-	V
Collector Base Breakdown Voltage at I_C = 100 µA, I_E = 0	$V_{(BR)CBO}$	60	-	-	V
Collector Emitter Saturation Voltage					
at I_C = 150 mA, I_B = 15 mA	V_{CEsat}	-	-	0.4	V
at I_C = 50 mA, I_B = 50 mA			-	0.75	V
Collector Saturation Voltage					
at I_C = 150 mA, I_B= 15 mA	V_{BEsat}	0.75	-	0.95	V
at I_C = 500 mA, I_B = 50 mA		-		1.2	
Emitter Base Breakdown Voltage at I_E = 100 µA, I_C = 0	$V_{BR(EBO)}$	6	-	-	V
Gain Bandwidth Product at V_{CE} = 10V, I_C= 20 mA, f = 100MHz					
HN / 2N 4400		200	-	-	MHz
HN / 2N 4401	f_T	250	-	-	MHz
Collector Base Capacitance at V_{CB} = 5 V, f = 100MHz, I_E = 0	$C_{(CBO)}$	-	-	6.5	pF
Turn On Time at V_{CC} = 30 V, V_{BE} = 2V, I_C = 150 mA, I_B1 = 15 mA	t_{on}	-	-	35	ns
Turn Off Time at V_{CC} = 30 V, I_C = 150 mA, I_B1 = I_B2 = 15mA	t_{off}	-	-	255	ns
[1] Valid provided that leads are kept at ambient temperature at a distance of 2 mm from case.					

G S P FORM A AVAILABLE

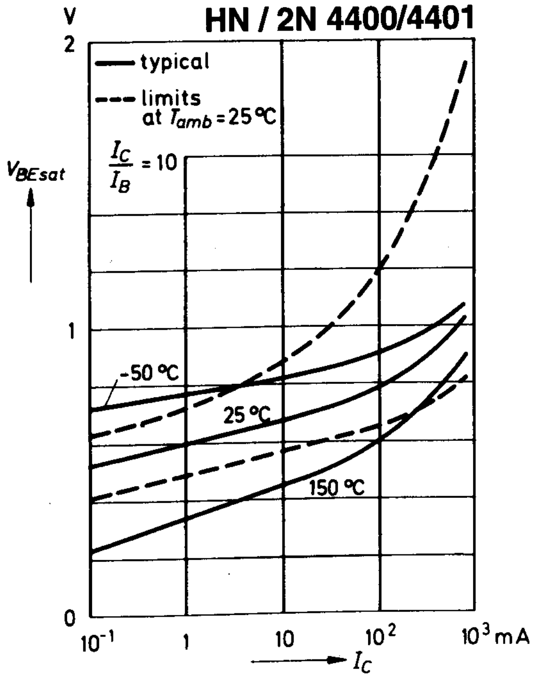
Collector saturation voltage versus collector current



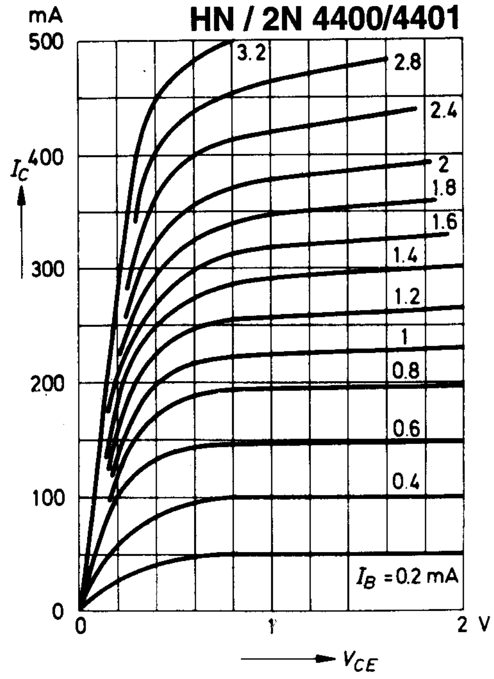
DC current gain versus collector current



Base saturation voltage versus collector current



Common emitter collector characteristics



FAIRCHILD
SEMICONDUCTOR™

September 1983
Revised February 1999

MM74HC04
Hex Inverter

General Description

The MM74HC04 inverters utilize advanced silicon-gate CMOS technology to achieve operating speeds similar to LS-TTL gates with the low power consumption of standard CMOS integrated circuits.

