ICL8063

Power Transistor Driver-Amplifier

FEATURES:

- **Converts ±12V Outputs from Op Amps and other linear functions to ±30V levels**
- **When used in conjunction with general-purpose op amps and external complementary power transistors, system can deliver > 50 Watts to external loads**
- **Has built-in Safe Area Protection and short-circuit protection**
- **Produces 25mA quiescent current in power amp configuration while delivering ±2 Amps output current**
- **Has built in ±13V Regulators to power op amps or other external functions**
  500kΩ input impedance with R_{BIAS} = 1MΩ

GENERAL DESCRIPTION

The ICL8063 is a unique monolithic power transistor driver and amplifier that allows construction of minimum chip power amplifier systems, complete with built in safe operating area circuitry, short circuit protection and voltage regulators. It is primarily intended for complementary symmetrical outputs.

Designed to operate with all varieties of operational amplifiers and other functions, two external power transistors of any construction technique, and 8 to 10 passive components, the ICL8063 is ideal for use in such applications as linear and rotary actuator drivers, stepper motor drivers, servo motor drivers, power supplies, power DACs and electronically controlled orifices.

The ICL8063 takes the output levels (typically ±11V) from an op amp and boosts them to ±30V to drive power transistors, (e.g. 2N3055 (NPN) and 2N3789 (PNP)). The outputs from the ICL8063 supply up to 100mA to the base leads of the external power transistors.

This amplifier-driver contains internal positive and negative regulators, to drive an op amp or numerous other functions; thus, only ±30V supplies are needed for a complete power amp.

The ICL8063 provides built-in power supplies and will operate from inputs generated by most of the op amps in use today—regardless of technology—as well as many other linear functions, such as timers, comparators and waveform generators. And it will drive almost all power transistors with breakdown voltages up to 70 volts.

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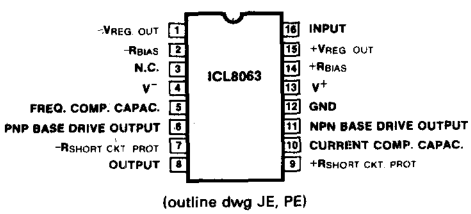
PIN CONFIGURATION

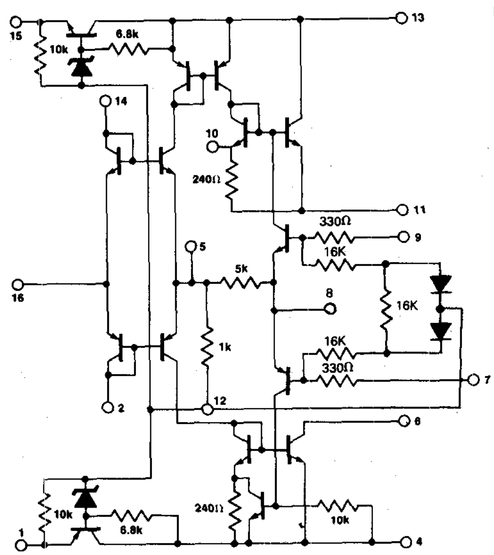


(outline dwg JE, PE)

ORDERING INFORMATION

ICL8063MJE	- CERDIP, -55°C TO 125°C
ICL8063CJE	- CERDIP, 0°C TO +70°C
ICL8063CPE	- PLASTIC DIP, 0°C TO 70°C

SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS @ T_A = 25°C

Supply Voltage	±35V
Power Dissipation	500mW
Input Voltage (Note 1)	±30V
Operating Temperature Range	ICL8063MJE −55°C to +125°C ICL8063CPE 0°C to 70°C ICL8063CJE 0°C to 70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C
Regulator Output Currents	10 mA

Note 1: For supply voltages less than ±30V the absolute maximum input voltage is equal to the supply voltage.

