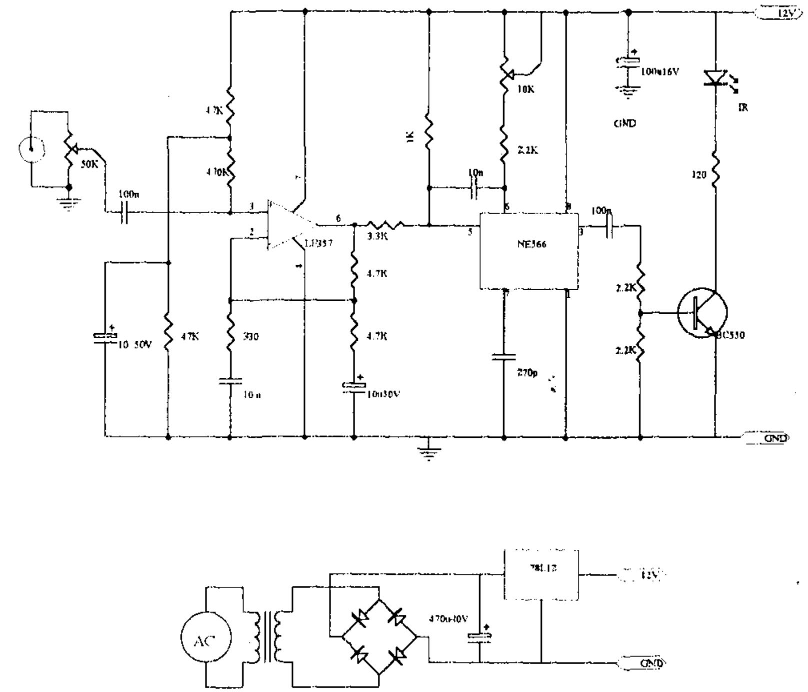
LAMPIRAN A



Title	TRANSMITTER INFRA RED & POWER SUPPLY	
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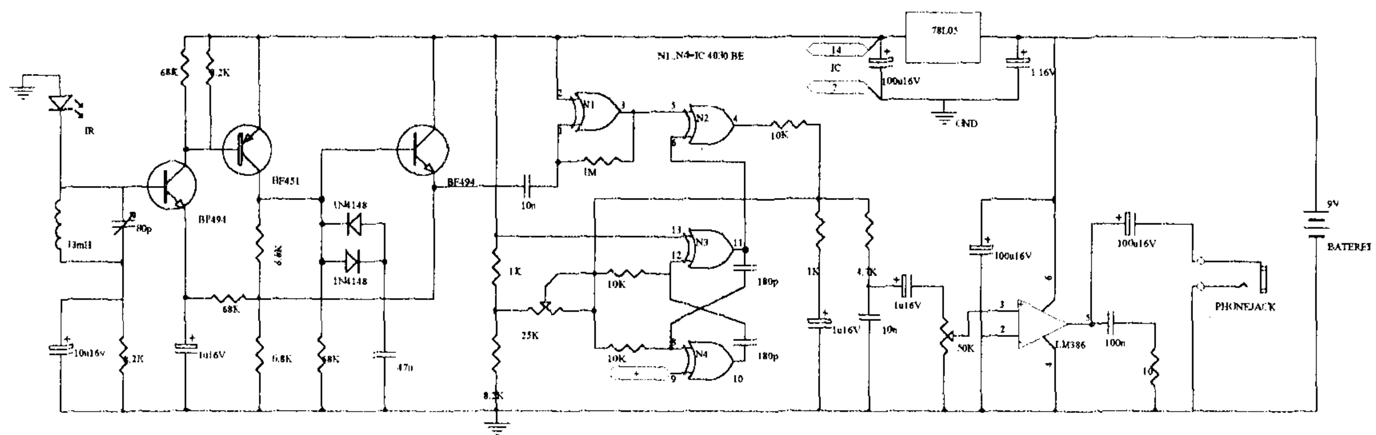
Date:	8-Oct-2001	Sheet of
File:	D:\SCHEMAT\AMING.SCH	Drawn By:



Title: RECEIVER INFRA RED		
Size: B	Number: HAMINGGUS 5103094037	Revision
Date: 8-Oct-2001		Sheet of
File: D:\SCHEMAT\AMINGZ.SCH		Drawn By:

LAMPIRAN B

Industrial/Automotive/Functional Blocks

LM566/LM566C voltage controlled oscillator

general description

The LM566/LM566C are general purpose voltage controlled oscillators which may be used to generate square and triangular waves, the frequency of which is a very linear function of a control voltage. The frequency is also a function of an external resistor and capacitor.

The LM566 is specified for operation over the −55°C to +125°C military temperature range. The LM566C is specified for operation over the 0°C to +70°C temperature range.

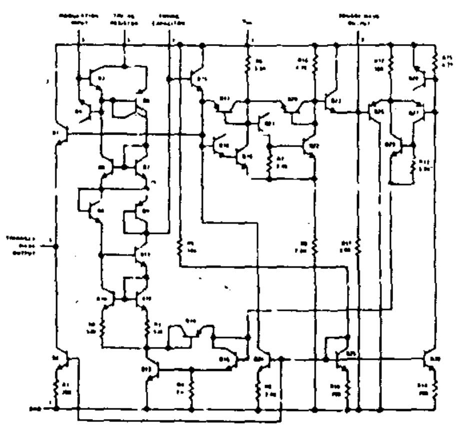
features

- Wide supply voltage range: 10 to 24 volts
- Very linear modulation characteristics
- High temperature stability
- Excellent supply voltage rejection
- 10 to 1 frequency range with fixed capacitor
- Frequency programmable by means of current, voltage, resistor or capacitor.

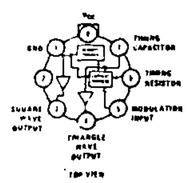
applications

- FM modulation
- Signal generation
- Function generation
- Frequency shift keying
- Tone generation

schematic and connection diagrams

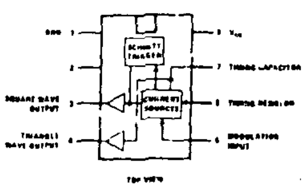


Metal Can Package



Order Number LM566H or LM566CH
See Package 11

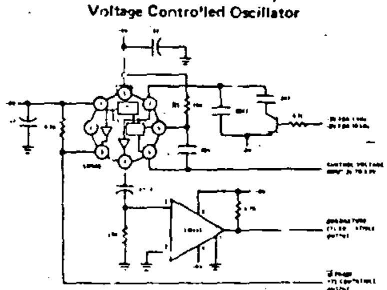
Dual-In-Line Package



Order Number LM566CN
See Package 20

typical application

1 kHz and 10 kHz TTL Compatible Voltage Controlled Oscillator



applications information

The LM566 may be operated from either a single supply as shown in this test circuit, or from a split (±) power supply. When operating from a split supply, the square wave output (pin 4) is TTL compatible (2 mA current sink) with the addition of a 4.7 kΩ resistor from pin 3 to ground.

A .001 μF capacitor is connected between pins 5 and 6 to prevent parasitic oscillations that may occur during VCO switching.

$$f_o = \frac{2(V^+ - V_5)}{R_1 C_1 V^+}$$

where

$2K < R_1 < 20K$

and V_5 is voltage between pin 5 and pin 1

applications information

In designing with phase locked loops such as the LM565, the important parameters of interest are:

FREE RUNNING FREQUENCY

$$f_o \cong \frac{1}{3.7\,R_0C_0}$$

LOOP GAIN: relates the amount of phase change between the input signal and the VCO signal for a shift in input signal frequency (assuming the loop remains in lock). In servo theory, this is called the "velocity error coefficient".

$$\text{Loop gain} = K_oK_D \left(\frac{1}{\text{sec}}\right)$$

$$K_c = \text{oscillator sensitivity} \left(\frac{\text{radians/sec}}{\text{volt}}\right)$$

$$K_D = \text{phase detector sensitivity} \left(\frac{\text{volts}}{\text{radian}}\right)$$

The loop gain of the LM565 is dependent on supply voltage, and may be found from:

$$K_oK_D = \frac{33.6\,f_o}{V_c}$$

f_o = VCO frequency in Hz

V_c = total supply voltage to circuit.

Loop gain may be reduced by connecting a resistor between pins 6 and 7; this reduces the load impedance on the output amplifier and hence the loop gain.

HOLD IN RANGE: the range of frequencies that the loop will remain in lock after initially being locked.

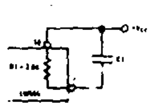
$$f_H = \pm\,\frac{8\,f_o}{V_c}$$

f_o = free running frequency of VCO

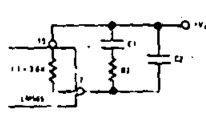
V_c = total supply voltage to the circuit.

THE LOOP FILTER

In almost all applications, it will be desirable to filter the signal at the output of the phase detector (pin 7) this filter may take one of two forms:



Simple Lag Filter



Lag-Lead Filter

A simple lag filter may be used for wide closed loop bandwidth applications such as modulation following where the frequency deviation of the carrier is fairly high (greater than 10%), or where wideband modulating signals must be followed.

The natural bandwidth of the closed loop response may be found from:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_oK_D}{R_1C_1}}$$

Associated with this is a damping factor:

$$\delta = \frac{1}{2}\sqrt{\frac{1}{R_1C_1K_oK_D}}$$

For narrow band applications where a narrow noise bandwidth is desired, such as applications involving tracking a slowly varying carrier, a lead lag filter should be used. In general, if $1/R_1C_1 < K_oK_d$, the damping factor for the loop becomes quite small resulting in large overshoot and possible instability in the transient response of the loop. In this case, the natural frequency of the loop may be found from

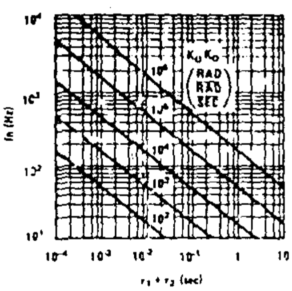
$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_oK_D}{\tau_1 + \tau_2}}$$

$$\tau_1 + \tau_2 = (R_1 + R_2)\,C_1$$

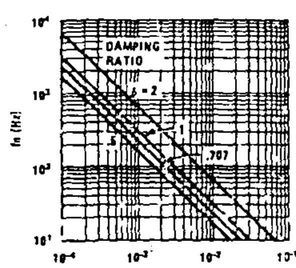
R_2 is selected to produce a desired damping factor δ, usually between 0.5 and 1.0. The damping factor is found from the approximation:

$$\delta \simeq \pi\,\tau_2 f_n$$

These two equations are plotted for convenience.



Filter Time Constant vs Natural Frequency

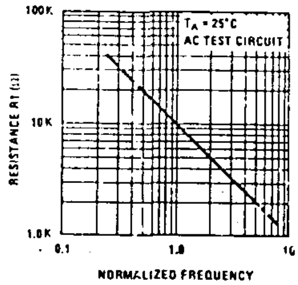


Damping Time Constant vs Natural Frequency

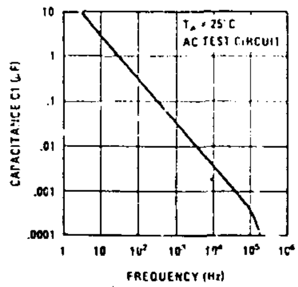
Capacitor C_2 should be much smaller than C_1 since its function is to provide filtering of carrier. In general $C_2 \leq 0.1\,C_1$.

typical performance characteristics

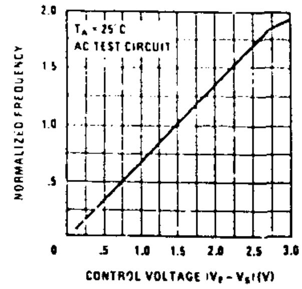
Operating Frequency as a Function of Timing Resistor



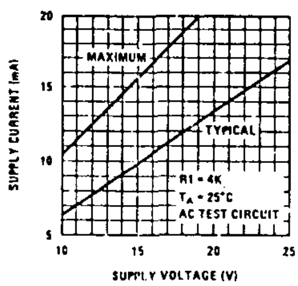
Operating Frequency as a Function of Timing Capacitor



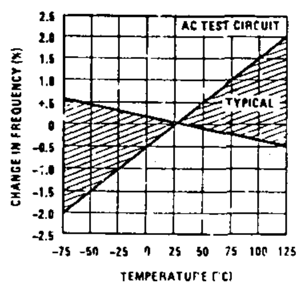
Normalized Frequency as a Function of Control Voltage



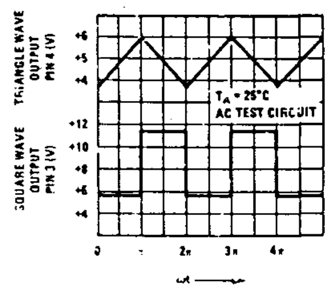
Power Supply Current



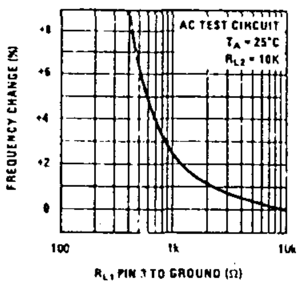
Temperature Stability



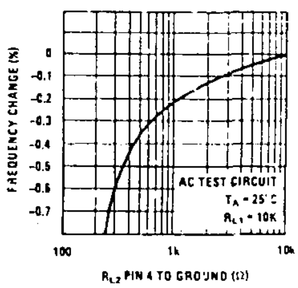
VCO Waveforms



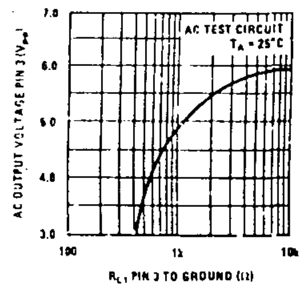
Frequency Stability vs Load Resistance (Square Wave Output)



