LINEAR INTEGRATED CIRCUITS

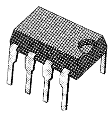
LM158
LM258
LM358
LM2904

DUAL OPERATIONAL AMPLIFIERS

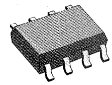
- SINGLE SUPPLY (3V to 30V) OR DUAL SUPPLIES (± 1.5V to 15V)
- VERY LOW SUPPLY CURRENT DRAIN (500μA) ESSENTIALLY INDIPENDENT OF SUPPLY VOLTAGE
- LOW INPUT BIASING CURRENT (TEMPERATURE COMPENSATED)
- LOW INPUT OFFSET VOLTAGE AND OFFSET CURRENT
- DIFFERENTIAL INPUT VOLTAGE RANGE EQUAL TO THE POWER SUPPLY VOLTAGE
- INTERNALLY FREQUENCY COMPENSATED FOR UNITY GAIN
- LARGE OUTPUT VOLTAGE SWING (3.5V WITH $V_s = 5V$)

The LM158 series consists of two independent, high gain, internally frequency compensated operational amplifiers designed specifically to operate from a single power supply over a wide range of voltages. Operation from dual power supplies is also possible and the low power supply current drain is independent of the supply voltage.

In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though opperated from only a single power supply voltage. The unity gain cross frequency is temperature compensated. The input bias current is also temperature compensated. The LM158 is available in minidip plastic or ceramic package and in a 8-lead micropackage version.

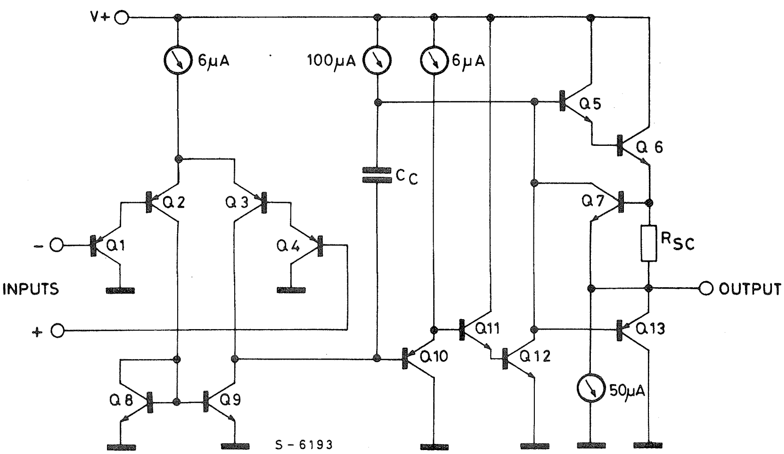


Minidip (Plastic and Ceramic)



SO-8

SCHEMATIC DIAGRAM (One section)



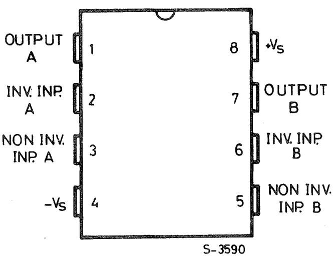
LM158
LM258
LM358
LM2904

ABSOLUTE MAXIMUM RATINGS

V_s	Supply voltage	32 or ± 16	V
V_s	Supply voltage: (**LM2904** only)	26 or ± 13	V
V_i	Differential input voltage	32	V
V_i	Input voltage	-0.3 to + 32	V
	Output short-circuit to GND $V+ < 15V$ and $T_{amb} = 25°C$	Continuous	
T_{op}	Operating temperature: **LM358/358A**	0 to 70	°C
	LM2904	-40 to 85	°C
	LM258/258A	-25 to 85	°C
	LM158/158A	-55 to 125	°C
T_j	Junction temperature	150	°C
T_{stg}	Storage temperature	-65 to 150	°C

CONNECTION DIAGRAM AND ORDERING NUMBERS

(top view)