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

ELECTRICAL CHARACTERISTICS (@ 25°C; V_{SUPP} = ±30V)

SYMBOL	CHARACTERISTIC	TEST CONDITIONS	MIN/MAX LIMITS						UNITS
			ICL8063M			ICL8063C			
			−55°C	+25°C	+125°C	0°C	+25°C	+70°C	
V_{OS}	Max. Offset Voltage	See Figure 1	150	50	50	150	75	75	mV
I_{OH}	Min. Positive Drive Current	See Figure 2	50	50	50	40	40	40	mA
I_{OQ}	Max. Positive Output Quiescent Current	See Figure 3	500	250	250	600	300	300	μA
I_{OL}	Min. Negative Drive Current	See Figure 2	25	25	25	20	20	20	mA
I_{QL}	Max. Negative Output Quiescent Current	See Figure 4	500	250	250	600	300	300	μA
$V_{\pm REG}$	Regulator Output Voltages Range	See Figure 5	±13.7 ±1.2V	±13.7 ±1.0V	±13.7 ±1.5V	±13.7 ±1.0V	±13.7 ±1.0V	±13.7 ±1.0V	V
Z_{IN}	A.C. Input Impedance	See Figure 6	400	400	400	400	400	400	kΩ
V_{SUPP}	Power Supply Range		±5 to ±35V						V
I_Q	Power Supply Quiescent Currents		10	6	6	12	7	7	mA
A_V	Range of Voltage Gain	See Figure 7 V_{IN} = 8Vp-p	6±2	6±2	6±2	6±2	6±2	6±2	V/V
$V_{OUT(MIN)}$	Minimum Output Swing	See Figure 7; Increase V_{IN} until V_{OUT} flattens	±27	±27	±27	±27	±27	±27	V
I_{IN}	Input Bias Current	See Figure 8	100	100	100	100	100	100	μA
I_{REG}	Regulator Output Current	(See Note 2)	10	10	7	10	10	7	mA

Note 2: Care should be taken to ensure that maximum power dissipation is not exceeded.