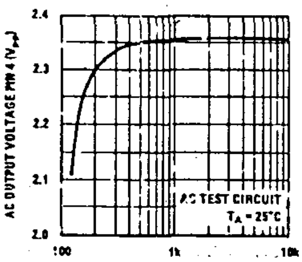
Frequency Stability vs Load Impedance (Triangle Output)



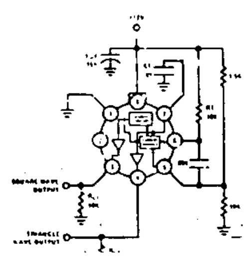
Square Wave Output Characteristics



Triangle Wave Output Characteristics



ac test circuit



absolute maximum ratings

Power Supply Voltage		26V
Power Dissipation (Note 1)		300 mW
Operating Temperature Range	LM566	-55°C to +125°C
	LM566C	0°C to 70°C
Lead Temperature (Soldering, 10 sec)		300°C

electrical characteristics V_{CC} = 12V, T_A = 25°C, AC Test Circuit

PARAMETER	CONDITIONS	LM566 MIN	LM566 TYP	LM566 MAX	LM566C MIN	LM566C TYP	LM566C MAX	UNITS
Maximum Operating Frequency	R0 = 2k C0 = 2.7 pF		1			1		MHz
Input Voltage Range Pin 5		3/4 V_{CC}		V_{CC}	3/4 V_{CC}		V_{CC}	
Average Temperature Coefficient of Operating Frequency			100			200		ppm/°C
Supply Voltage Rejection	10-20V		0.1	1		0.1	2	%/V
Input Impedance Pin 5		0.5	1		0.5	1		MΩ
VCO Sensitivity	For Pin 5, From 8–10V, f_O = 10 kHz	6.4	6.6	6.8	6.0	6.6	7.2	kHz/V
FM Distortion	±10% Deviation		0.2	0.75		0.2	1.5	%
Maximum Sweep Rate		800	1		500	1		MHz
Sweep Range			10:1			10:1		
Output Impedance								
Pin 3			50			50		Ω
Pin 4			50			50		Ω
Square Wave Output Level	R_{L1} = 10k	5.0	5.4		5.0	5.4		Vp-p
Triangle Wave Output Level	R_{L2} = 10k	2.0	2.4		2.0	2.4		Vp-p
Square Wave Duty Cycle		45	50	55	40	50	60	%
Square Wave Rise Time			20			20		ns
Square Wave Fall Time			50			50		ns
Triangle Wave Linearity	+1V Segment at 1/2 V_{CC}		0.2	0.75		0.5	1	%

Note 1: The maximum junction temperature of the LM566 is 150°C, while that of the LM566C is 100°C. For operating at elevated junction temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W. The thermal resistance of the dual-in-line package is 100°C/W.

absolute maximum ratings

Input Voltage: V_O = 5V to 8V	30V
V_O = 12V to 18V	35V
V_O = 24V	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	0°C to +70°C
Maximum Junction Temperature	150°C
Storage Temperature Range	
Metal Can (H Package)	−65°C to +150°C
Molded TO-92	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2) T_J = 0°C to +125°C, I_O = 40 mA, C_{IN} = 0.33µF, C_O = 0.1µF (unless noted)

LM78LXXAC OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
	(Note 4)	1 mA ≤ I_O ≤ 70 mA	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.2		18.9	22.8		25.2	V
		1 mA ≤ I_O ≤ 40 mA and	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.2		18.9	22.8		25.2	V
		$V_{MIN} \le V_{IN} \le V_{MAX}$		$(7 \le V_{IN} \le 20)$			$(8.3 \le V_{IN} \le 21)$			$(10.5 \le V_{IN} \le 23)$			$(12.5 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 27)$			$(17.5 \le V_{IN} \le 30)$			$(20.7 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
ΔV_O	Line Regulation	T_J = 25°C		10	54		10	68		12	85		16	105		20	110		25	140		35	190		50	200	mV
				$(8 \le V_{IN} \le 20)$			$(9 \le V_{IN} \le 21)$			$(11 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(16 \le V_{IN} \le 27)$			$(20 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(28 \le V_{IN} \le 38)$		V
				18	75		18	90		20	100		25	140		30	180		37	250		45	275		60	300	mV
				$(7 \le V_{IN} \le 20)$			$(8.3 \le V_{IN} \le 21)$			$(10.5 \le V_{IN} \le 23)$			$(12.5 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 27)$			$(17.5 \le V_{IN} \le 30)$			$(20.7 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA		5	30		6	35		8	40		9	45		10	50		12	75		15	85		20	100	mV
		T_J = 25°C, 1 mA ≤ I_O ≤ 100 mA		20	60		22	70		25	80		27	90		30	100		35	150		40	170		50	200	mV
ΔV_O	Long Term Stability			12			15			20			22			24			30			45			56		mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C		3	5		3	5		3	5		3	5		3	5		3.1	5		3.1	5		3.1	5	mA
		T_J = 125°C			4.7			4.7			4.7			4.7			4.7			4.7			4.7			4.7	
ΔI_Q	Quiescent Current Change	1 mA ≤ I_O ≤ 40 mA			0.1			0.1			0.1			0.1			0.1			0.1			0.1			0.1	mA
		$V_{MIN} \le V_{IN} \le V_{MAX}$			1.0			1.0			1.0			1.0			1.0			1.0			1.0			1.0	mA
				$(8 \le V_{IN} \le 20)$			$(9 \le V_{IN} \le 21)$			$(11 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(16 \le V_{IN} \le 27)$			$(20 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(28 \le V_{IN} \le 38)$		V
V_n	Output Noise Voltage	T_J = 25°C, (Note 3) f = 10 Hz − 10 kHz		40			50			60			70			80			90			150			200		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz	47	62		45	60		43	57		41	55		40	54		37	51		36	48		34	45		dB
				$(8 \le V_{IN} \le 16)$			$(9 \le V_{IN} \le 18)$			$(12 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(15 \le V_{IN} \le 25)$			$(18.5 \le V_{IN} \le 28.5)$			$(23 \le V_{IN} \le 33)$			$(29 \le V_{IN} \le 35)$		V
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C	7			8.3			10.5			12.5			14.5			17.5			20.7			27			V

Note 1: Thermal resistance of the Metal Can Package (H) without a heat sink is 40°C/W junction to case and 140°C/W junction to ambient. Thermal resistance of the TO-92 package is 180°C/W junction to ambient with 0.4" leads from a PC board and 160°C/W junction to ambient with 0.125" lead length to a PC board.

Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of test.

Note 3: Recommended minimum load capacitance of 0.01µF to limit high frequency noise bandwidth.

Note 4: The temperature coefficient of V_{OUT} is typically within ±0.01% V_O/°C.

Voltage Regulators

LM78LXX series three terminal positive regulators

general description

The LM78LXX series of three terminal positive regulators is available with several fixed output voltages making them useful in a wide range of applications. When used as a zener diode/resistor combination replacement, the LM78LXX usually results in an effective output impedance improvement of two orders of magnitude, and lower quiescent current. These regulators can provide local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow the LM78LXX to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78LXX is available in the metal three lead TO-5 (H) and the plastic TO-92 (Z). With adequate heat sinking the regulator can deliver 100 mA output current. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

features

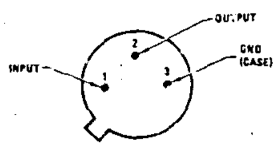
- Output voltage tolerances of ±5% (LM78LXXAC) and ±10% (LM78LXXC) over the temperature range
- Output current of 100 mA
- Internal thermal overload protection
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-92 and metal TO-39 low profile packages

voltage range

LM78L05	5V	LM78L12	12V
LM78L06	6V	LM78L15	15V
LM78L08	8V	LM78L18	18V
LM78L10	10V	LM78L24	24V

connection diagrams

Metal Can Package

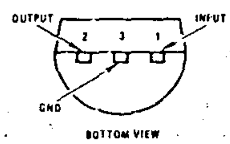


Order Numbers:

LM78L05ACH	LM78L05CH
LM78L06ACH	LM78L06CH
LM78L08ACH	LM78L08CH
LM78L10ACH	LM78L10CH
LM78L12ACH	LM78L12CH
LM78L15ACH	LM78L15CH
LM78L18ACH	LM78L18CH
LM78L24ACH	LM78L24CH

See Package 9

Plastic Package

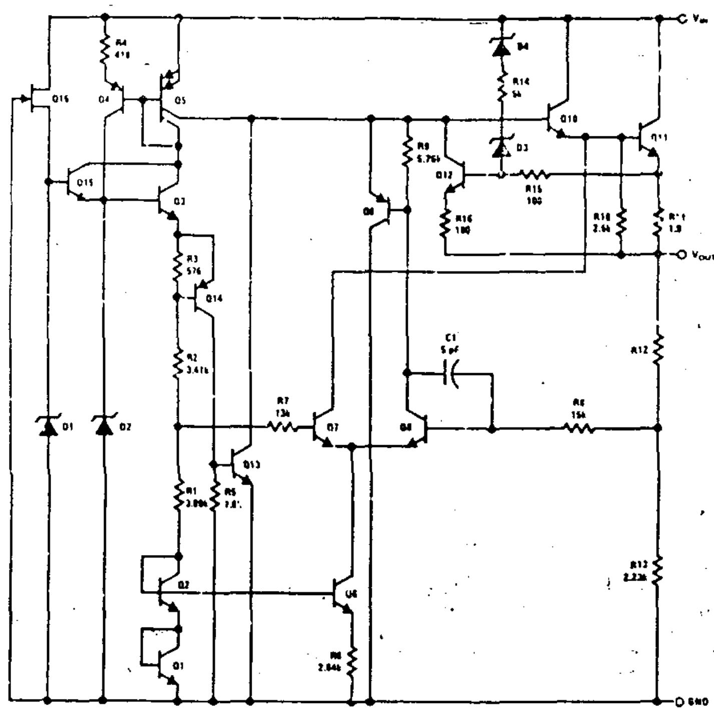


Order Numbers:

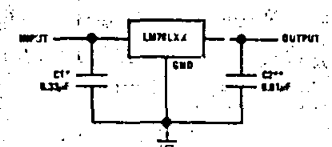
LM78L05ACZ	LM78L05CZ
LM78L06ACZ	LM78L06CZ
LM78L08ACZ	LM78L08CZ
LM78L10ACZ	LM78L10CZ
LM78L12ACZ	LM78L12CZ
LM78L15ACZ	LM78L15CZ
LM78L18ACZ	LM78L18CZ
LM78L24ACZ	LM78L24CZ

See Package 38

equivalent circuit

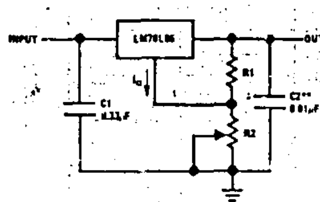


typical applications



*Required if the regulator is located far from the power supply filter.
**See Note 3 in the electrical characteristics table.

Fixed Output Regulator

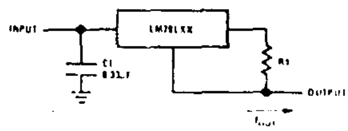


$V_{OUT} = 6V + (6V/R1 + I_Q)\,R2$

$6V/R1 > 3\,I_Q$, load regulation $(L_r) \approx [(R1 + R2)/R1]$ (L_r of LM78L06)

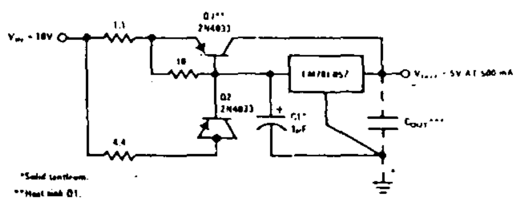
Adjustable Output Regulator

typical applications (con't)



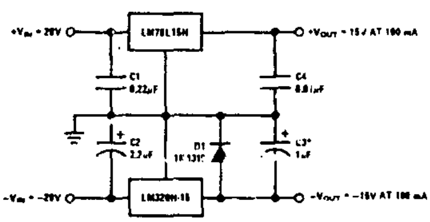
$I_{OUT} = (V_{23}/R1) + I_Q$
$\Delta I_Q = 1.5$ mA over line and load changes

Current Regulator



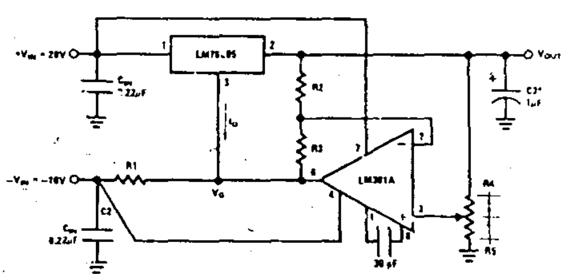
*Solid tantalum.
**Heat sink Q1.
***Optional: Improves ripple rejection and transient response.
Load Regulation: 0.6% $0 \le I_L \le 250$ mA pulsed with t_{ON} = 50 ms.