The MM74HC04 is a triple buffered inverter. It has high noise immunity and the ability to drive 10 LS-TTL loads. The 74HC logic family is functionally as well as pin-out compatible with the standard 74LS logic family. All inputs are protected from damage due to static discharge by internal diode clamps to V_{CC} and ground.

Features

- Typical propagation delay: 8 ns
- Fan out of 10 LS-TTL loads
- Quiescent power consumption: 10 μW maximum at room temperature
- Low input current: 1 μA maximum

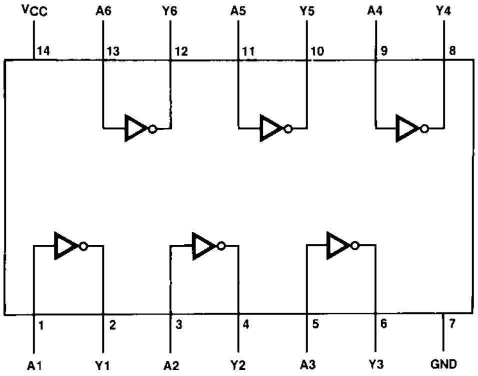
Ordering Code:

Order Number	Package Number	Package Description
MM74HC04M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150” Narrow
MM74HC04SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.5mm Wide
MM74HC04MTC	MTC14	14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
MM74HC04N	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300” Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter “X” to the ordering code.

Connection Diagram

Pin Assignments for DIP, SOIC, SOP and TSSOP



Top View

Logic Diagram

1 of 6 Inverters

Absolute Maximum Ratings(Note 1)

(Note 2)

Supply Voltage (V_{CC})	−0.5 to +7.0V
DC Input Voltage (V_{IN})	−1.5 to V_{CC} +1.5V
DC Output Voltage (V_{OUT})	−0.5 to V_{CC} +0.5V
Clamp Diode Current (I_{IK}, I_{OK})	±20 mA
DC Output Current, per pin (I_{OUT})	±25 mA
DC V_{CC} or GND Current, per pin (I_{CC})	±50 mA
Storage Temperature Range (T_{STG})	−65°C to +150°C
Power Dissipation (P_D)	
(Note 3)	600 mW
S.O. Package only	500 mW
Lead Temperature (T_L)	
(Soldering 10 seconds)	260°C

Recommended Operating Conditions

	Min	Max	Units
Supply Voltage (V_{CC})	2	6	V
DC Input or Output Voltage (V_{IN}, V_{OUT})	0	V_{CC}	V
Operating Temperature Range (T_A)	−40	+85	°C
Input Rise or Fall Times			
(t_r, t_f) $V_{CC} = 2.0V$		1000	ns
$V_{CC} = 4.5V$		500	ns
$V_{CC} = 6.0V$		400	ns

Note 1: Absolute Maximum Ratings are those values beyond which damage to the device may occur.

Note 2: Unless otherwise specified all voltages are referenced to ground.

Note 3: Power Dissipation temperature derating — plastic "N" package: −12 mW/°C from 65°C to 85°C.

DC Electrical Characteristics (Note 4)

Symbol	Parameter	Conditions	V_{CC}	$T_A = 25°C$		$T_A = -40$ to 85°C	$T_A = -55$ to 125°C	Units
				Typ	Guaranteed Limits			
V_{IH}	Minimum HIGH Level Input Voltage		2.0V		1.5	1.5	1.5	V
			4.5V		3.15	3.15	3.15	V
			6.0V		4.2	4.2	4.2	V
V_{IL}	Maximum LOW Level Input Voltage		2.0V		0.5	0.5	0.5	V
			4.5V		1.35	1.35	1.35	V
			6.0V		1.8	1.8	1.8	V
V_{OH}	Minimum HIGH Level Output Voltage	$V_{IN} = V_{IL}$ $\|I_{OUT}\| \le 20$ µA	2.0V	2.0	1.9	1.9	1.9	V
			4.5V	4.5	4.4	4.4	4.4	V
			6.0V	6.0	5.9	5.9	5.9	V
		$V_{IN} = V_{IL}$ $\|I_{OUT}\| \le 4.0$ mA	4.5V	4.2	3.98	3.84	3.7	V
		$\|I_{OUT}\| \le 5.2$ mA	6.0V	5.7	5.48	5.34	5.2	V
V_{OL}	Maximum LOW Level Output Voltage	$V_{IN} = V_{IH}$ $\|I_{OUT}\| \le 20$ µA	2.0V	0	0.1	0.1	0.1	V
			4.5V	0	0.1	0.1	0.1	V
			6.0V	0	0.1	0.1	0.1	V
		$V_{IN} = V_{IH}$ $\|I_{OUT}\| \le 4.0$ mA	4.5V	0.2	0.26	0.33	0.4	V
		$\|I_{OUT}\| \le 5.2$ mA	6.0V	0.2	0.26	0.33	0.4	V
I_{IN}	Maximum Input Current	$V_{IN} = V_{CC}$ or GND	6.0V		±0.1	±1.0	±1.0	µA
I_{CC}	Maximum Quiescent Supply Current	$V_{IN} = V_{CC}$ or GND $I_{OUT} = 0$ µA	6.0V		2.0	20	40	µA