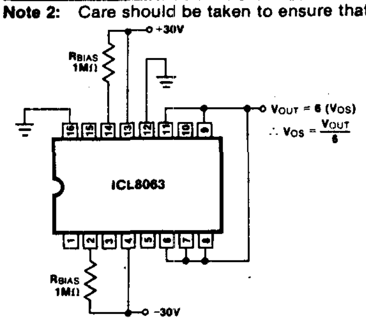


Figure 1: Offset Voltage Measurement

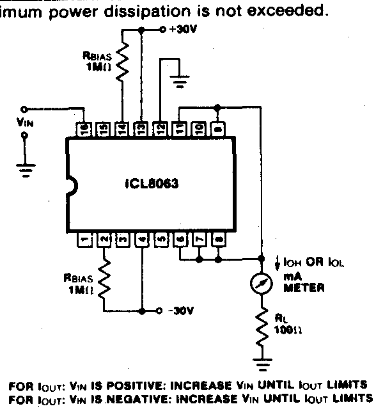


Figure 2: Output Current Measurement

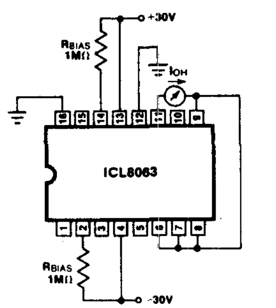


Figure 3: Positive Output Quiescent Current

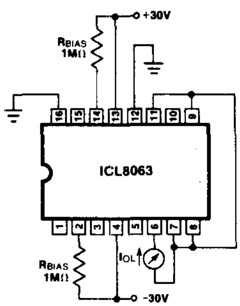


Figure 4: Negative Output Quiescent Current

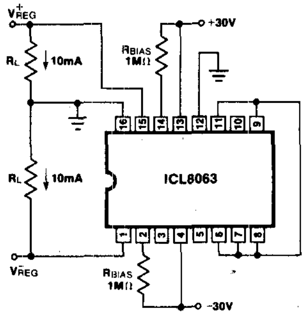


Figure 5: On Chip Regulator Measurement

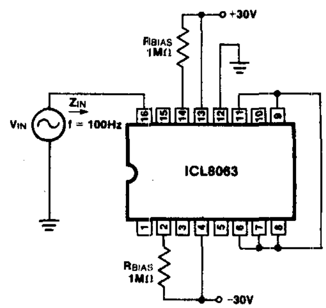


Figure 6: A.C. Input Impedance Measurement

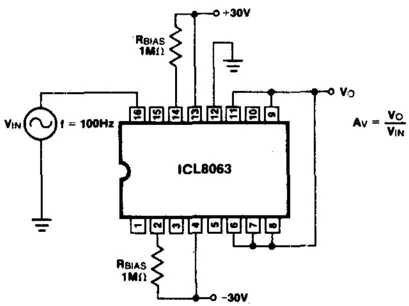


Figure 7: Gain and Output Voltage Swing Measurement

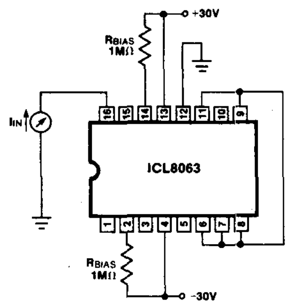


Figure 8: Input Bias Current Measurement

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APPLICATION

One problem faced almost every day by circuit designers is how to interface low voltage, low current output world of standard linear and digital devices to that of power transistors and darlingtons—higher by several orders of magnitude.

For example, a low level op amp has a typical voltage range of ±6 to ±12V, and output current usually on the order of about 5 milliamperes. A power transistor with a ±35 volt supply, a collector current of 5 amperes, and a beta, or gain of 100 needs at least 50 milliamperes of drive.

In the past, connecting two transistors with widely dissimilar requirements meant that a rather ornate discrete circuit had to be built to convert the weak output signals from the first into levels large enough to drive the second. However, in addition to converting voltage and current, it was also necessary to include a number of protection circuits to guard against damage from shorts, for example, and all this design work was both tedious and expensive.

The ICL8063 provides a solution to these problems. It's a monolithic power transistor driver and power transistor amplifier circuit on the same chip, has all the necessary safe operating area circuitry and short circuit protection, and has on-chip ±13V voltage regulators to eliminate the need for extra external power supplies.

1. Using the ICL8063 to make a complete Power Amplifier

As Figure 9 shows, using the ICL8063 allows the circuit designer to build a power amplifier block capable of delivering ±2 amperes at ±25 volts (50 watts) to any load, with only three additional discrete devices and 8 passive components. Moreover, the circuit draws only about ±30 milliamperes of quiescent current from either of the ±30V power supplies. A similar design using discrete components would require anywhere from 50 to 100 components.

Slew rate is about the same as that of a 741 op amp, except that the output current can slew up to 2 amps at roughly 1V/μs (that's a 10 ohm load to ground and ±20V output across this resistance). Input current, voltage offset, CMRR and PSRR are also the same. Use of 1,000 picofarad compensation capacitors (three in this configuration) allows good stability down to unity gain non-inverting (the worst case). This circuit will drive a 1000pF C_L to Gnd, or in other words, the circuit can drive 30 feet of RG-58 coaxial cable for line driver applications with no problems.

As Figure 10 indicates, setting up a current limiting (safe area) protection circuit is straightforward. The 0.4 ohm, 5 watt resistors set the maximum current one can get out of the output. The equation this SOA circuit follows is:

for V_{OUT} positive,

$$V_{be} = I_L R_3 - \frac{R_2}{R_1 + R_2}(V_{OUT} + I_L R_3 - 0.7V)$$

$$\approx I_L R_3 - \frac{R_2}{R_1 + R_2}(V_{OUT})$$

for V_{OUT} negative,

$$V_{be} = I_L R_3 - \frac{R_2}{R_1 + R_2 + R_4}(V_{OUT} + I_2 R_3 + 0.7)$$

$$\approx I_L R_3 - \frac{R_2}{R_1 + R_2 + R_4}(V_{OUT})$$

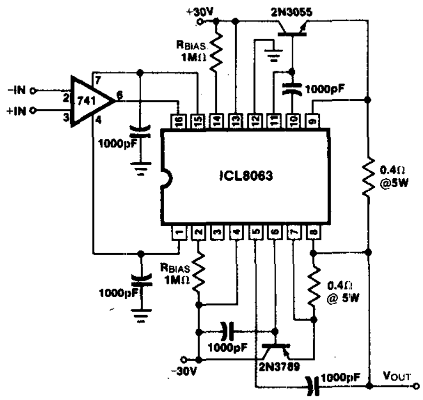


Figure 9: Standard Circuit Diagram

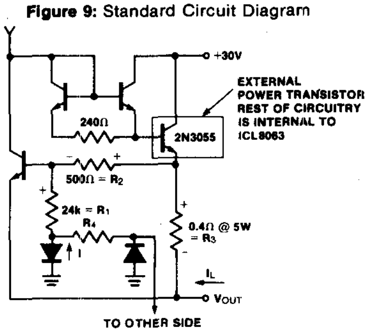


Figure 10: Current Limiting (Safe Area) Protection Circuit (one side shown)

Solving these equations we get the following:

V_{OUT}	I	I_L @ 25°C	I_L @ 125°C
24V	1mA	3 amps	2.4 amps
20V	830μA	2.8 amps	
16V	670μA	2.6 amps	
12V	500μA	2.4 amps	1.8 amps
8V	333μA	2.1 amps	
4V	167μA	1.9 amps	
0V	0μA	1.7 amps	1.1 amps

As these equations indicate, maximum power delivered to a load is obtained when $V_{OUT} \geq 24V$.

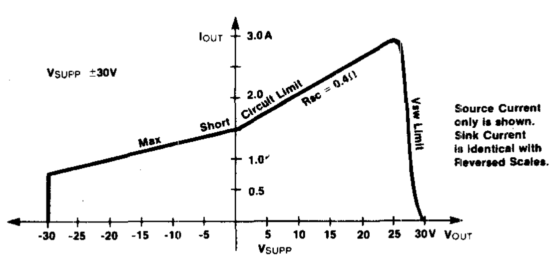
Often design requirements necessitate an unsymmetrical output current capability. In that case, instead of the 0.4 ohm resistors protecting the npn and pnp output stages, as shown in Figure 9, simply substitute any other value. For example, if up to 3 amps are required when $V_{OUT} \geq +24V$ and only 1 amp out when $V_{OUT} \geq -24V$, use a 0.4 ohm resistor between pin 8 and pin 9 on the ICL8063 and a 1 ohm, 2 watt resistor between pin 7 and pin 8. Maximum output current versus V_{OUT} for varying values of protection resistors are as follows:

V_{OUT}	0.4Ω @ 25°C	0.68Ω @ 25°C	1Ω @ 25°C
24V	3 amps	1.7 amps	1.2 amps
12V	2.4 amps	1.4 amps	0.9 amps
0V	1.7 amps	1.0 amps	0.7 amps

The biasing resistors located between pin 13 and pin 14 and between pin 2 and pin 4 are typically 1M-ohm for $V_{SUPP} = \pm30V$, which guarantees adequate performance in such applications as DC motor drivers, power DACs, programmable power supplies and line drivers (with ±30 volt supplies). The table that follows shows the proper value for R_{BIAS} for optimum output current capability with supply voltages between ±5V and ±30V.

±V_{CC}	R_{BIAS}
30V	1 MΩ
25V	680kΩ
20V	500kΩ
15V	300kΩ
10V	150kΩ
5V	62kΩ

If 30V and 1 meg ohms are used, performance curves appear as shown in Figure 11.