5V, 500 mA Regulator with Short Circuit Protection



*Solid tantalum.

±15V, 100 mA Dual Power Supply



*Solid tantalum.
$V_{OUT} = V_G + 5V$, $R1 = (-V_{IN}/I_{Q\ LM78L05})$
V_{OUT} = 5V (R2/R4) for (R2 + R3) = (R4 + R5)
A 0.5V output will correspond to (R2/R4) = 0.1, (R3/R4) = 0.9

Variable Output Regulator 0.5V – 18V

absolute maximum ratings

Input Voltage V_O = 5V to 8V	30V
V_O = 12V to 18V	35V
V_O = 24V	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	0°C to +70°C
Maximum Junction Temperature	150°C
Storage Temperature Range	
Metal Can (H Package)	−65°C to +150°C
Molded TO-92	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2) T_J = 0°C to +125°C, I_O = 40 mA, C_{IN} = 0.33μF, C_O = 0.1μF (unless noted)

LM78LXXC OUTPUT VOLTAGE			5V			6V			8V			10V		
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V		
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
V_O	Output Voltage	T_J = 25°C	4.6	5	5.4	5.5	6	6.5	7.36	8	8.64	9.2	10	10.8
	(Note 4)	1 mA ≤ I_O ≤ 70 mA or	4.5		5.5	5.4		6.6	7.2		8.8	9.0		11
		1 mA ≤ I_O ≤ 40 mA and ΔV_{IN}	(7 ≤ V_{IN} ≤ 20)			(8.5 ≤ V_{IN} ≤ 21)			(10.5 ≤ V_{IN} ≤ 23)			(13 ≤ V_{IN} ≤ 25)		
ΔV_O	Line Regulation	T_J = 25°C		10	150		10	150		12	150		16	175
			(8 ≤ V_{IN} ≤ 20)			(9 ≤ V_{IN} ≤ 21)			(11 ≤ V_{IN} ≤ 23)			(14 ≤ V_{IN} ≤ 25)		
				18	200		18	200		20	200		25	225
			(7 ≤ V_{IN} ≤ 20)			(8.5 ≤ V_{IN} ≤ 21)			(10.5 ≤ V_{IN} ≤ 23)			(13 ≤ V_{IN} ≤ 25)		
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA		5	30		6	35		8	40		9	45
		T_J = 25°C, 1 mA ≤ I_O ≤ 100 mA		20	60		22	70		25	80		27	90
ΔV_O	Long Term Stability			12			15			20			22	
I_Q	Quiescent Current	T_J = 25°C		3	6		3	6		3	6		3	6
		T_J = 125°C			5.5			5.5			5.5			5.5
ΔI_Q	Quiescent Current	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA			0.2			0.2			0.2			0.2
					1.5			1.5			1.5			1.5
	Change	T_J = 25°C	(8 ≤ V_{IN} ≤ 20)			(9 ≤ V_{IN} ≤ 21)			(11 ≤ V_{IN} ≤ 23)			(14 ≤ V_{IN} ≤ 25)		
V_n	Output Noise Voltage	T_J = 25°C, (Note 3) f = 10 Hz – 10 kHz		40			50			60			70	
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 125 Hz	40	60		38	58		36	55		36	53	
			(8 ≤ V_{IN} ≤ 18)			(9 ≤ V_{IN} ≤ 19)			(12 ≤ V_{IN} ≤ 23)			(14 ≤ V_{IN} ≤ 25)		
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C		7			8.3			10.5			13	

LM78LXXC OUTPUT VOLTAGE			12V			15V			18V			24V			UNI
INPUT VOLTAGE (unless otherwise noted)			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	11.1	12	12.9	13.8	15	16.2	16.6	18	19.4	22.1	24	25.9	
	(Note 4)	1 mA ≤ I_O ≤ 70 mA or	10.8		13.2	13.5		16.5	16.2		19.8	21.4		26.4	
		1 mA ≤ I_O ≤ 40 mA and ΔV_{IN}	(14.5 ≤ V_{IN} ≤ 27)			(18 ≤ V_{IN} ≤ 30)			(21.4 ≤ V_{IN} ≤ 33)			(28 ≤ V_{IN} ≤ 38)			
ΔV_O	Line Regulation	T_J = 25°C		20	200		25	250		27	275		30	300	
			(16 ≤ V_{IN} ≤ 27)			(20 ≤ V_{IN} ≤ 30)			(22 ≤ V_{IN} ≤ 33)			(28 ≤ V_{IN} ≤ 38)			
				30	250		30	300		32	325		35	350	
			(14.5 ≤ V_{IN} ≤ 27)			(18 ≤ V_{IN} ≤ 30)			(21.4 ≤ V_{IN} ≤ 33)			(27.5 ≤ V_{IN} ≤ 38)			
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA		10	60		12	75		15	85		20	100	
		T_J = 25°C, 1 mA ≤ I_O ≤ 100 mA		30	100		35	150		40	170		40	200	
ΔV_O	Long Term Stability			24			30			45			56		mV/10
I_Q	Quiescent Current	T_J = 25°C		3	6.5		3.1	6.5		3.1	6.5		3.1	6.5	
		T_J = 125°C			6			6			6			6	
ΔI_Q	Quiescent Current	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA			0.2			0.2			0.2			0.2	
					1.5			1.5			1.5			1.5	
	Change	T_J = 25°C	(16 ≤ V_{IN} ≤ 27)			(20 ≤ V_{IN} ≤ 30)			(22 ≤ V_{IN} ≤ 33)			(28 ≤ V_{IN} ≤ 38)			
V_n	Output Noise Voltage	T_J = 25°C, (Note 3) f = 10 Hz – 10 kHz		80			90			150			200		
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 125 Hz	36	52		33	49		32	46		30	43		
			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)			(23 ≤ V_{IN} ≤ 33)			(29 ≤ V_{IN} ≤ 35)			
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C		14.5			18			21.4			27.5		

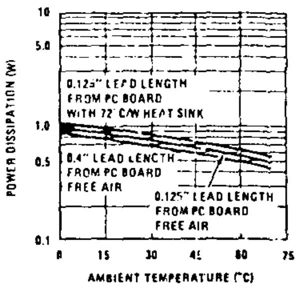
Note 1: Thermal resistance of the Metal Can Package (H) without a heat sink is 40°C/W junction to case and 140°C/W junction to ambient. Thermal resistance of the TO-92 package is 180°C/W juncti ambient with 0.4" leads from a PC board and 160°C/W junction to ambient with 0.125" lead length to a PC board.

Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with jun temperatures as indicated at the initiation of test.

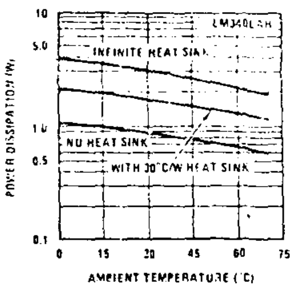
Note 3: Recommended minimum load capacitance of 0.01μF to limit high frequency noise bandwidth.

Note 4: The temperature coefficient of V_{OUT} is typically within ±0.01% V_O/°C.

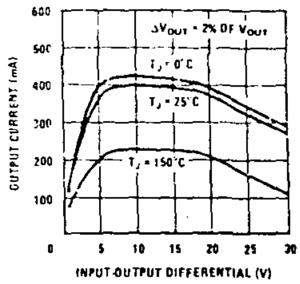
Maximum Average Power Dissipation (Plastic Package)



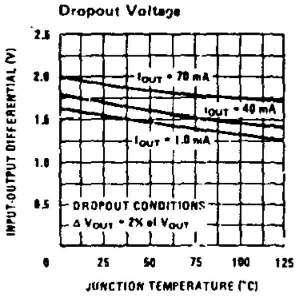
Maximum Average Power Dissipation (Metal Can Package)



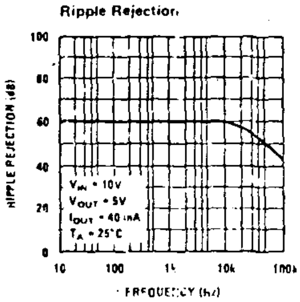
Peak Output Current



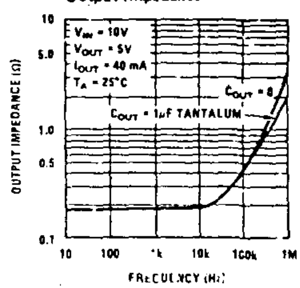
Dropout Voltage



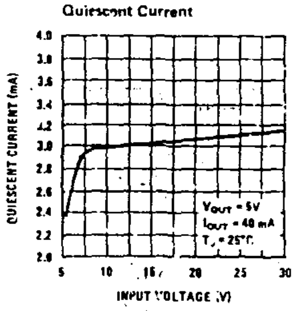
Ripple Rejection



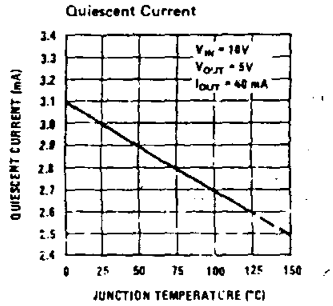
Output Impedance



Quiescent Current



Quiescent Current



Typical Applic

LF147/LF347/LF347B

ɔctor
'157 Series Monolithic
ational Amplifiers
:55/LF355/LF355A/
/ Current
:56/LF356/LF356A/
:57/LF357/LF357A/
LF357B Wide Band Decompensated (A_{VMIN} = 5)

General Description

These are the first monolithic JFET input operational amplifiers to incorporate well matched, high voltage JFETs on the same chip with standard bipolar transistors (BI-FET™ Technology). These amplifiers feature low input bias and offset currents/low offset voltage and offset voltage drift, coupled with offset adjust which does not degrade drift or common-mode rejection. The devices are also designed for high slew rate, wide bandwidth, extremely fast settling time, low voltage and current noise and a low 1/f noise corner.

Advantages

- Replace expensive hybrid and module FET op amps
- Rugged JFETs allow blow-out free handling compared with MOSFET input devices
- Excellent for low noise applications using either high or low source impedance—very low 1/f corner
- Offset adjust does not degrade drift or common-mode rejection as in most monolithic amplifiers
- New output stage allows use of large capacitive loads (10,000 pF) without stability problems
- Internal compensation and large differential input voltage capability

Applications

- Precision high speed integrators
- Fast D/A and A/D converters
- High impedance buffers
- Wideband, low noise, low drift amplifiers
- Logarithmic amplifiers
- Photocell amplifiers
- Sample and Hold circuits

Common Features

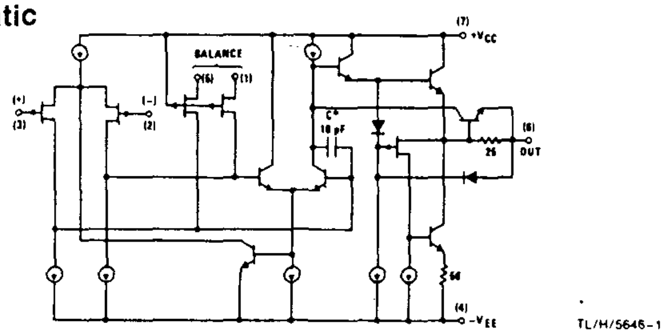
(LF155A, LF156A, LF157A)

■ Low input bias current	30 pA
■ Low Input Offset Current	3 pA
■ High input impedance	$10^{12}\Omega$
■ Low input offset voltage	1 mV
■ Low input offset voltage temp. drift	3 μV/°C
■ Low input noise current	0.01 pA/$\sqrt{Hz}$
■ High common-mode rejection ratio	100 dB
■ Large dc voltage gain	106 dB

Uncommon Features

	LF155A	LF156A	LF157A (A_V = 5)	Units
■ Extremely fast settling time to 0.01%	4	1.5	1.5	μs
■ Fast slew rate	5	12	50	V/μs
■ Wide gain bandwidth	2.5	5	20	MHz
■ Low input noise voltage	20	12	12	nV/$\sqrt{Hz}$

Simplified Schematic



*3 pF in LF157 series.