Temperature range	Ceramic Minidip	Plastic Minidip	SO-8
Commercial 0 to 70°C	LM358J LM358AJ	LM358N LM358AN	LM358D
Industrial -25 to 85°C	LM258J LM258AJ	LM258N	LM258D
Automotive -40 to 85°C	LM2904J	LM2904N	LM2904D
Military -55 to 125°C	LM158J LM158AJ	–	–

THERMAL DATA

			Plastic Minidip	Ceramic Minidip	SO-8
$R_{th\ j\text{-}amb}$	Thermal resistance junction-ambient	max.	120°C/W	150°C/W	200°C/W

ELECTRICAL CHARACTERISTICS (V_s = + 5V, T_{amb}= -55 to 125°C for the LM158/LM158A and T_{amb} = -25 to 85°C for the LM258/LM258A, unless otherwise specified)

	Parameter	Test conditions		LM158/258 Min.	LM158/258 Typ.	LM158/258 Max.	LM158A Min.	LM158A Typ.	LM158A Max.	LM258A Min.	LM258A Typ.	LM258A Max.	Unit
I_S	Supply current	$R_L = \infty$	V_s = 30V		1	2		1	2		1	2	mA
					0.7	1.2		0.7	1.2		0.7	1.2	
I_b	Input bias current	T_{amb}= 25°C			45	150		20	50		40	80	nA
					40	300		40	100		40	100	
V_{os}	Input offset voltage	R_g= 0 V_s = 5V to 30V	T_{amb}= 25°C		2	5		1	2		1	3	mV
						7			4			4	
$\frac{\Delta V_{os}}{\Delta T}$	Input offset voltage drift	R_g= 0			7			7	20		7	20	μV/°C
I_{os}	Input offset current	T_{amb}= 25°C			3	30		2	10		2	15	nA
						100			30			30	
$\frac{\Delta I_{os}}{\Delta T}$	Input offset current drift				10			10	200		10	200	pA/°C
I_{sc}	Output short circuit to ground current	T_{amb}= 25°C (*)			40	60		40	60		40	60	mA
G_v	Large signal open loop voltage gain	V_s = 15V $R_L \geq 2$ KΩ	T_{amb}= 25°C	94	100		94	100		94	100		dB
				88			88			88			
	Input common-mode voltage range	V_s = 30V	T_{amb}= 25°C	0		V_s-1.5	0		V_s-1.5	0		V_s-1.5	V
				0		V_s-2	0		V_s-2	0		V_s-2	
V_o	Output voltage swing	T_{amb}= 25°C	R_L= 2 KΩ			V_s-1.5			V_s-1.5				V
			$R_L \geq 10$ KΩ									V_s-1.5	
		V_s = 30V	R_L= 2 KΩ	26			26			26			V
			$R_L \geq 10$ KΩ	27	28		27	28		27	28		
$V_{o\ sat}$	Output saturation voltage to ground	$R_L \leq 10$ KΩ			5	20		5	20		5	20	mV
CMR	Common mode rejection	T_{amb}= 25°C		70	85		70	85		70	85		dB
SVR	Supply voltage rejection	T_{amb}= 25°C		65	100		65	100		65	100		dB
CS	Channel separation	f = 1 KHz to 20 KHz T_{amb}= 25°C (Input referred)			120			120			120		dB
I_o^+	Output source current	V_s = 15V V_{i^+} = 1V V_{i^-} = 0V	T_{amb}= 25°C	20	40		20	40		20	40		mA
				10	20		10	20		10	20		
I_o^-	Output sink current	V_{i^+} = 0V V_{i^-} = 1V V_o= 200 mV	T_{amb}= 25°C	12	50		12	50		12	50		μA
		V_{i^-} = 1V V_{i^+} = 0V V_s= 15V	T_{amb}= 25°C	10	20		10	20		10	20		mA
				5	8		10	15		5	8		

(*) Short circuits from the output to positive supply voltage can cause excessive heating and eventual destruction. The maximum output current is 40 mA typ. independent of the magnitude of V_s. Destructive dissipation can result from simultaneous shorts on all amplifiers.