Note 4: For a power supply of 5V ±10% the worst case output voltages (V_{OH}, and V_{OL}) occur for HC at 4.5V. Thus the 4.5V values should be used when designing with this supply. Worst case V_{IH} and V_{IL} occur at V_{CC}=5.5V and 4.5V respectively. (The V_{IH} value at 5.5V is 3.85V.) The worst case leakage current (I_{IN}, I_{CC}, and I_{OZ}) occur for CMOS at the higher voltage and so the 6.0V values should be used.

AC Electrical Characteristics

$V_{CC} = 5V$, $T_A = 25°C$, $C_L = 15$ pF, $t_r = t_f = 6$ ns

Symbol	Parameter	Conditions	Typ	Guaranteed Limit	Units
t_{PHL}, t_{PLH}	Maximum Propagation Delay		8	15	ns

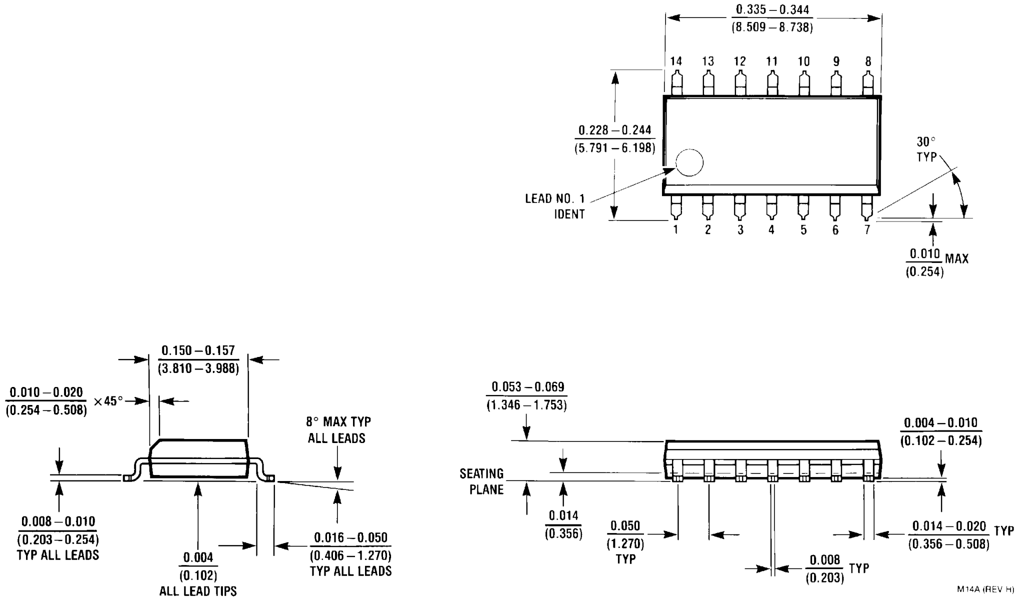
AC Electrical Characteristics

$V_{CC} = 2.0V$ to $6.0V$, $C_L = 50$ pF, $t_r = t_f = 6$ ns (unless otherwise specified)