TL/H/5646-1

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, contact the National Semiconductor Sales Office/Distributors for availability and specifications.
(Note 8)

	LF155A/6A/7A	LF155/6/7	LF355B/6B/7B LF255/6/7	LF355/6/7 LF355A/6A/7A
Supply Voltage	±22V	±22V	±22V	±18V
Differential Input Voltage	±40V	±40V	±40V	±30V
Input Voltage Range (Note 2)	±20V	±20V	±20V	±16V
Output Short Circuit Duration	Continuous	Continuous	Continuous	Continuous
T_{jMAX}				
H-Package	150°C	150°C	115°C	115°C
N-Package			100°C	100°C
J-Package		150°C	115°C	115°C
M-Package			100°C	100°C
Power Dissipation at T_A = 25°C (Notes 1 and 9)				
H-Package (Still Air)	560 mW	560 mW	400 mW	400 mW
H-Package (400 LF/Min Air Flow)	1200 mW	1200 mW	1000 mW	1000 mW
N-Package			670 mW	670 mW
J-Package		1260 mW	900 mW	900 mW
M-Package			380 mW	380 mW
Thermal Resistance (Typical) θ_{JA}				
H-Package (Still Air)	160°C/W	160°C/W	160°C/W	160°C/W
H-Package (400 LF/Min Air Flow)	65°C/W	65°C/W	65°C/W	65°C/W
N-Package			130°C/W	130°C/W
J-Package		100°C/W	100°C/W	100°C/W
M-Package			195°C/W	195°C/W
(Typical) θ_{JC}				
H-Package	23°C/W	23°C/W	23°C/W	23°C/W
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Soldering Information (Lead Temp.)				
Metal Can Package				
Soldering (10 sec.)	300°C	300°C	300°C	300°C
Dual-In-Line Package				
Soldering (10 sec.)		260°C	260°C	260°C
Small Outline Package				
Vapor Phase (60 sec.)			215°C	215°C
Infrared (15 sec.)			220°C	220°C

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

ESD tolerance (100 pF discharged through 1.5 kΩ)	1200V	1200V	1200V	1200V

DC Electrical Characteristics (Note 3) $T_A = T_j = 25°C$

Symbol	Parameter	Conditions	LF155A/6A/7A			LF355A/6A/7A			Units
			Min	Typ	Max	Min	Typ	Max	
V_{OS}	Input Offset Voltage	R_S=50Ω, T_A=25°C Over Temperature		1	2 2.5		1	2 2.3	mV mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R_S=50Ω		3	5		3	5	μV/°C
$\Delta TC/\Delta V_{OS}$	Change in Average TC with V_{OS} Adjust	R_S=50Ω, (Note 4)		0.5			0.5		μV/°C per mV
I_{OS}	Input Offset Current	T_j=25°C, (Notes 3, 5) $T_j \le T_{HIGH}$		3	10 10		3	10 1	pA nA
I_B	Input Bias Current	T_j=25°C, (Notes 3, 5) $T_j \le T_{HIGH}$		30	50 25		30	50 5	pA nA
R_{IN}	Input Resistance	T_j=25°C		10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	V_S=±15V, T_A=25°C V_O=±10V, R_L=2k Over Temperature	50 25	200		50 25	200		V/mV V/mV
V_O	Output Voltage Swing	V_S=±15V, R_L=10k V_S=±15V, R_L=2k	±12 ±10	±13 ±12		±12 ±10	±13 ±12		V V

DC Electrical Characteristics (Note 3) $T_A = T_j = 25°C$ (Continued)

Symbol	Parameter	Conditions	LF155A/6A/7A			LF355A/6A/7A			Units
			Min	Typ	Max	Min	Typ	Max	
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm 15V$	±11	+15.1 −12		±11	+15.1 −12		V V
CMRR	Common-Mode Rejection Ratio		85	100		85	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	85	100		85	100		dB

AC Electrical Characteristics $T_A = T_j = 25°C, V_S = \pm 15V$

Symbol	Parameter	Conditions	LF155A/355A			LF156A/356A			LF157A/357A			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
SR	Slew Rate	LF155A/6A; $A_V = 1$, LF157A; $A_V = 5$	3	5		10	12		 40	 50		V/µs V/µs
GBW	Gain Bandwidth Product			2.5		4	4.5		15	20		MHz
t_s	Settling Time to 0.01%	(Note 7)		4			1.5			1.5		µs
e_n	Equivalent Input Noise Voltage	$R_S = 100\Omega$ f = 100 Hz f = 1000 Hz		 25 25			 15 12			 15 12		 nV/√Hz nV/√Hz
i_n	Equivalent Input Noise Current	f = 100 Hz f = 1000 Hz		0.01 0.01			0.01 0.01			0.01 0.01		pA/√Hz pA/√Hz
C_{IN}	Input Capacitance			3			3			3		pF

DC Electrical Characteristics (Note 3)

Symbol	Parameter	Conditions	LF155/6/7			LF255/6/7 LF355B/6B/7B			LF355/6/7			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_{OS}	Input Offset Voltage	$R_S = 50\Omega$, $T_A = 25°C$ Over Temperature		3	5 7		3	5 6.5		3	10 13	mV mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 50\Omega$		5			5			5		µV/°C
$\Delta TC/\Delta V_{OS}$	Change in Average TC with V_{OS} Adjust	$R_S = 50\Omega$, (Note 4)		0.5			0.5			0.5		µV/°C per mV
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 3, 5) $T_j \le T_{HIGH}$		3	20 20		3	20 1		3	50 2	pA nA
I_B	Input Bias Current	$T_j = 25°C$, (Notes 3, 5) $T_j \le T_{HIGH}$		30	100 50		30	100 5		30	200 8	pA nA
R_{IN}	Input Resistance	$T_j = 25°C$		10^{12}			10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 15V$, $T_A = 25°C$ $V_O = \pm 10V$, $R_L = 2k$ Over Temperature	50 25	200		50 25	200		25 15	200		V/mV V/mV
V_O	Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k$ $V_S = \pm 15V$, $R_L = 2k$	±12 ±10	±13 ±12		±12 ±10	±13 ±12		±12 ±10	±13 ±12		V V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm 15V$	±11	+15.1 −12		±11	±15.1 −12		+10	+15.1 −12		V V
CMRR	Common-Mode Rejection Ratio		85	100		85	100		80	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	85	100		85	100		80	100		dB

DC Electrical Characteristics $T_A = T_j = 25°C, V_S = \pm 15V$

Parameter	LF155A/155, LF255, LF355A/355B		LF355		LF156A/156, LF256/356B		LF356A/356		LF157A/157 LF257/357B		LF357A/357		Units
	Typ	Max	Typ	Max	Typ	Max	Typ	Max	Typ	Max	Typ	Max	
Supply Current	2	4	2	4	5	7	5	10	5	7	5	10	mA

AC Electrical Characteristics $T_A = T_j = 25°C, V_S = \pm 15V$

Symbol	Parameter	Conditions	LF155/255/ 355/355B	LF156/256, LF356B	LF156/256/ 356/356B	LF157/257, LF357B	LF157/257/ 357/357B	Units
			Typ	Min	Typ	Min	Typ	
SR	Slew Rate	LF155/6: $A_V = 1$, LF157: $A_V = 5$	5	7.5	12	 30	 50	V/µs V/µs
GBW	Gain Bandwidth Product		2.5		5		20	MHz
t_s	Settling Time to 0.01%	(Note 7)	4		1.5		1.5	µs
e_n	Equivalent Input Noise Voltage	$R_S = 100\Omega$ f = 100 Hz f = 1000 Hz	 25 20		 15 12		 15 12	 nV/√Hz nV/√Hz
i_n	Equivalent Input Current Noise	f = 100 Hz f = 1000 Hz	0.01 0.01		0.01 0.01		0.01 0.01	pA/√Hz pA/√Hz
C_{IN}	Input Capacitance		3		3		3	pF

Notes for Electrical Characteristics

Note 1: The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T_{jMAX}, θ_{jA}, and the ambient temperature, T_A. The maximum available power dissipation at any temperature is $P_d = (T_{jMAX} - T_A)/\theta_{jA}$ or the 25°C P_{dMAX}, whichever is less.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: Unless otherwise stated, these test conditions apply:

	LF155A/6A/7A LF155//6/7	LF255//6/7	LF355A/6A/7A	LF355B/6B/7B	LF355//6/7
Supply Voltage, V_S	$\pm 15V \le V_S \le \pm 20V$	$\pm 15V \le V_S \le \pm 20V$	$\pm 15V \le V_S \le \pm 18V$	$\pm 15V \le V_S \pm 20V$	$V_S = \pm 15V$
T_A	$-55°C \le T_A \le +125°C$	$-25°C \le T_A \le +85°C$	$0°C \le T_A \le +70°C$	$0°C \le T_A \le +70°C$	$0°C \le T_A \le +70°C$
T_{HIGH}	+125°C	+85°C	+70°C	+70°C	+70°C

and V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

Note 4: The Temperature Coefficient of the adjusted input offset voltage changes only a small amount (0.5µV/°C typically) for each mV of adjustment from its original unadjusted value. Common-mode rejection and open loop voltage gain are also unaffected by offset adjustment.

Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_J. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, Pd. $T_j = T_A + \theta_{jA}$ Pd where θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 6: Supply Voltage Rejection is measured for both supply magnitudes increasing or decreasing simultaneously, in accordance with common practice.

Note 7: Settling time is defined here, for a unity gain inverter connection using 2 kΩ resistors for the LF155/6. It is the time required for the error voltage (the voltage at the inverting input pin on the amplifier) to settle to within 0.01% of its final value from the time a 10V step input is applied to the inverter. For the LF157, $A_V = -5$, the feedback resistor from output to input is 2 kΩ and the output step is 10V (See Settling Time Test Circuit).

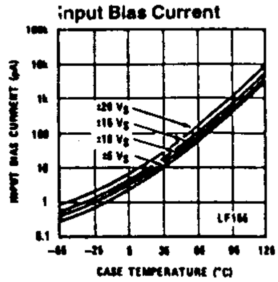
Note 8: Refer to RETS155AX for LF155A, RETS155X for LF155, RETSF156AX for LF156A, RETS156X for LF156, RETS157A for LF157A and RETS157X for LF157 military specifications.

Note 9: Max. Power Dissipation is defined by the package characteristics. Operating the part near the Max. Power Dissipation may cause the part to operate outside guaranteed limits.

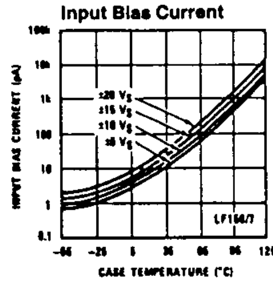
Typical DC Performance Characteristics

Curves are for LF155, LF156 and LF157 unless otherwise specified.

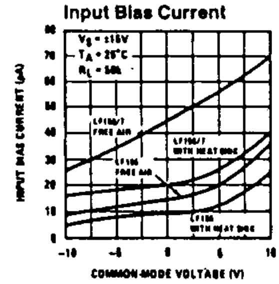
Input Bias Current



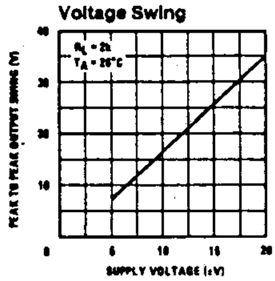
Input Bias Current



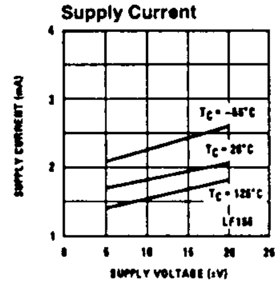
Input Bias Current



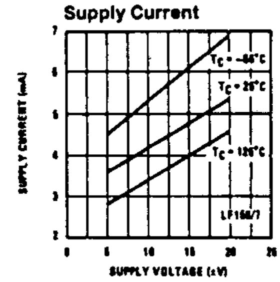
Voltage Swing



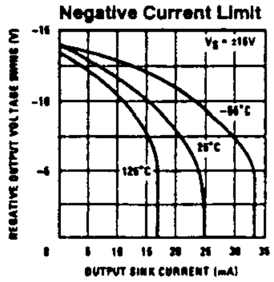
Supply Current



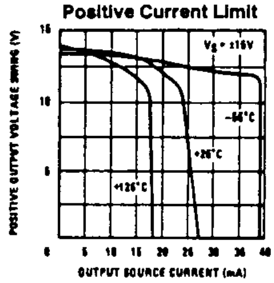
Supply Current



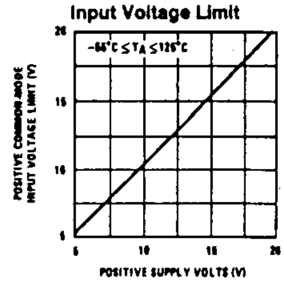
Negative Current Limit



Positive Current Limit

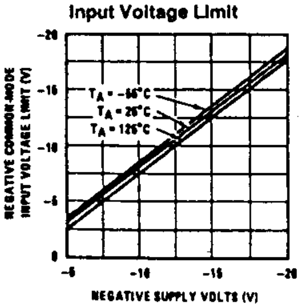


Positive Common-Mode Input Voltage Limit

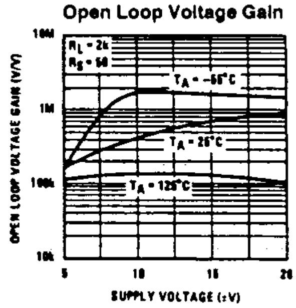


TL/H/5646-2

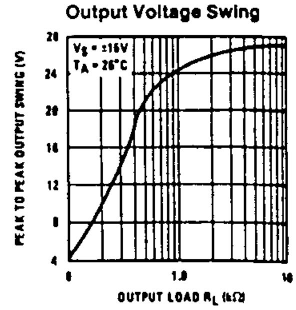
Negative Common-Mode Input Voltage Limit