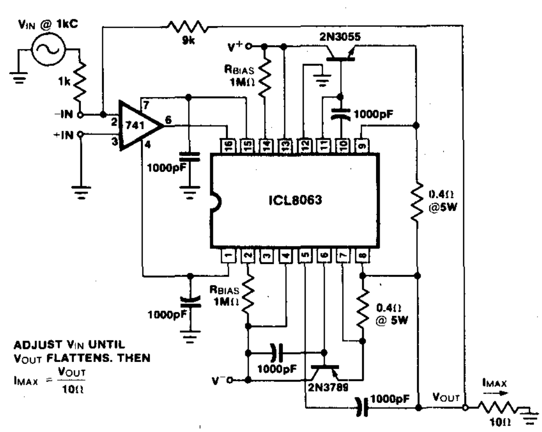


Figure 11: Typical Performance Curve of Max. Output Current Vs. V_{SUPP} For Fixed R_{BIAS} = 1MΩ

When buying external power transistors, careful attention should be paid to beta values. For 2N3055 and 2N3789 transistors used in this circuit, beta should be no more than 150 max at $I_C = 20mA$ and $V_{CE} = 30V$. This beta value sets the quiescent current at less than 30mA when not delivering power to a load.

The design in Figure 9 will tolerate a short to ground indefinitely, provided adequate heat sinking is used. However if V_{OUT} is shunted to ±30V the output transistors (2N3055 and 2N3789) will be destroyed, but since the safe operating area for these devices is 4 amps at 30 volts, the problem does not occur for $V_{SUPP} = \pm15V$.

A typical bode plot of the power amplifier system is shown in Figure 12. Referring to Figure 6, the schematic for this bode plot is shown below:

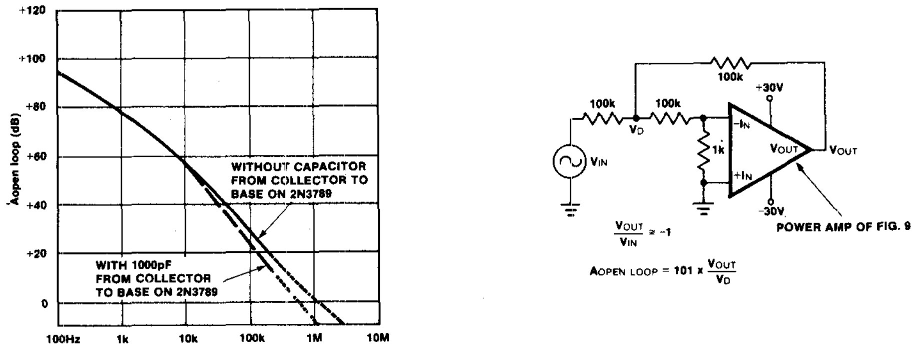


Figure 12: Bode Plot of Open Loop Gain of Above Schematic

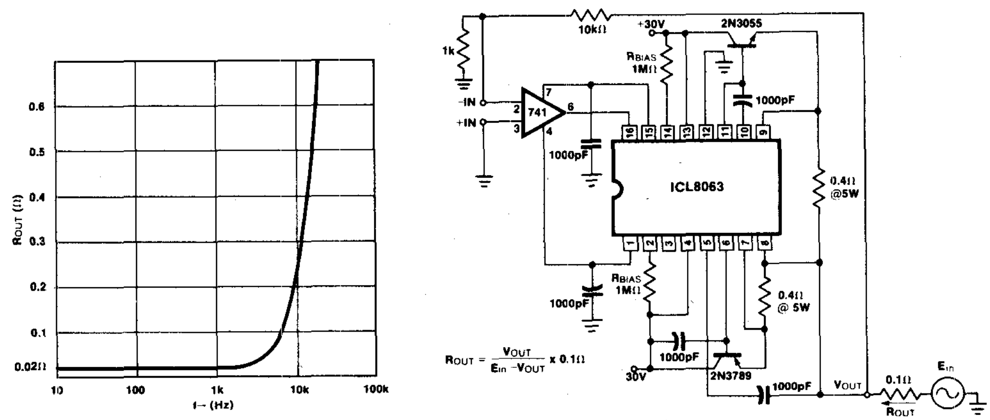


Figure 13: Typical Performance of R_{OUT} vs. Frequency of Power Amplifier System