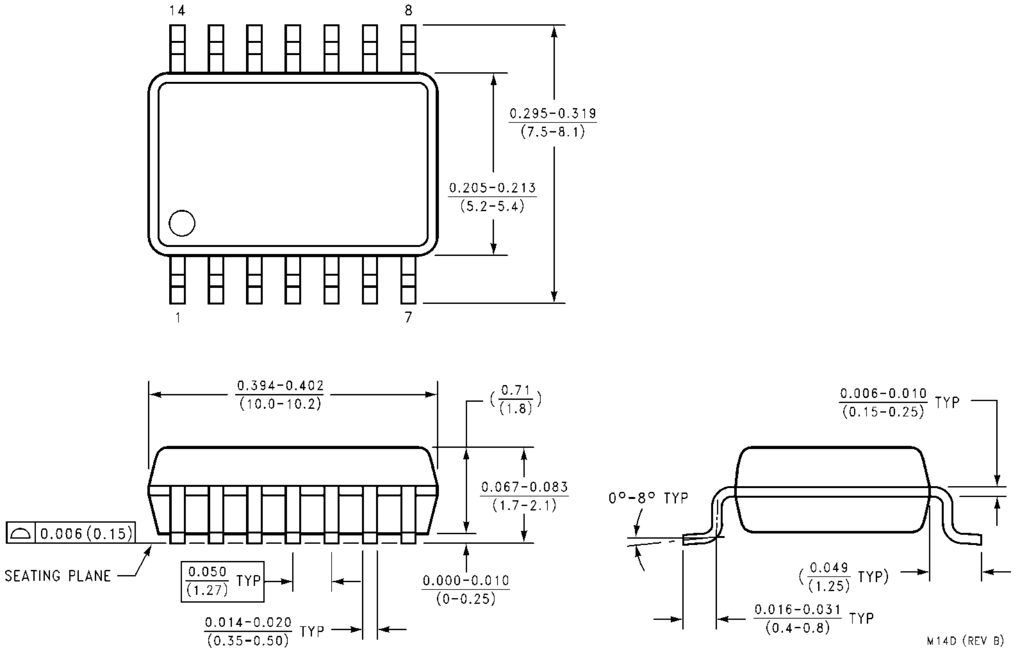
Symbol	Parameter	Conditions	V_{CC}	$T_A = 25°C$		$T_A = -40$ to $85°C$	$T_A = -55$ to $125°C$	Units
				Typ	Guaranteed Limits			
t_{PHL}, t_{PLH}	Maximum Propagation Delay		2.0V	55	95	120	145	ns
			4.5V	11	19	24	29	ns
			6.0V	9	16	20	24	ns
t_{TLH}, t_{THL}	Maximum Output Rise and Fall Time		2.0V	30	75	95	110	ns
			4.5V	8	15	19	22	ns
			6.0V	7	13	16	19	ns
C_{PD}	Power Dissipation Capacitance (Note 5)	(per gate)		20				pF
C_{IN}	Maximum Input Capacitance			5	10	10	10	pF

Note 5: C_{PD} determines the no load dynamic power consumption, $P_D = C_{PD} V_{CC}^2 f + I_{CC} V_{CC}$, and the no load dynamic current consumption, $I_S = C_{PD} V_{CC} f + I_{CC}$.