ELECTRICAL CHARACTERISTICS (V_s = 5V, T_{amb} = 0 to 70°C for the **LM358/LM358A** and T_{amb} = -40 to 85°C for the LM2904, unless otherwise specified)

	Parameter	Test conditions		LM358			LM358A			LM2904			Unit
				Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
I_S	Supply current	$R_L = \infty$	V_s = 30V (*)		1	2		11	2		1	2	mA
					0.5	1.2		0.5	1.2		0.5	1.2	
I_b	Input bias current	T_{amb} = 25°C			45	250		45	100		45	250	nA
						500			200			500	
V_{os}	Input offset voltage	R_g = 0 V_s = 5V to 30V (*)	T_{amb} = 25°C		2	7		2	3		2	7	mV
						9			5			10	
$\frac{\Delta V_{os}}{\Delta T}$	Input offset voltage drift	R_g = 0			7			7	30		7		µV/°C
I_{os}	Input offset current	T_{amb} = 25°C			5	50		5	30		5	50	nA
						150			75			200	
$\frac{\Delta I_{os}}{\Delta T}$	Input offset current drift				10			10	300		10		pA/°C
I_{sc}	Output short circuit to ground current	T_{amb} = 25°C (**)			40	60		40	60		40	60	mA
G_v	Large signal open loop voltage gain	V_s = 15V $R_L \geq$ 2 KΩ	T_{amb} = 25°C	88	100		88	100			100		dB
				83			83			83			
	Input common-mode voltage range	V_s = 30V (*)	T_{amb} = 25°C	0		V_s-1.5	0		V_s-1.5	0		V_s-1.5	V
				0		V_s-2	0		V_s-2	0		V_s-2	
V_o	Output voltage swing	T_{amb} = 25°C	R_L = 2 KΩ			V_s-1.5			V_s-1.5				V
			$R_L \geq$ 10 KΩ									V_s-1.5	
		V_s = 30V (*)	R_L = 2 KΩ	26			26			22			V
			$R_L \geq$ 10 KΩ	27	28		27	28		23	24		
$V_{o\ sat}$	Output saturation voltage to ground	$R_L \leq$ 10 KΩ			5	20		5	20		5	100	mV
CMR	Common mode rejection	T_{amb} = 25°C		65	70		65	85		50	70		dB
SVR	Supply voltage rejection	T_{amb} = 25°C		65	70		65	100		50	70		dB
CS	Channel separation	f = 1 KHz to 20 KHz T_{amb} = 25°C (Input referred)			120			120			120		dB
$I_o{}^+$	Output source current	V_s = 15V $V_i{}^+$ = 1V $V_i{}^-$ = 0V	T_{amb} = 25°C	20	40		20	40		20	40		mA
				10	20		10	20		10	20		
$I_o{}^-$	Output sink current	$V_i{}^+$ = 0V $V_i{}^-$ = 1V V_o = 200 mV	T_{amb} = 25°C	12	50		12	50					µA
		$V_i{}^-$ = 1V $V_i{}^+$ = 0V V_s = 15V	T_{amb} = 25°C	10	20		10	20		10	20		mA
				5	8		5	8		5	8		

(*) 26V for LM2904.

(**) Short circuits from the output to positive supply voltage can cause excessive heating and eventual destruction. The maximum output current is 40 mA typ. independent of the magnitude of V_s. Destructive dissipation can result from simultaneous shorts on all amplifiers.