2. Designing A Simple Function Generator

Using a variation of the fundamental power amplifier building block described in the previous section, the ICL8063 can be implemented in the design of a simple, low cost function generator (Figure 14). It will supply sine waves, triangular waves and square waves from 2 hertz to 20 kilohertz. This complete test instrument can be plugged into a standard 110VAC line for power. V_{OUT} will be up to ±25V (50V p-p) across loads as small as 10 ohms (about 2.5 amps maximum output current).

Capacitor working voltages should be greater than 50V DC and all resistors should be 1/2W, unless otherwise indicated. The interconnecting leads from the 741 pins 2 and 3 to their respective resistors should be kept short, less than 2 inches if possible; longer leads may result in oscillation.

Full output swing is possible to about 5KHz; after that the output begins to taper off due to the slew rate of the 741, until at 20KHz the output swing will be about $20V_{pp}$ (±10V). This problem can be remedied by simply using an op amp with a higher slew rate, such as the LF156.

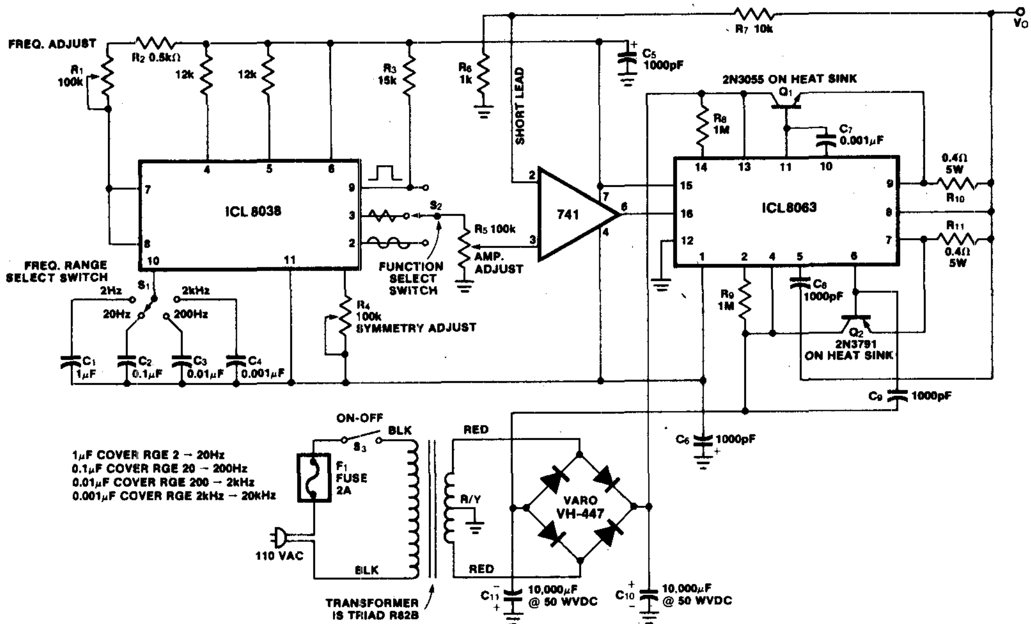


Figure 14: Power Function Generator

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3. Building a Constant Current Motor Drive Circuit

The constant current motor drive configuration shown in Figure 15 is an extremely simple circuit to construct using the ICL8063. This minimum device circuit can be used to drive DC motors where there is some likelihood of stalling or lock up; if the motor locks, the current drive remains constant and the system does not destroy itself. Using this approach two 6V batteries are sufficient for decent performance. A 10 volt input will produce one amp of output current to drive the motor, and if the motor is stalled, I_{OUT} remains at 1 amp.