Physical Dimensions inches (millimeters) unless otherwise noted



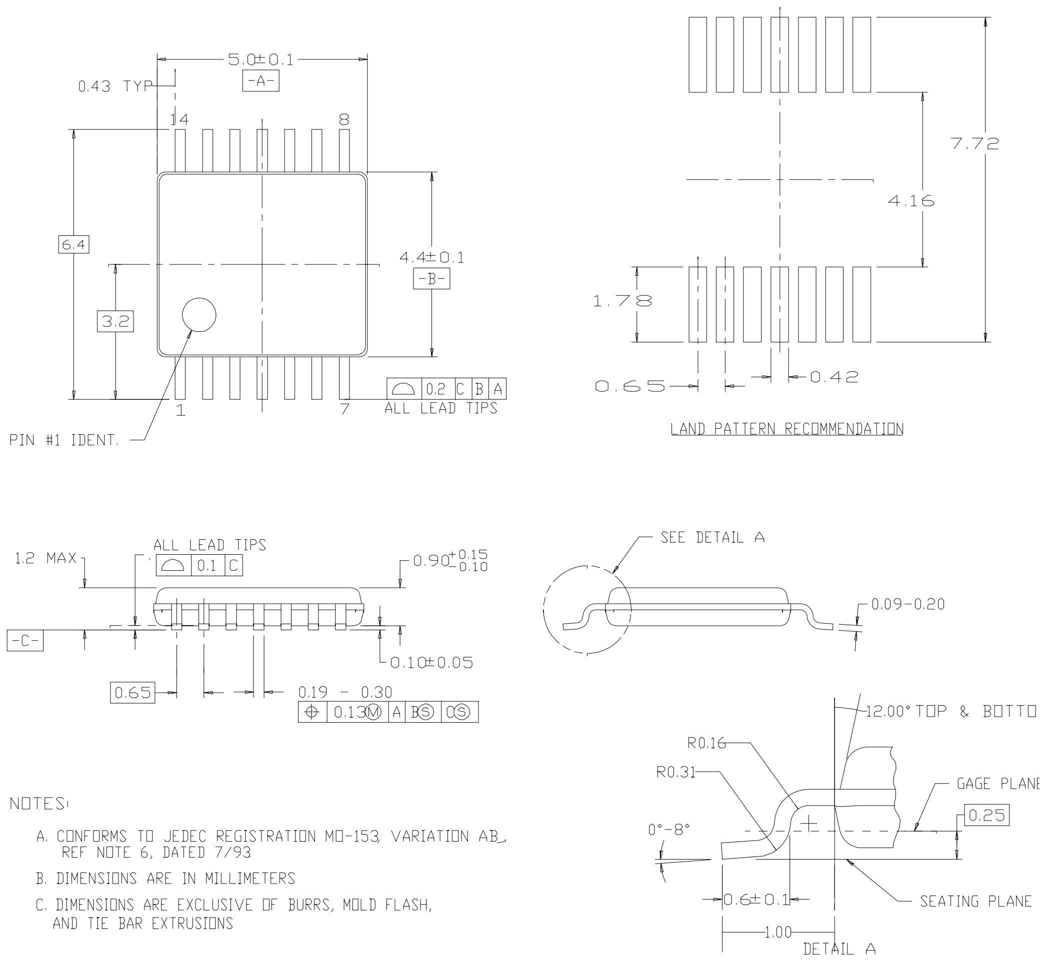
14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150” Narrow Package Number M14A



14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide Package Number M14D

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

14LD, TSSOP, JEDEC MO-153, 4.4MM WIDE



NOTES:

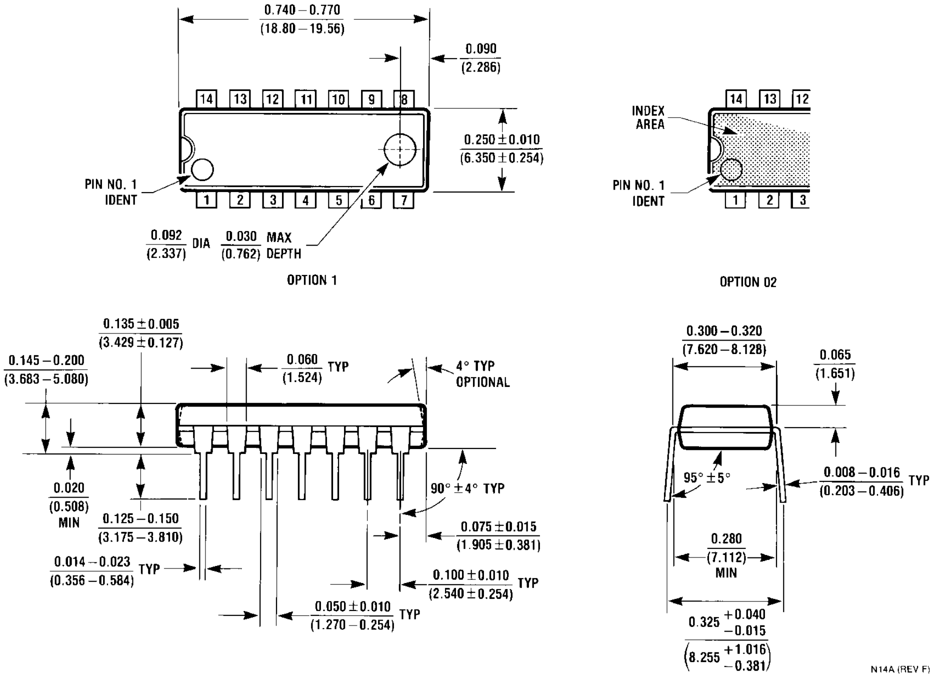
A. CONFORMS TO JEDEC REGISTRATION MO-153, VARIATION AB, REF NOTE 6, DATED 7/93

B. DIMENSIONS ARE IN MILLIMETERS

C. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS

14-Lead Thin Shrink Small Outline Package (TSSOP), JEDEC MO-153, 4.4mm Wide
Package Number MTC14