Fig. 1 - Supply current vs. supply voltage

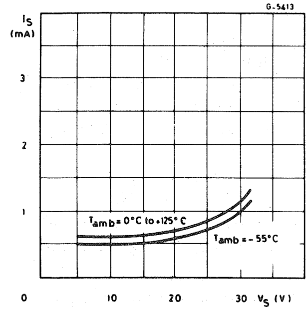


Fig. 2 - Input voltage range vs. supply voltage

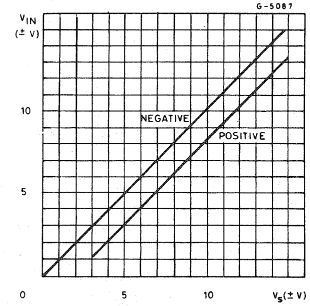


Fig. 3 - Output short circuit current vs. ambient temperature

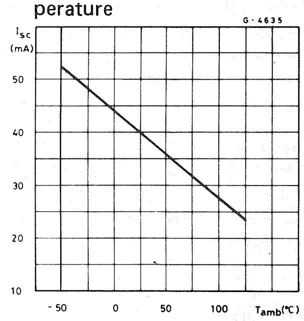


Fig. 4 - Open loop frequency reponse

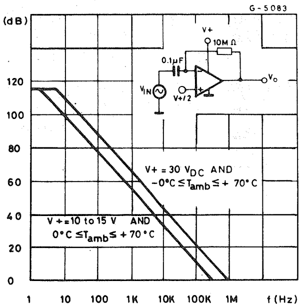


Fig. 5 - Large signal frequency response

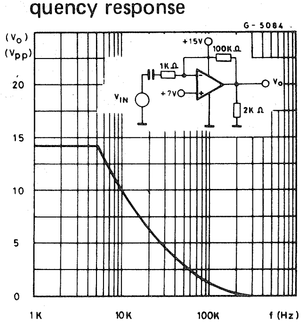


Fig. 6 - Voltage follower pulse response (small signal)

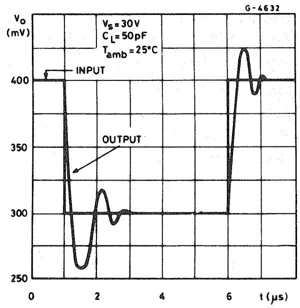


Fig. 7 - Input current

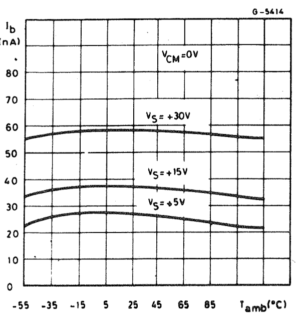


Fig. 8 - Output characteristics vs. current sourcing

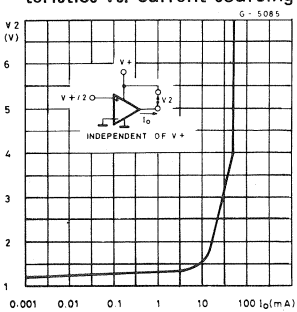
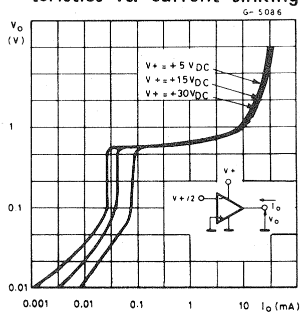


Fig. 9 - Output characteristics vs. current sinking



APPLICATION INFORMATION

The LM158 can operate with a single power supply voltage, has true-differential inputs and remains in the linear mode with an input common-mode voltage of 0V. The two included op amps work over a wide range of power supply voltage with little change in performance characteristics. At 25°C operation is possible down to a minimum supply voltage of 2.3V.

The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is V_s-15V, but either or both inputs can go to + 32V without damage.

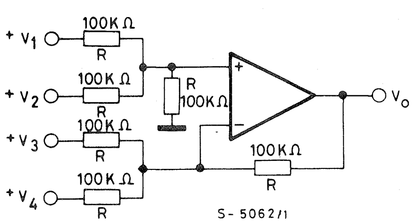
If the voltage at any of the input leads is driven negative (V_{in} < -0.3), the collector-base junction of the input PNP transistor becomes forward biased and thereby acts as an input diode clamps (max current: 50mA). In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This can cause the output voltage to go to the positive supply voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage again returns positive (V_{in} > -0.3V). The output stage design allows the amplifiers to both source and sink large output currents.