Open Loop Voltage Gain



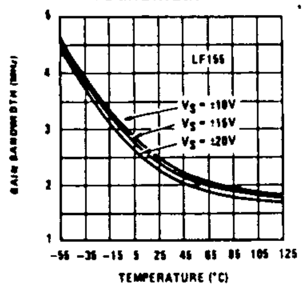
Output Voltage Swing



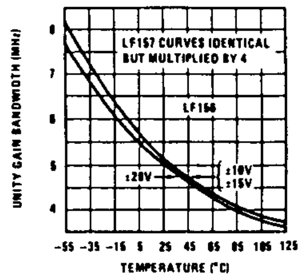
TL/H/5646-3

Typical AC Performance Characteristics

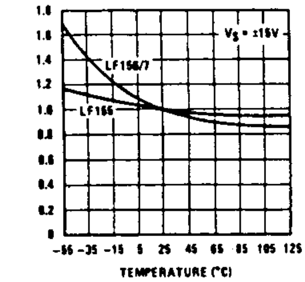
Gain Bandwidth



Gain Bandwidth

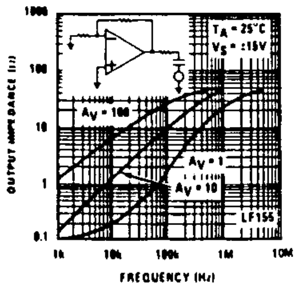


Normalized Slew Rate

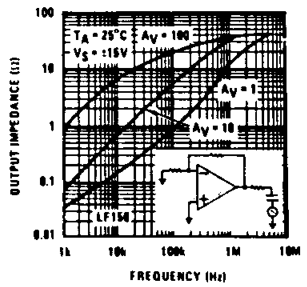


TL/H/5646-4

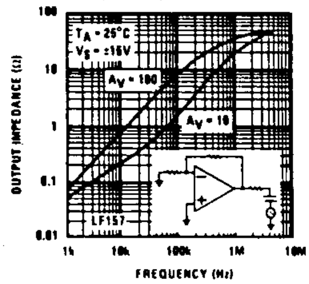
Output Impedance



Output Impedance

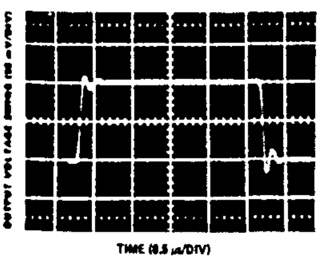


Output Impedance



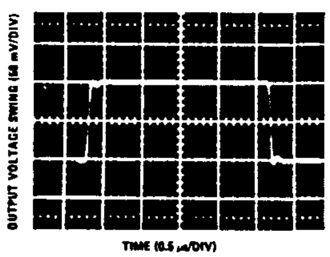
TL/H/5646-12

LF155 Small Signal Pulse Response, $A_V = +1$



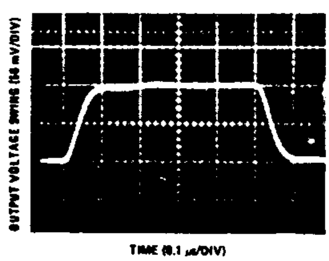
TL/H/5646-5

LF156 Small Signal Pulse Response, $A_V = +1$



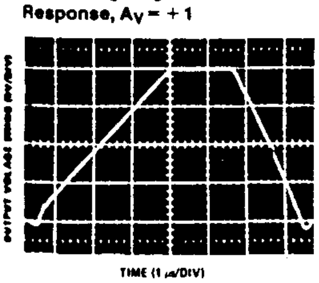
TL/H/5646-6

Small Signal Pulse Response, $A_V = +5$



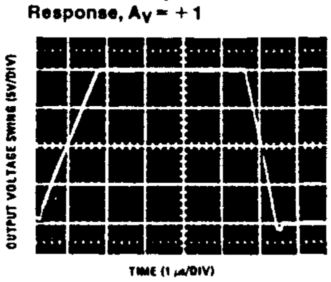
TL/H/5646-7

LF155 Large Signal Pulse Response, $A_V = +1$



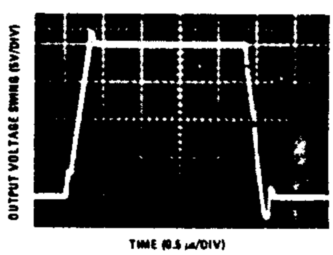
TL/H/5646-8

LF156 Large Signal Pulse Response, $A_V = +1$



TL/H/5646-9

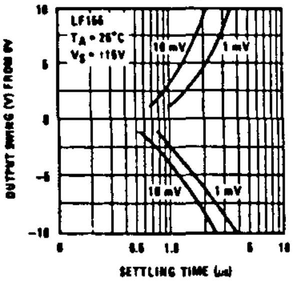
LF157 Large Signal Pulse Response, $A_V = +5$



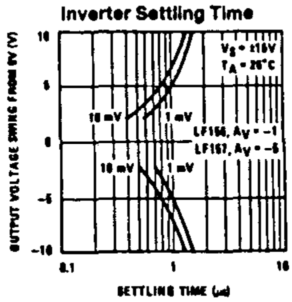
TL/H/5646-10

Typical AC Performance Characteristics (Continued)

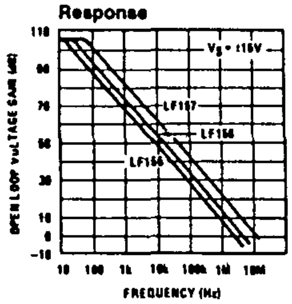
Inverter Settling Time



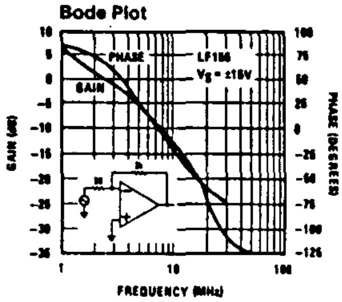
Inverter Settling Time



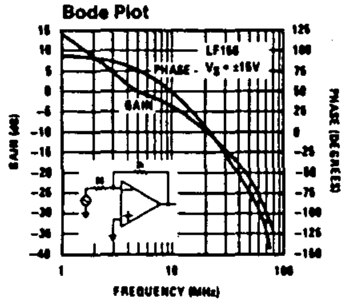
Open Loop Frequency Response



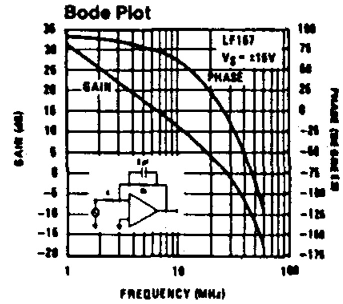
Bode Plot



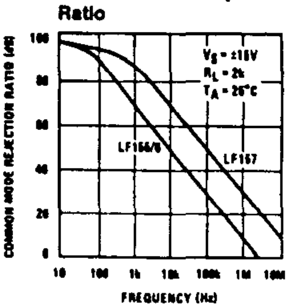
Bode Plot



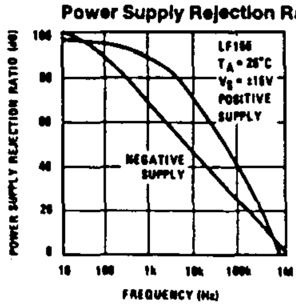
Bode Plot



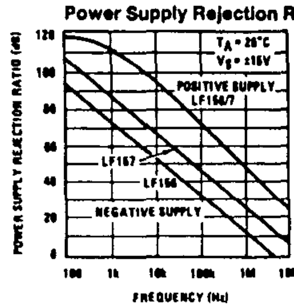
Common-Mode Rejection Ratio



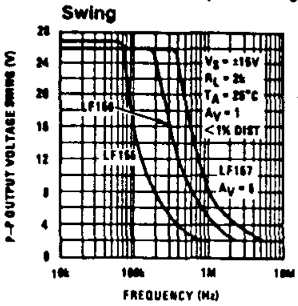
Power Supply Rejection Ratio



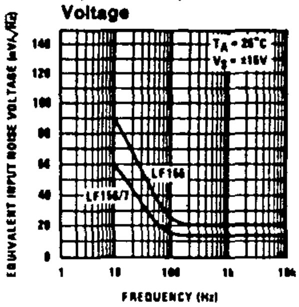
Power Supply Rejection Ratio



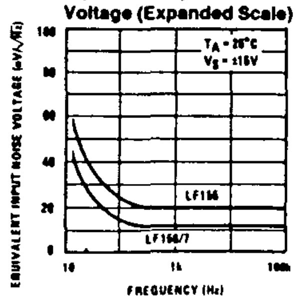
Undistorted Output Voltage Swing



Equivalent Input Noise Voltage

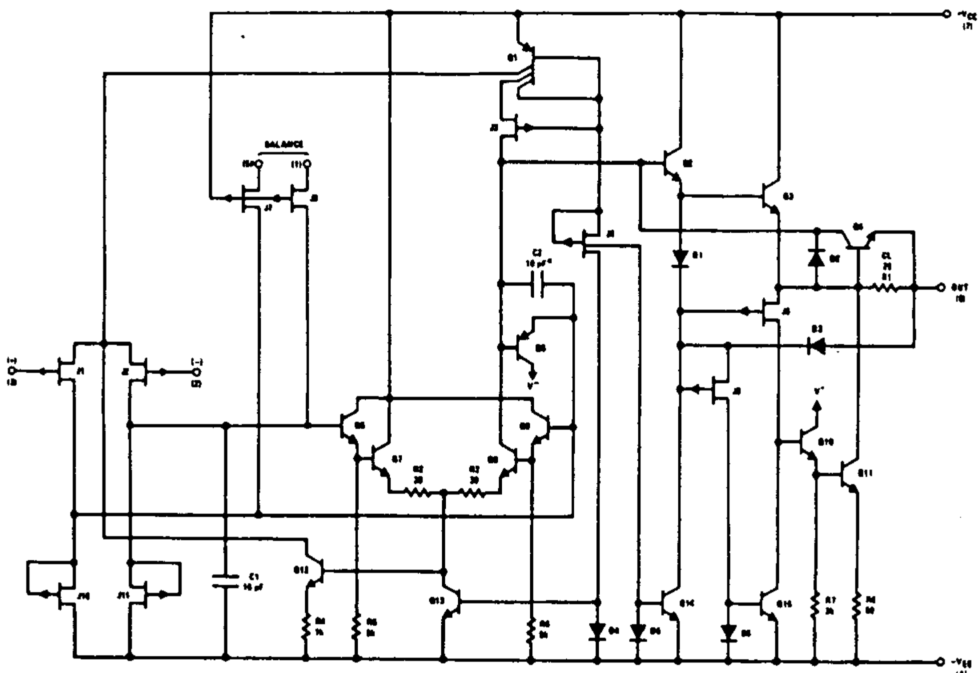


Equivalent Input Noise Voltage (Expanded Scale)



TL/H/5646-11

Detailed Schematic

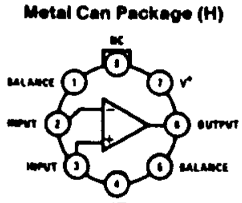


*C = 3 pF in LF157 series.

TL/H/5646-13

Connection Diagrams (Top Views)

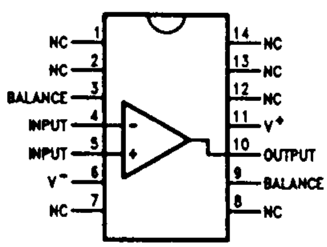
Metal Can Package (H)



TL/H/5646-14

Order Number
LF155AH, LF156AH, LF157AH,
LF155H, LF156H, LF157H,
LF255H, LF256H, LF257H,
LF355AH, LF356AH, LF357AH,
LF355BH, LF356BH, LF357BH,
LF355H, LF356H or LF357H
See NS Package Number H08C

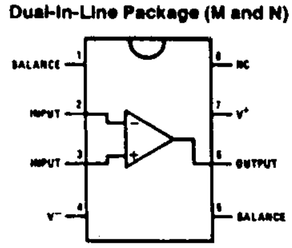
Dual-In-Line Package (J)



TL/H/5646-30

Order Number
LF155J, LF156J, LF157J,
LF355J, LF356J, LF357J,
LF355BJ, LF356BJ or LF357BJ
See NS Package Number J14A

Dual-In-Line Package (M and N)



TL/H/5646-29

Order Number
LF355M, LF356M, LF357M,
LF356BM, LF355BN, LF356BN,
LF357BN, LF355N, LF356N or
LF357N
See NS Package Number
M08A or N08E

Application Hints

The LF155/6/7 series are op amps with JFET input devices. These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore large differential input voltages can easily be accomodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will force the output to a high state, potentially causing a reversal of phase to the output. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

These amplifiers will operate with the common-mode input voltage equal to the positive supply. In fact, the common-mode voltage can exceed the positive supply by approximately 100 mV independent of supply voltage and over the full operating temperature range. The positive supply can therefore be used as a reference on an input as, for example, in a supply current monitor and/or limiter.

Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

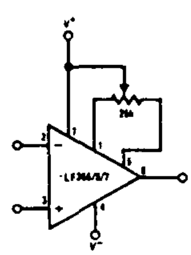
All of the bias currents in these amplifiers are set by FET current sources. The drain currents for the amplifiers are therefore essentially independent of supply voltage.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pickup" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to ac ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

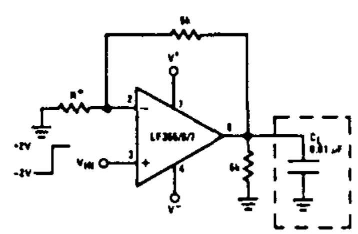
Typical Circuit Connections

V_{OS} Adjustment



- V_{OS} is adjusted with a 25k potentiometer
- The potentiometer wiper is connected to V^+
- For potentiometers with temperature coefficient of 100 ppm/°C or less the additional drift with adjust is ≈ 0.5 µV/°C/mV of adjustment
- Typical overall drift: 5 µV/°C ±(0.5 µV/°C/mV of adj.)