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



14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
Package Number N14A

LIFE SUPPORT POLICY

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2. A critical component in any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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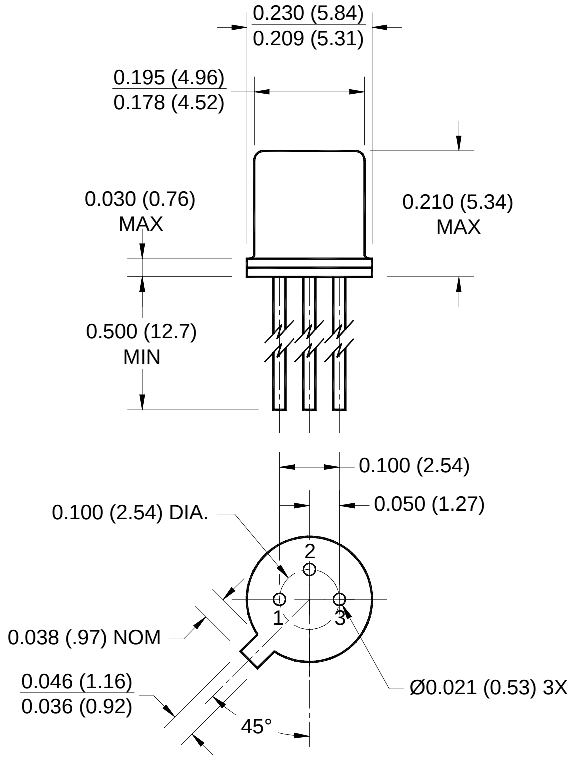
HERMETIC SILICON PHOTOTRANSISTOR

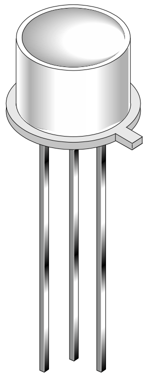
L14C1 L14C2

PACKAGE DIMENSIONS

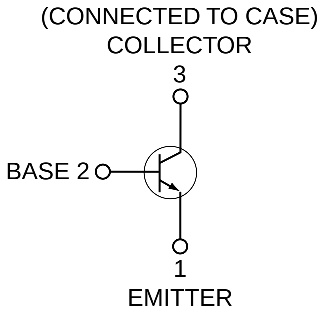


NOTES:

1. Dimensions for all drawings are in inches (mm).
2. Tolerance of ± .010 (.25) on all non-nominal dimensions unless otherwise specified.



SCHEMATIC



DESCRIPTION

The L14C1/L14C2 are silicon phototransistors mounted in a wide angle, TO-18 package.

FEATURES

- Hermetically sealed package
- Wide reception angle

ABSOLUTE MAXIMUM RATINGS (T_A = 25°C unless otherwise specified)

Parameter	Symbol	Rating	Unit
Operating Temperature	T_{OPR}	-65 to +125	°C
Storage Temperature	T_{STG}	-65 to +150	°C
Soldering Temperature (Iron)$^{(3,4,5 \text{ and } 6)}$	T_{SOL-I}	240 for 5 sec	°C
Soldering Temperature (Flow)$^{(3,4 \text{ and } 6)}$	T_{SOL-F}	260 for 10 sec	°C
Collector to Emitter Breakdown Voltage	V_{CEO}	50	V
Collector to Base Breakdown Voltage	V_{CBO}	50	V
Emitter to Base Breakdwon Voltage	V_{EBO}	7	V
Power Dissipation (T_A = 25°C)$^{(1)}$	P_D	300	mW
Power Dissipation (T_C = 25°C)$^{(2)}$	P_D	600	mW

NOTE:

1. Derate power dissipation linearly 3.00 mW/°C above 25°C ambient.
2. Derate power dissipation linearly 6.00 mW/°C above 25°C case.
3. RMA flux is recommended.
4. Methanol or isopropyl alcohols are recommended as cleaning agents.
5. Soldering iron tip 1/16” (1.6mm) minimum from housing.
6. As long as leads are not under any stress or spring tension.
7. Light source is a GaAs LED emitting light at a peak wavelength of 940 nm.
8. Figure 1 and figure 2 use light source of tungsten lamp at 2870°K color temperature. A GaAs source of 3.0 mW/cm^2 is approximately equivalent to a tungsten source, at 2870°K, of 10 mW/cm^2.