Therefore both NPN and PNP external current boost transistors can be used extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperature. **Putting direct short-circuit on more than one amplifier at a time, the total IC power dissipation will increase to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers.** The larger value of output source current which a available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

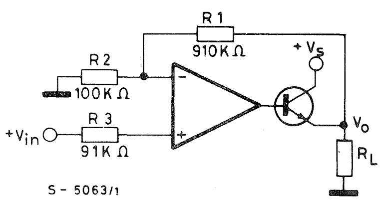
Typical single supply application circuits (V_s = 5V)

Fig. 10 - DC summing amplifier



where: $V_o = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2)' \geq (V_3 + V_4)$ to keep $V_o > 0V$

Fig. 11 - Power amplifier



V_o = 0V for V_{IN} = 0V
G_v = 20 dB

APPLICATION INFORMATION (continued)

Fig. 12 - LED driver

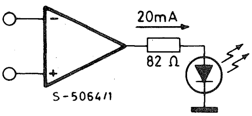


Fig. 13 - Lamp driver

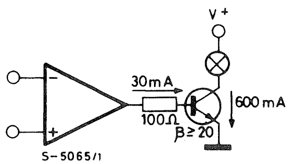
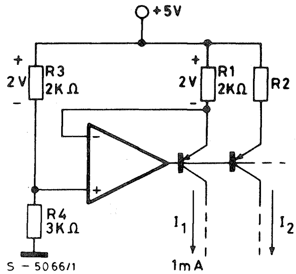
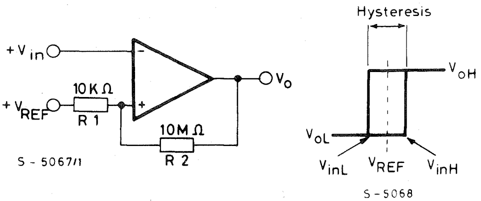


Fig. 14 - Fixed current sources



$$I_2 = \left(\frac{R1}{R2}\right) I_1$$

Fig. 15 - Comparator with Hysteresis

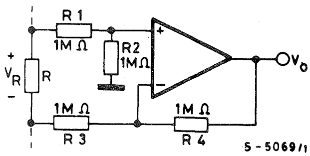


$$V_{in\,L} = \frac{R1}{R1 + R2}(V_{OL} - V_{REF}) + V_{REF}$$

$$V_{in\,H} = \frac{R1}{R1 + R2}(V_{OH} - V_{REF}) + V_{REF}$$

$$\text{Hysteresis} = \frac{R1}{R1 + R2}(V_{OH} - V_{OL})$$

Fig. 16 - Ground referencing a differential input signal



$$V_O = V_R$$

Fig. 17 - Driving TTL

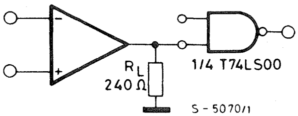
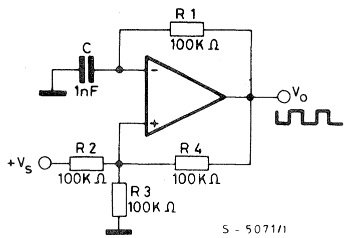
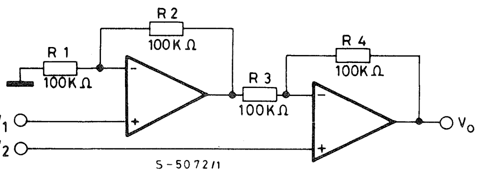


Fig. 18 - Squarewave oscillator



APPLICATION INFORMATION (continued)

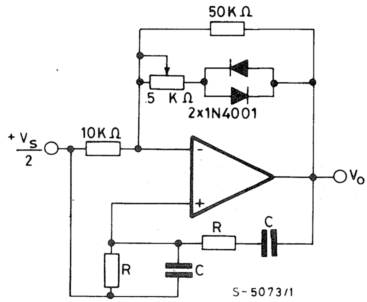
Fig. 19 - High input Z, DC differential amplifier