Driving Capacitive Loads



*LF155/6 R = 5k

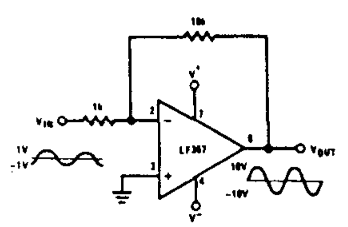
LF157 R = 1.25k

Due to a unique output stage design, these amplifiers have the ability to drive large capacitive loads and still maintain stability. $C_{L(MAX)}$ ≅ 0.01 µF.

Overshoot ≤ 20%

Settling time (t_s) ≅ 5 µs

LF157. A Large Power BW Amplifier

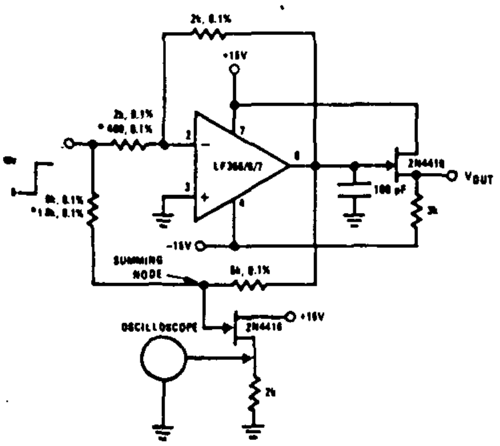


TL/H/5646-15

For distortion ≤ 1% and a 20 Vp-p V_{OUT} swing power bandwidth is: 500 kHz.

Typical Applications

Settling Time Test Circuit

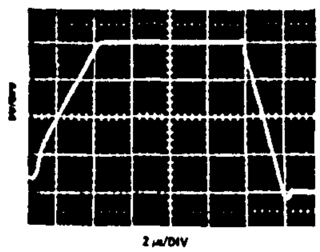


- Settling time is tested with the LF155/6 connected as unity gain inverter and LF157 connected for $A_V = -5$
- FET used to isolate the probe capacitance
- Output = 10V step
- $A_V = -5$ for LF157

TL/H/5646-16

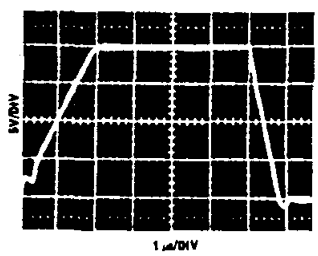
Large Signal Inverter Output, V_{OUT} (from Settling Time Circuit)

LF355



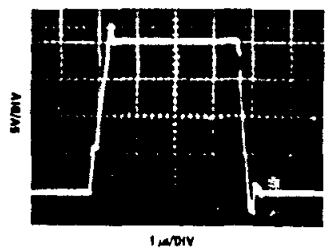
TL/H/5646-17

LF356



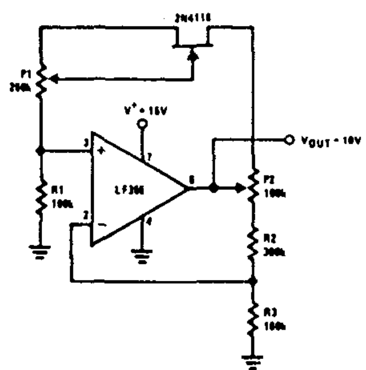
TL/H/5646-18

LF357



TL/H/5646-19

Low Drift Adjustable Voltage Reference

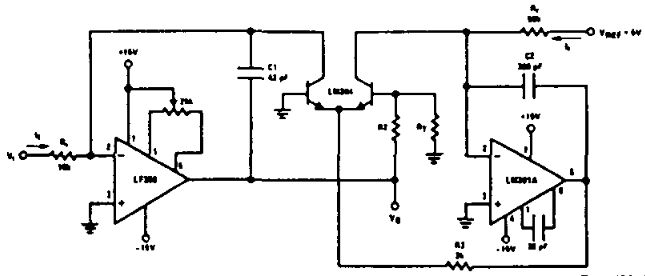


- $\Delta V_{OUT}/\Delta T = \pm 0.002\%/°C$
- All resistors and potentiometers should be wire-wound
- P1: drift adjust
- P2: V_{OUT} adjust
- Use LF155 for
  - Low I_B
  - Low drift
  - Low supply current

TL/H/5646-20

Typical Applications (Continued)

Fast Logarithmic Converter

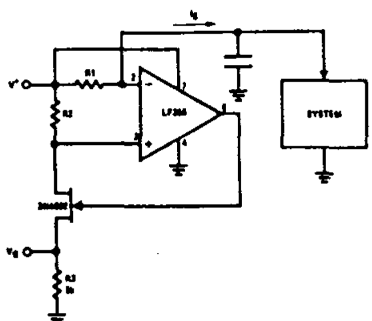


- Dynamic range: 100 μA ≤ I_i ≤ 1 mA (5 decades), $|V_O|$ = 1V/decade
- Transient response: 3 μs for ΔI_i = 1 decade
- C1, C2, R2, R3: added dynamic compensation
- V_{OS} adjust the LF156 to minimize quiescent error
- R_T: Tel Labs type Q81 + 0.3%/°C

TL/H/5646-21

$$|V_{OUT}| = \left[1 + \frac{R2}{R_T}\right]\frac{kT}{q}\ln V_i\left[\frac{R_r}{V_{REF}\,R_i}\right] = \log V_i \frac{1}{R_i I_r} R2 = 15.7k, R_T = 1k, 0.3\%/°C \text{ (for temperature compensation)}$$

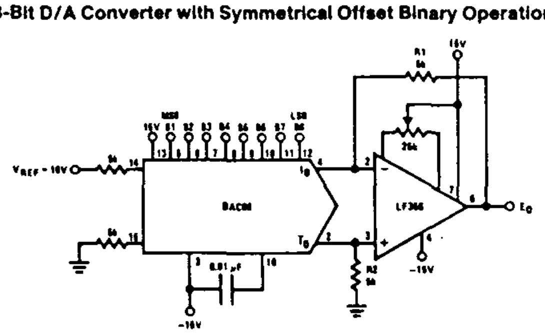
Precision Current Monitor



- V_O = 5 R1/R2 (V/mA of I_S)
- R1, R2, R3: 0.1% resistors
- Use LF155 for
  - Common-mode range to supply range
  - Low I_B
  - Low V_{OS}
  - Low Supply Current

TL/H/5646-31

8-Bit D/A Converter with Symmetrical Offset Binary Operation



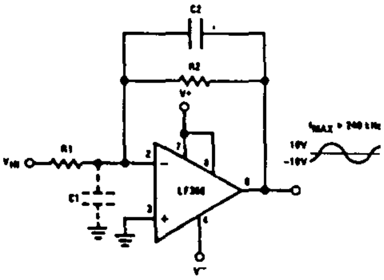
TL/H/5646-32

- R1, R2 should be matched within ±0.05%
- Full-scale response time: 3μs

E_O	B1	B2	B3	B4	B5	B6	B7	B8	Comments
+9.920	1	1	1	1	1	1	1	1	Positive Full-Scale
+0.040	1	0	0	0	0	0	0	0	(+) Zero-Scale
−0.040	0	1	1	1	1	1	1	1	(−) Zero-Scale
−9.920	0	0	0	0	0	0	0	0	Negative Full-Scale

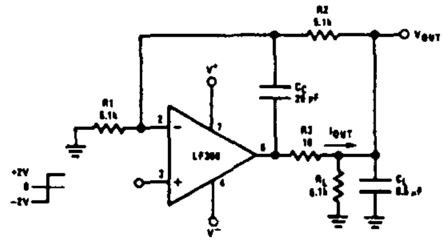
Typical Applications (Continued)

Wide BW Low Noise, Low Drift Amplifier



- Power BW: $f_{MAX} = \frac{S_r}{2\pi V_p} \approx 240$ kHz
- Parasitic input capacitance C1 ≈ (3 pF for LF155, LF156 and LF157 plus any additional layout capacitance) interacts with feedback elements and creates undesirable high frequency pole. To compensate add C2 such that: R2C2 ≈ R1C1.

Isolating Large Capacitive Loads

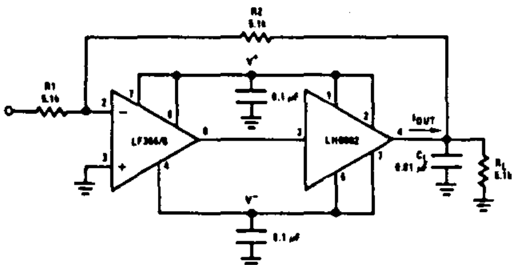


TL/H/5646–22

- Overshoot 6%
- t_s 10 μs
- When driving large C_L, the V_{OUT} slew rate determined by C_L and $I_{OUT(MAX)}$:

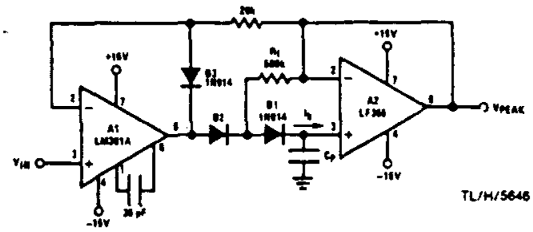
$$\frac{\Delta V_{OUT}}{\Delta T} = \frac{I_{OUT}}{C_L} \approx \frac{0.02}{0.5} \text{ V}/\mu\text{s} = 0.04 \text{ V}/\mu\text{s (with } C_L \text{ shown)}$$

Boosting the LF156 with a Current Amplifier



- $I_{OUT(MAX)} \cong 150$ mA (will drive $R_L \geq 100\Omega$)
- $\frac{\Delta V_{OUT}}{\Delta T} = \frac{0.15}{10^{-2}}$ V/μs (with C_L shown)
- No additional phase shift added by the current amplifier

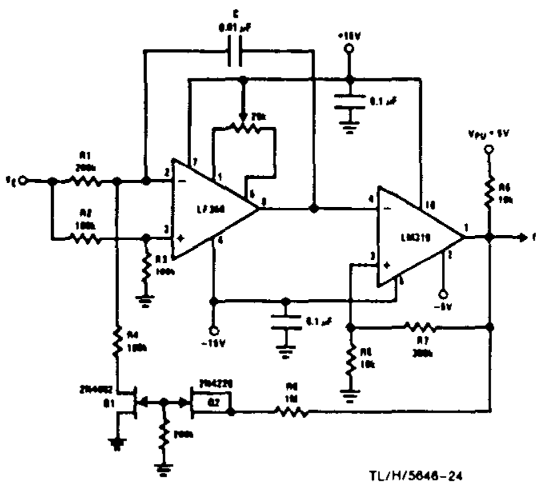
Low Drift Peak Detector



TL/H/5646

- By adding D1 and R_f, $V_{D1} = 0$ during hold mode. Leakage of D2 provided by feedback path through R_f.
- Leakage of circuit is essentially I_b (LF155, LF156) plus capacitor leakage of Cp.
- Diode D3 clamps V_{OUT} (A1) to $V_{IN} - V_{D3}$ to improve speed and to limit reverse bias of D2.
- Maximum input frequency should be << $\frac{1}{2}\pi R_f C_{D2}$ where C_{D2} is the shunt capacitance of D2.

3 Decades VCO

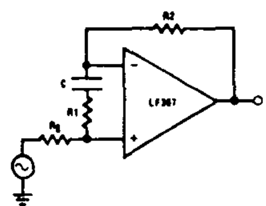


TL/H/5646–24

$f = \frac{V_C (R8 + R7)}{(8 V_{PU} R8 R1) C}$, $0 \leq V_C \leq 30$V, 10 Hz ≤ f ≤ 10 kHz

R1, R4 matched. Linearity 0.1% over 2 decades.