ELECTRICAL / OPTICAL CHARACTERISTICS (T_A =25°C) (All measurements made under pulse conditions)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
Collector-Emitter Breakdown	I_C = 10 mA, Ee = 0	BV_{CEO}	50		—	V
Emitter-Base Breakdown	I_E = 100 µA, Ee = 0	BV_{EBO}	7.0		—	V
Collector-Base Breakdown	I_C = 100 µA, Ee = 0	BV_{CBO}	50		—	V
Collector-Emitter Leakage	V_{CE} = 20 V, Ee = 0	I_{CEO}	—		100	nA
Reception Angle at 1/2 Sensitivity		θ		±40		Degrees
On-State Collector Current L14C1	Ee = 0.5 mW/cm^2, V_{CE} = 5 V$^{(7,8)}$	$I_{C(ON)}$	.16		—	mA
On-State Collector Current L14C2	Ee = 0.5 mW/cm^2, V_{CE} = 5 V$^{(7,8)}$	$I_{C(ON)}$	.08		—	mA
On-State Collector Current L14C2	Ee = 1.0 mW/cm^2, V_{CE} = 5 V$^{(7,8)}$	$I_{C(ON)}$	.16		—	mA
Turn-On Time	I_C = 2 mA, V_{CC} = 10 V, R_L =100 Ω	t_{on}		5		µs
Turn-Off Time	I_C = 2 mA, V_{CC} = 10 V, R_L =100 Ω	t_{off}		5		µs
Saturation Voltage	I_C = 0.40 mA, Ee = 6.0 mW/cm$^{2(7,8)}$	$V_{CE(SAT)}$	—		0.40	V