For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$$V_O = 1 + \frac{R4}{R3}\ (V2 - V1)$$

Fig. 20 - Wien bridge oscillator



$$f_o = \frac{1}{2\pi RC}$$

Fig. 21 - Full wave rectifier

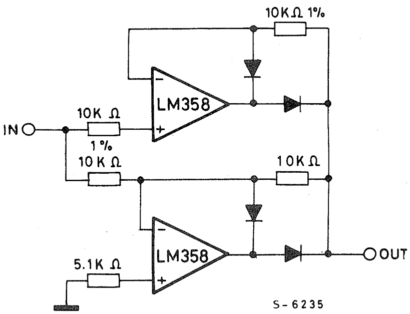


Fig. 22 - Half wave rectifier

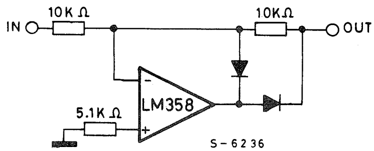
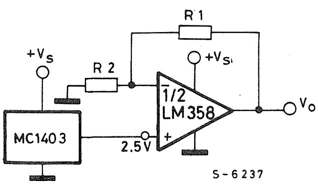
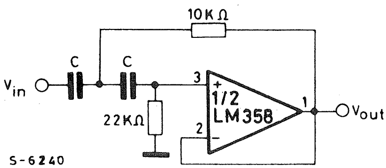


Fig. 23 - Voltage reference



$$V_o = 2.5\ V\ (1 + \frac{R1}{R2})$$

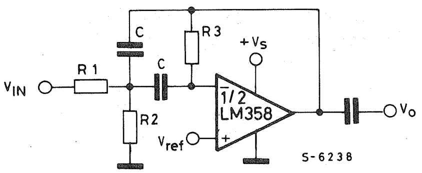
Fig. 24 - High-pass filter



$f_c = 100$ Hz with $C = 0.1\ \mu F$

APPLICATION INFORMATION (continued)

Fig. 25 - Multiple feedback bandpass filter



Given f_o = Center Frequency
$A(f_o)$ = Gain at Center Frequency

Choose Value f_o, C
Then:

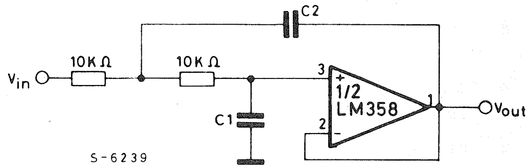
$$R3 = \frac{Q}{\pi f_o C} \; ; R1 = \frac{R3}{2A(f_o)} \; ; R2 = \frac{R1\ R3}{4Q^2\ R1 - R3}$$

For less than 10% error from operational amplifier

$$\frac{Q_o\ f_o}{BW} < 0.1$$ Where f_o and BW are expressed in Hz.

If source impedance varies, filter may be preceeded with voltage follower buffer to stabilize filter parameters.

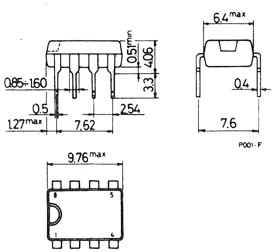
Fig. 26 - Low-pass filter



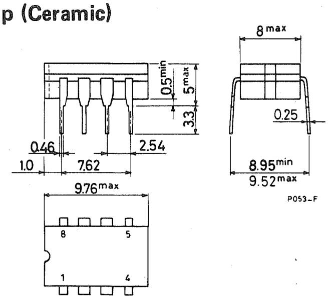
f_c = 3KHz with C1 = 3.9 nF and C2 = 6.8 nF.

MECHANICAL DATA (Dimensions in mm.)

Minidip (Plastic)



Minidip (Ceramic)



SO-8 (Micropackage)