Non-Inverting Unity Gain Operation for LF157



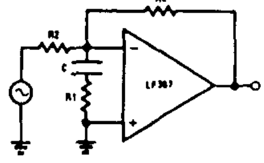
$R1C \geq \frac{1}{(2\pi)(5 \text{ MHz})}$

$R1 = \frac{R2 + R_S}{4}$

$A_{V(DC)} = 1$

$f_{-3 dB} \approx 5$ MHz

Inverting Unity Gain for LF157



$R1C \geq \frac{1}{(2\pi)(5 \text{ MHz})}$

$R1 = \frac{R2}{4}$

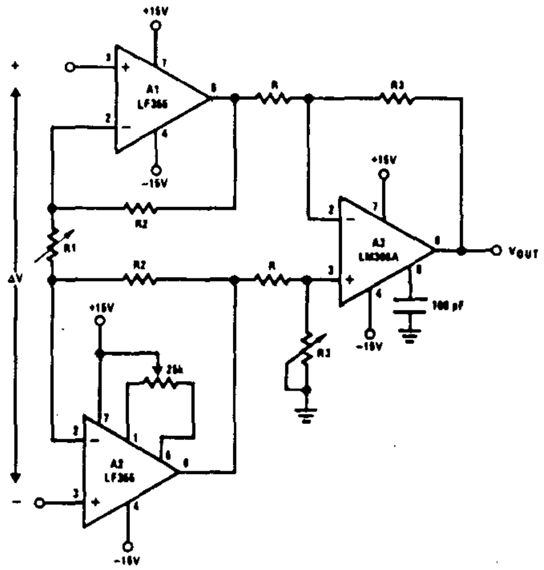
$A_{V(DC)} = -1$

$f_{-3 dB} \approx 5$ MHz

TL/H/5646–25

Typical Applications (Continued)

High Impedance, Low Drift Instrumentation Amplifier

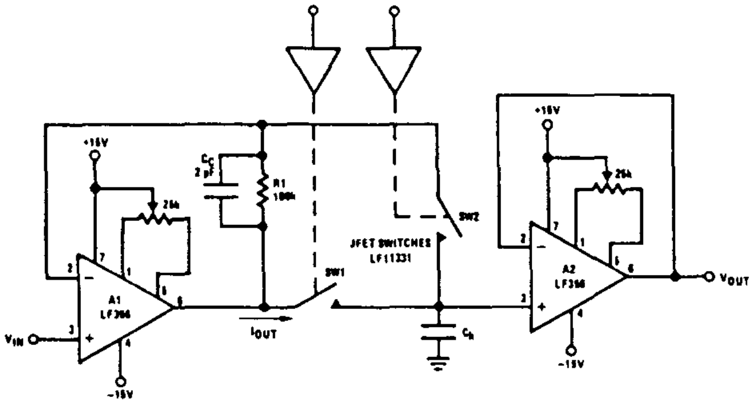


TL/H/5646-26

- $V_{OUT} = \frac{R3}{R}\left[\frac{2R2}{R1} + 1\right] \Delta V$, $V^- + 2V \le V_{IN}$ common-mode $\le V^+$
- System V_{OS} adjusted via A2 V_{OS} adjust
- Trim R3 to boost up CMRR to 120 dB. Instrumentation amplifier resistor array recommended for best accuracy and lowest drift

Typical Applications (Continued)

Fast Sample and Hold



TL/H/5646-33

- Both amplifiers (A1, A2) have feedback loops individually closed with stable responses (overshoot negligible)
- Acquisition time T_A, estimated by:

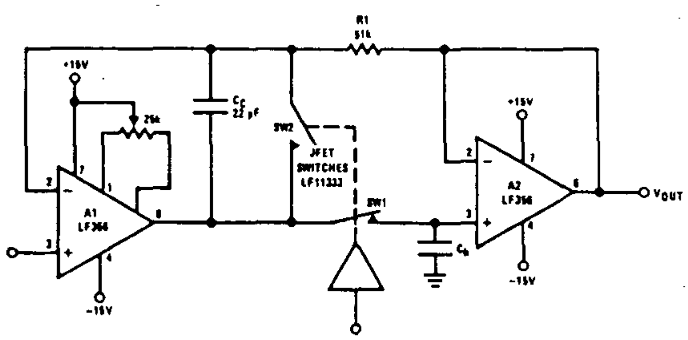
$$T_A \approx \left[\frac{2R_{ON} \cdot V_{IN} \cdot C_h}{S_r}\right]^{1/2} \text{ provided that:}$$

$$V_{IN} < 2\pi S_r R_{ON} C_h \text{ and } T_A > \frac{V_{IN} C_h}{I_{OUT(MAX)}},\ R_{ON} \text{ is of SW1}$$

If inequality not satisfied: $T_A \approx \frac{V_{IN} C_h}{20\text{ mA}}$

- LF156 develops full S_r output capability for $V_{IN} \geq 1V$
- Addition of SW2 improves accuracy by putting the voltage drop across SW1 inside the feedback loop
- Overall accuracy of system determined by the accuracy of both amplifiers, A1 and A2

High Accuracy Sample and Hold

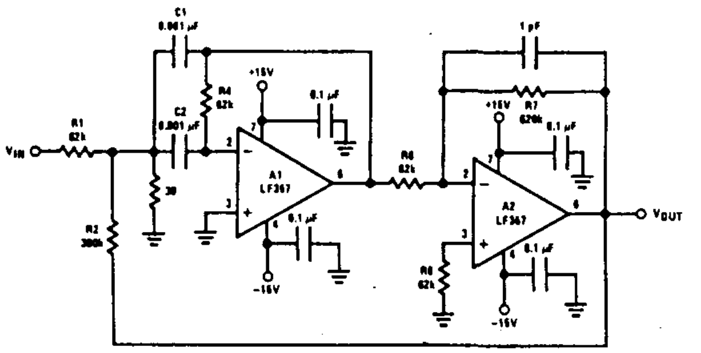


TL/H/5646-27

- By closing the loop through A2, the V_{OUT} accuracy will be determined uniquely by A1. No V_{OS} adjust required for A2.
- T_A can be estimated by same considerations as previously but, because of the added propagation delay in the feedback loop (A2) the overshoot is not negligible.
- Overall system slower than fast sample and hold
- R1, C_C: additional compensation
- Use LF156 for
  - Fast settling time
  - Low V_{OS}

Typical Applications (Continued)

High Q Band Pass Filter



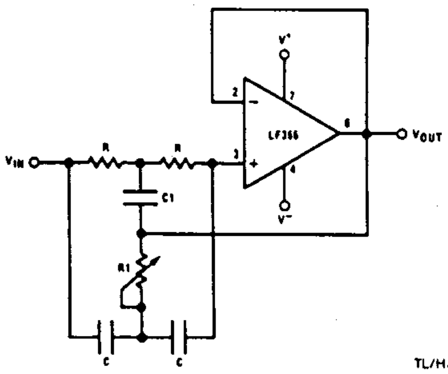
TL/H/5646-28

- By adding positive feedback (R2) Q increases to 40
- $f_{BP} = 100$ kHz

$$\frac{V_{OUT}}{V_{IN}} = 10\sqrt{Q}$$

- Clean layout recommended
- Response to a 1 Vp-p tone burst: 300 μs

High Q Notch Filter



TL/H/5646-34

- $2R1 = R = 10$ MΩ
  $2C = C1 = 300$ pF
- Capacitors should be matched to obtain high Q
- $f_{NOTCH} = 120$ Hz, notch $= -55$ dB, Q > 100
- Use LF155 for
  - Low I_B
  - Low supply current

TRANSISTOR NUMBER	POL	MAT	PACKAGE	LEAD INFO	V_{cb} MAX	V_{ce} MAX	V_{eb} MAX	I_c MAX	T_j MAX	P TOT	F_t MIN	C_{ib} MAX	H_{fe}	H_{fe} BIAS	USE	MFR	ALTERNATIVES AND NOTES	
BC523C	N	S	TO92	L16	80V	80V	12V	100mA	150C	625mWF	-	-	380mn	2mA	ALH	FCD	BC107B	
BC524	N	S	TO92	L16	45V	45V	6V	100mA	150C	625mWF	-	-	240mn	2mA	ALN	FCD	BC109C	2N930
BC524B	N	S	TO92	L16	45V	45V	6V	100mA	150C	625mWF	-	-	240mn	2mA	ALN	FCD	BC109	2N930
BC524C	N	S	TO92	L16	45V	45V	6V	100mA	150C	625mWF	-	-	450mn	2mA	ALN	FCD	BC109C	2N930
BC525	P	S	TO92	L16	45V	35V	6V	100mA	135C	625mWF	200M	6P0	100mn	2mA	ALG	FCD	BC350A	2N3906
BC526	P	S	TO92	L16	60V	50V	6V	200mA	150C	625mWF	200M	5P0	60mn	2mA	ALG	FCD	BC177	2N5401
BC526A	P	S	TO92	L16	60V	50V	6V	200mA	150C	625mWF	200M	5P0	100mn	2mA	ALG	FCD	BC177	2N5401
BC526B	P	S	TO92	L16	60V	50V	6V	200mA	150C	625mWF	200M	5P0	200mn	2mA	ALG	FCD	BC177	2N5401
BC526C	P	S	TO92	L16	80V	50V	6V	200mA	150C	625mWF	200M	5P0	350mn	2mA	ALG	FCD	BC352B	2N3906
BC527	P	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	50/300	150mA	AMG	FCD	-	
BC527-6	P	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	40/100	100mA	AMG	FCD	-	
BC527-10	P	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	63/160	100mA	AMG	FCD	-	
BC527-16	P	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	100mn	100mA	AMG	FCD	-	
BC527-25	P	S	TO92	L16	60V	60V	5V	1A	150C	625mWF	-	15P	160mn	100mA	AMG	FCD	-	
BC528	P	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	50/300	150mA	AMH	FCD		
BC528-6	P	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	40/100	150mA	AMH	FCD	-	
BC528-10	P	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	63/160	100mA	AMH	FCD	-	
BC528-16	P	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	100mn	100mA	AMH	FCD	-	
BC528-25	P	S	TO92	L23	80V	80V	6V	1A	150C	625mWF	-	15P	160mn	150mA	AMH	FCD	-	
BC529	P	S	TO92	L16	60V	30V	6V	200mA	-	625mWF	100M	12P	60/300	50mA	AMG	FCD	BC178	2N2907A
BC530	P	S	TO92	L16	130V	120V	6V	100mA	150C	625mWF	100M	6P0	40/160	10mA	ALE	FCD	BFW43	2N4358
BC530-06	P	S	TO92	L16	130V	120V	6V	100mA	150C	625mWF	100M	6P0	40/100	10mA	ALH	FCD	BC530	
BC530-10	P	S	TO92	L16	130V	120V	6V	100mA	150C	625mWF	100M	6P0	63/160	10mA	ALH	FCD	BC530	
BC530-16	P	S	TO92	L16	130V	120V	6V	100mA	150C	625mWF	100M	6P0	100mn	10mA	ALH	FCD	BC530	
BC530-25	P	S	TO92	L16	130V	120V	6V	100mA	150C	625mWF	100M	6P0	160mn	10mA	ALH	FCD	BC530	
BC531	P	S	TO92	L16	160V	160V	6V	100mA	150C	625mWF	100M	6P0	80/240	10mA	ALE	FCD	BFW43	2N4364
BC532	N	S	TO92	L16	160V	140V	6V	100mA	135C	625mWF	100M	6P0	80/250	10mA	ALE	FCD	BFT59	2N2896
BC533	N	S	TO92	L16	180V	180V	6V	100mA	135C	625mWF	100M	6P0	80/250	10mA	ALE	FCD	BFT59	2N2896
BC534	P	S	TO92	L16	80V	80V	6V	500mA	150C	625mWF	100M	6P5	50mn	10mA	AMH	FCD	BC327	
BC535	N	S	TO92	L16	80V	80V	6V	500mA	150C	625mWF	50M	6P0	50mn	10mA	AMH	FCD	BFR25	2N4390
BC537	N	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	50/300	150mA	AMH	FCD	BC337	2N5561
BC537-6	N	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	40/100	100mA	AMH	FCD	BC337	2N5561
BC537-10	N	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	63/160	100mA	AMH	FCD	BC337	2N5561
BC537-16	N	S	TO92	L16	60V	60V	6V	1A	150C	625mWF	-	15P	100mn	100mA	AMH	FCD	BC337	2N5561
BC538	N	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	50/300	150mA	AMH	FCD	-	
BC538-6	N	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	40/100	100mA	AMH	FCD	-	
BC538-10	N	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	63/160	100mA	AMH	FCD	-	
BC538-16	N	S	TO92	L16	80V	80V	6V	1A	150C	625mWF	-	15P	100mn	100mA	AMH	FCD	-	
BC538-25	N	S	TO92	L23	80V	80V	6V	1A	150C	625mWF	-	15P	160mn	150mA	AMH	FCD	-	
BC546	N	S	TO92	L74	80V	65V	6V	100mA	150C	500mWF	200M	4P5	125mn	2mA	AMG	PHI	BC338	2N5818
BC546A	N	S	TO92	L16	80V	65V	6V	100mA	150C	500mWF	150M	-	110mn	2mA	ALH	PHI	BC300	2N4410
BC546B	N	S	TO92	L16	80V	65V	6V	100mA	150C	500mWF	150M	-	200mn	2mA	ALH	PHI	BC300	2N5551
BC546AP	N	S	X11	L23	80V	65V	6V	100mA	150C	500mWF	150M	-	110mn	2mA	ALH	ZTX	-	
BC546BP	N	S	X11	L23	80V	65V	6V	100mA	150C	500mWF	150M	-	200mn	2mA	ALH	ZTX	-	
BC546VI	N	S	TO92	L74	80V	65V	6V	100mA	150C	500mWF	150M	4P5	75/150	2mA	ALH	SIE	BC533	2N6219
BC547	N	S	TO92	L74	50V	45V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	AMG	PHI	BC338	2N5818
BC547A	N	S	TO92	L74	50V	45V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	AMG	PHI	BC338	2N5818
BC547B	N	S	TO92	L74	50V	45V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	AMG	PHI	BC337	2N5818
BC547C	N	S	TO92	L74	50V	45V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	AMG	PHI	BC239	2N5827
BC547AP	N	S	X11	L23	50V	45V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	ALG	ZTX	-	
BC547BP	N	S	X11	L23	50V	45V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	ALG	ZTX	-	
BC547VI	N	S	TO92	L74	50V	45V	6V	100mA	150C	500mWF	150M	4P5	75/150	2mA	ALG	SIE	BC237B	2N5825
BC548	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	AMG	PHI	BC547	2N5818
BC548A	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	AMG	PHI	BC547A	2N5818
BC548B	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	AMG	PHI	BC547B	2N5818
BC548C	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	AMG	PHI	BC547C	2N5818
BC548AP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	ALG	ZTX	-	
BC548BP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	ALG	ZTX	-	
BC548CP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	ALG	ZTX	-	
BC549	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	AMG	PHI	BC548	2N5818
BC549A	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	ALG	PHI	BC237B	2N5825
BC549B	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	AMG	PHI	BC548B	2N5818
BC549C	N	S	TO92	L74	30V	30V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	AMG	PHI	BC548C	2N5818
BC549AP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	ALN	ZTX	-	
BC549BP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	ALN	ZTX	-	
BC549CP	N	S	X11	L23	30V	30V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	ALN	ZTX	-	
BC550	N	S	TO92	L16	50V	45V	5V	100mA	150C	500mWF	200M	-	240mn	2mA	AMG	PHI	BC547B	2N5818
BC550B	N	S	TO92	L74	50V	45V	5V	100mA	150C	500mWF	150M	-	200mn	2mA	ALN	PHI	BC109C	2N930
BC550C	N	S	TO92	L74	50V	45V	5V	100mA	150C	500mWF	150M	-	420mn	2mA	ALN	PHI	BC109C	2N930
BC550AP	N	S	X11	L23	50V	45V	6V	100mA	150C	500mWF	200M	4P5	110mn	2mA	ALN	ZTX	-	
BC550BP	N	S	X11	L23	50V	45V	6V	100mA	150C	500mWF	200M	4P5	200mn	2mA	ALN	ZTX	-	
BC550CP	N	S	X11	L23	50V	45V	6V	100mA	150C	500mWF	200M	4P5	420mn	2mA	ALN	ZTX	-	
BC561	P	S	TO92	L74	50V	45V	-	100mA	150C	500mWF	-	-	140mn	2mA	ALG	PHI	BC307	2N6015
BC556	P	S	TO92	L74	80V	65V	5V	100mA	150C	500mWF	150M	8P0	75/450	2mA	ALG	SIE	BC307	2N6015
BC556A	P	S	TO92	L74	80V	65V	5V	100mA	150C	500mWF	150M	8P0	125mn	2mA	ALG	TFK	BC309	2N6003