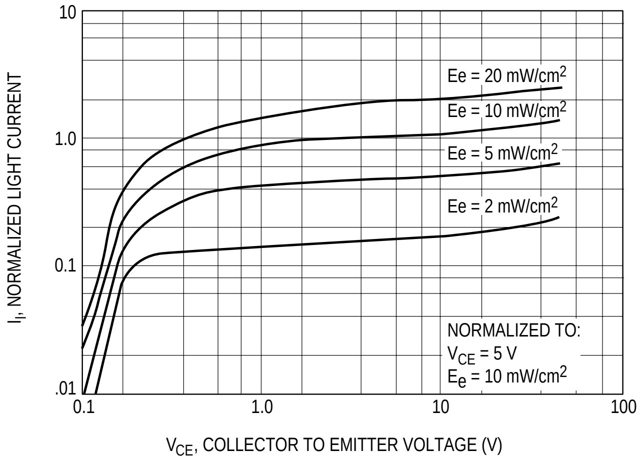


Figure 1. Light Current vs. Collector to Emitter Voltage

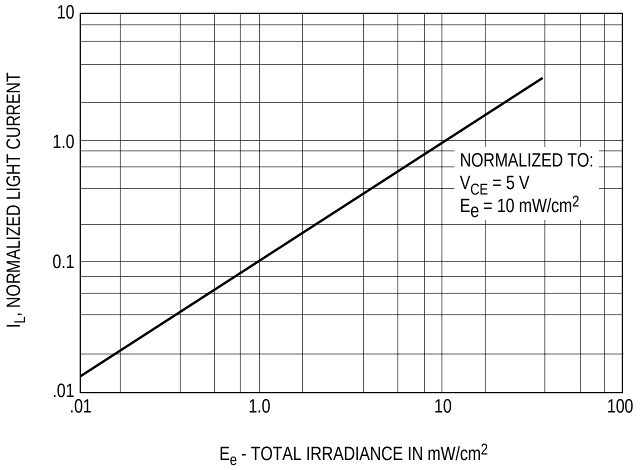


Figure 2. Normalized Light Current vs. Radiation

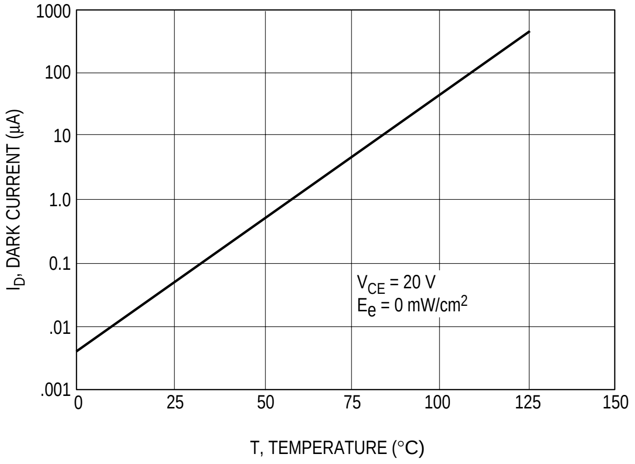


Figure 3. Dark Current vs. Temperature

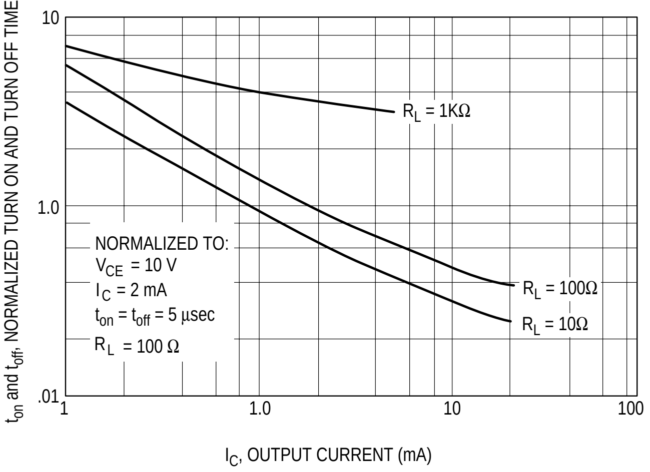


Figure 4. Switching Speed vs. Output Current

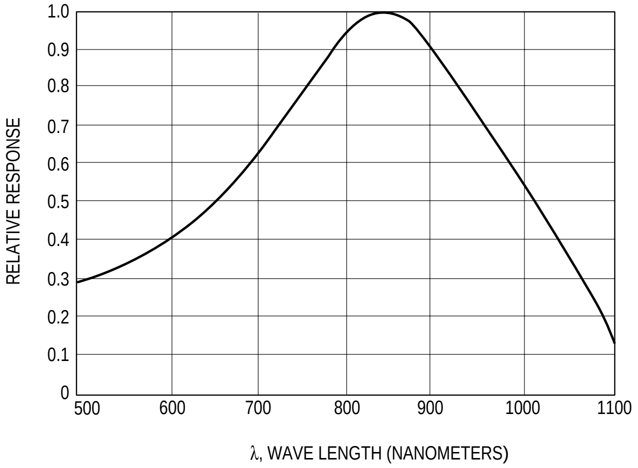


Figure 5. Spectral Response

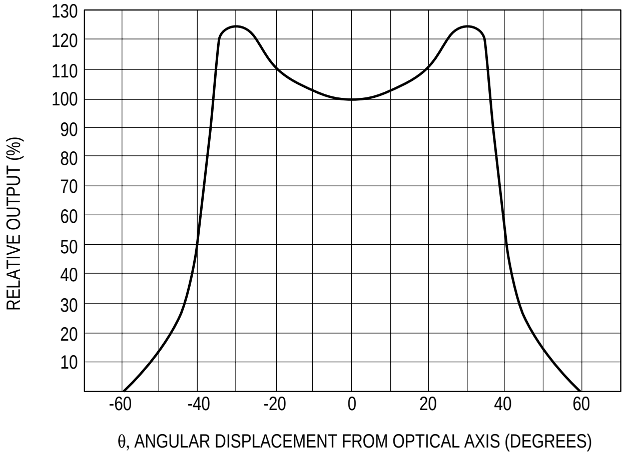


Figure 6. Angular Response Curve

HERMETIC SILICON PHOTOTRANSISTOR

L14C1 L14C2