TRANSISTOR NUMBER	POL	MAT	PACKAGE	LEAD INFO	V_{CB} MAX	V_{CE} MAX	V_{EB} MAX	I_C MAX	T_J MAX	P TOT	F_T MIN	C_{CB} MAX	H_{FE}	H_{FE} BIAS	USE	MFR	ALTERNATIVES AND NOTES
BF439	P	S	TO72	L06	20V	20V	3V	10mA	150C	100mWF	900M	1P0	30mn	2mA	ULA	MOT	BF324
BF440	P	S	X10	L19	40V	40V	4V	25mA	150C	300mWF	125M	0R8	60/220	1mA	FRH	TFK	-
BF441	P	S	X10	L19	40V	40V	4V	25mA	150C	300mWF	125M	0R8	30/125	1mA	FRM	TFK	-
BF450	P	S	X10	L19	40V	40V	4V	25mA	125C	150mWF	325M	0R7	60mn	1mA	TIG	ITT	BF324
BF451	P	S	X10	L19	40V	40V	4V	25mA	125C	150mWF	325M	0R7	30mn	1mA	TIA	ITT	BF324
BF454	N	S	X10	L19	35V	25V	4V	20mA	125C	200mWF	250M	0R8	65mn	1mA	FVG	STM	BF115
BF454B	N	S	X10	L19	35V	25V	4V	20mA	125C	200mWF	250M	0R8	110mn	1mA	FVG	STM	BF115
BF455	N	S	X10	L19	35V	25V	4V	20mA	125C	200mWF	250M	0R8	35/125	1mA	FVG	STM	BF115
BF455C	N	S	X10	L19	35V	25V	4V	20mA	125C	200mWF	250M	0R8	65/120	1mA	FVG	STM	BF115
BF455D	N	S	X10	L19	35V	25V	4V	20mA	125C	200mWF	250M	0R8	30/75	1mA	FVG	STM	BF115
BF456	N	S	TO126	L60	160V	160V	5V	100mA	150C	7WC	85M	-	40mn	30mA	ALE	TIS	BD232
BF457	N	S	TO126	L31	160V	160V	5V	100mA	150C	6WC	40M	-	26mn	30mA	RLE	RCA	BF458
BF458	N	S	TO126	L31	250V	250V	5V	100mA	150C	6WC	40M	-	26mn	30mA	RLE	RCA	BF459
BF459	N	S	TO126	L31	300V	300V	5V	100mA	150C	6WC	40M	-	26mn	30mA	RLE	RCA	BF459
BF460	N	S	X17	L35	250V	250V	6V	500mA	150C	2WC	45M	3R0	40/180	20mA	RME	MOT	BFR88 2N5058
BF461	N	S	X17	L36	300V	300V	6V	500mA	150C	2WC	45M	3R0	40/180	30mA	RME	MOT	BFR88 2N5058
BF462	N	S	X17	L36	350V	350V	6V	500mA	150C	2WC	45M	3R0	40/180	30mA	RME	MOT	BFR88 2N6058
BF463	P	S	X17	L36	250V	250V	5V	500mA	150C	2WC	20M	3R0	40/180	30mA	RME	MOT	BFT19B 2N5416
BF464	P	S	X17	L36	300V	300V	5V	500mA	150C	2WC	20M	3R0	40/180	30mA	RME	MOT	BFT19B 2N5416
BF465	P	S	X17	L35	350V	350V	5V	500mA	150C	2WC	20M	3R0	40/180	30mA	RME	MOT	BFT19B 2N5416
BF466	N	S	X17	L35	200V	150V	5V	1A	150C	2WC	100M	12P	40mn	10mA	RME	MOT	BF650 2N5058
BF467	N	S	X17	L35	250V	200V	5V	1A	150C	2WC	100M	12P	40mn	10mA	RME	MOT	BF650 2N5058
BF468	N	S	X17	L35	300V	250V	5V	1A	150C	2WC	100M	12P	40mn	10mA	RME	MOT	BF650 2N5058
BF469	N	S	TO126	L31	250V	250V	5V	30mA	150C	2WE	60M	1R6	50mn	25mA	RME	PHI	-
BF469S	N	S	TO126	L32	250V	250V	5V	30mA	150C	2WE	60M	1R8	50mn	25mA	TLE	TFK	-
BF470	P	S	TO126	L70	250V	250V	5V	30mA	150C	2WE	60M	1R8	50mn	25mA	RME	PHI	
BF470S	P	S	TO126	L32	250V	250V	5V	30mA	150C	2WE	60M	1R8	50mn	25mA	TLE	TFK	-
BF471	N	S	TO126	L31	300V	300V	5V	30mA	150C	2WE	60M	1P8	50mn	25mA	TVE	SIE	BF459 2N5058
BF471S	N	S	TO126	L32	300V	300V	5V	30mA	150C	2WE	60M	1R8	50mn	25mA	TLE	TFK	-
BF472	P	S	TO126	L31	300V	-	5V	100mA	150C	2WC	60M	1P8	50mn	25mA	TVE	SIE	-
BF472S	P	S	TO126	L32	300V	300V	5V	30mA	150C	2WE	60M	1R8	50mn	25mA	TLE	TFK	-
BF479	P	S	X37	L82	30V	25V	3V	50mA	150C	170mWF	800M	1P2	20mn	10mA	TUG	STM	-
BF479S	P	S	X32	X36	30V	25V	3V	50mA	150C	170mWF	700M	0P56	20mn	10mA	TUG	STM	-
BF479T	P	S	X11	L82	30V	20V	3V	50mA	150C	160mWF	1850M	0P5	20mn	10mA	TUG	TFK	-
BF480	N	S	X32	L70A	20V	15V	2V	20mA	125C	140mWF	1G	-	10mn	10mA	TUM	PHI	BF362
BF481	N	S	X32	L70A	20V	15V	-	20mA	125C	140mWF	800M	1P0	10mn	10mA	ULA	PHI	BFY90
BF483	N	S	TO92	L21	300V	250V	5V	50mA	150C	830mWF	90Mtp	-	50mn	25mA	ALH	PHI	MPSA42
BF485	N	S	TO92	L21	350V	300V	5V	50mA	150C	830mWF	90Mtp	-	50mn	25mA	ALH	PHI	MPSA42
BF487	N	S	TO92	L21	400V	350V	5V	50mA	150C	830mWF	90Mtp	-	50mn	25mA	ALH	PHI	-
BF491	P	S	TO92	L21	200V	200V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	MOT	BFT44 2N5416
BF491K	P	S	X11	L24	200V	200V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF491L	P	S	X11	L25	200V	200V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF491M	P	S	X11	L26	200V	200V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF492	P	S	TO92	L21	250V	250V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	MOT	BFT44 2N5416
BF492K	P	S	X11	L24	250V	250V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF492L	P	S	X11	L25	250V	250V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF492M	P	S	X11	L26	250V	250V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF493	P	S	TO92	L21	300V	300V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	MOT	BFT44 2N5416
BF493K	P	S	X11	L24	300V	300V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF493L	P	S	X11	L25	300V	300V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF493M	P	S	X11	L26	300V	300V	6V	500mA	150C	625mWF	50M	1R6	25mn	10mA	RME	ZTX	-
BF493S	P	S	TO92	L14	350V	350V	6V	500mA	150C	625mWF	50M	1R6	40mn	10mA	RME	MOT	-
BF493SP	P	S	X11	L26	350V	350V	6V	500mA	175C	625mWF	50M	1R6	40mn	10mA	RME	ZTX	-
BF494	N	S	TO92	L53	30V	20V	5V	30mA	150C	300mWF	150M	1R0	10mn	3mA	FVG	RTC	-
BF495	N	S	TO92	L53	30V	20V	5V	30mA	150C	300mWF	100M	1R0	10mn	3mA	FVG	RTC	-
BF496	N	S	TO92	L74	30V	20V	3V	20mA	150C	300mWF	350M	0R8	40tp	2mA	VLA	PHI	-
BF497	N	S	TO106	L17	40V	25V	4V	50mA	125C	200mWF	500M	0R7	40mn	7mA	TIA	STM	BF173
BF500	P	S	TO106	L18	30V	30V	4V	20mA	125C	200mWF	200M	0R7	30/50	1mA	ULA	STM	-
BF500A	P	S	TO106	L18	30V	30V	3V	20mA	125C	200mWF	200M	0R7	30/50	1mA	ULA	STM	-
BF501	P	S	TO106	L18	30V	30V	3V	20mA	125C	200mWF	200M	0R7	30/90	1mA	ULA	STM	-
BF502	N	S	TO92	L73	40V	30V	4V	20mA	150C	500mWF	400M	0P35	40tp	5mA	FVG	SIE	-
BF502S	N	S	TO92	L73	40V	25V	4V	20mA	150C	400mWF	500M	0P35	40tp	5mA	FVG	SIE	-
BF503	N	S	TO92	L73	40V	30V	4V	20mA	150C	500mWF	450M	0P35	40tp	5mA	FVG	SIE	-
BF505	N	S	TO92	L73	30V	25V	3V	20mA	150C	500mWF	750M	0P5	40tp	5mA	VLA	SIE	-
BF506	P	S	TO92	L74	40V	35V	4V	30mA	150C	250mWF	250M	1P2	20mn	3mA	FVG	STM	BF414
BF507	N	S	TO92	L73	30V	25V	3V	20mA	150C	500mWF	750M	0P75	40mn	5mA	FVG	SIE	-
BF509	P	S	TO92	L74	40V	35V	4V	30mA	150C	250mWF	400M	1P2	35mn	3mA	VLA	STM	BF414
BF509S	P	S	TO92	L74	40V	35V	4V	30mA	150C	300mWF	400M	0P5	25mn	3mA	VLN	SIE	-
BF509T	P	S	TO92	L74	40V	35V	4V	30mA	150C	300mWF	500M	0P5	35mn	3mA	VLN	SIE	-
BF516	P	S	TO72	L06	40V	35V	4V	20mA	175C	150mWF	500M	0R5	25mn	3mA	ULA	STM	BF576
BF517	N	S	X12	L29	20V	15V	3V	25mA	150C	280mWF	1G	0P75	25/250	5mA	ULA	SIE	-
BF523	N	S	X10	L19	45V	45V	5V	50mA	150C	625mWF	100M	4P0	600mn	10mA	ALN	TIS	BC107C
BF536	P	S	X12	L29	30V	30V	-	25mA	150C	200mWF	250M	-	25mn	1mA	FVG	PHI	-
BF540	P	S	X10	L19	50V	45V	5V	50mA	150C	250mWF	90M	1R0	60mn	1mA	FRH	TIS	BF440
BF541	P	S	X10	L19	50V	45V	5V	50mA	150C	250mWF	90M	1R0	45mn	1mA	RLG	TIS	BF440

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