For example, suppose it's necessary to drive a 24V DC motor with 1 amp of drive current. First make V_{SUPP} at least 6 volts more than the motor being driven (in this case 30 volts). Next select R_{BIAS} according to V_{SUPP} from the data sheet, which indicates $R_{BIAS} = 1M\Omega$. Then choose R_1, R_2, and R_a for optimum sensitivity. That means making $R_a = 1\Omega$ to minimize the voltage drop across R_a (the drop will be 1 amp x 1 ohm or 1 volt). If 1 amp/volt sensitivity is desirable let $R_2 = R_1 = 10k\Omega$ to minimize feedback current error. Then a ±1V input voltage will produce a ±1 amp current through the motor.

Capacitors should be at least 50 volts working voltage and all resistors 1/2W, except for those valued at 0.4 ohms, and R_a. Power across $R_a = I \times V = 1$ amp x 1 volt = 1 watt, so at least a 2 watt value should be used. Use large heat sinks for the 2N3055 and 2N3791 power transistors. A Delta NC-641 or the equivalent is appropriate. Use a thermal compound when mounting the transistor to the heat sink. (See Intersil ICH8510 data sheet).

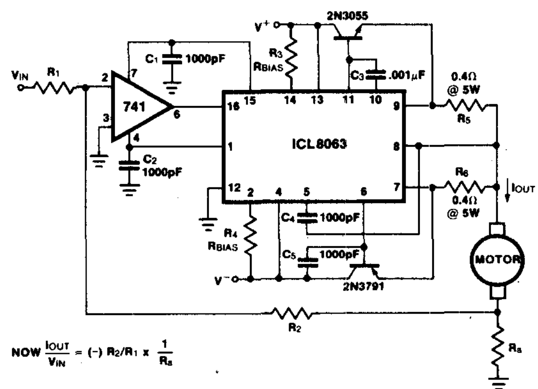


Figure 15: Constant Current Motor Drive

4. Building A Low Cost 8 ohm per channel Hi-fi Amplifier.

For about $20 per channel, it's possible to build a high fidelity amplifier using the ICL8063 to drive 8 ohm speakers. A channel is defined here as all amplification between turntable or tape output and power out. (Figure 16)

The input 741 stage is a preamplifier with R.I.A.A. equalization for records. Following the first 741 stage is a $10k\Omega$ control pot, whose wiper arm feeds into the power amplifier stage consisting of a second 741, the ICL8063 and the power transistors. To achieve good listening results, selection of proper resistance values in the power amplifier stage is important. Best listening is to be found at a gain value of 6 [(5kΩ + 1kΩ/1kΩ = 6)]. 3 is a practical minimum, since the first stage 741 preamp puts out only ±10 volt maximum signals, and if maximum power is necessary this value must be multiplied by 3 to get ±30 volt levels at the output of the power amp stage.

Each channel delivers about 56 volts p-p across an 8 ohm speaker and this converts to 50 watts RMS power. This is derived as follows:

$$\text{Power} = \frac{V_{rms}^2}{8\text{ ohms}},\quad V_{rms} = \frac{56\text{V p-p}}{2.82} = 20\text{V},\ 20\text{V}^2 = 400\text{V}^2$$

$$\therefore \text{Power} = \frac{400^2}{8\text{ ohms}} = 50\text{ watts RMS Power.}$$

Distortion will be < 0.1% up to about 100Hz, and then it increases as the frequency increases, reaching about 1% at 20kHz.

The ganged switch at the input is for either disc playing or FM, either from an FM tuner or a tape amplifier. Assuming DC coupling on the outputs, there is no need for a DC reference to ground (resistor) for FM position. To clear the signal in the FM position, place a 51kΩ resistor to ground as shown in Figure 16 (from FM input position to ground).

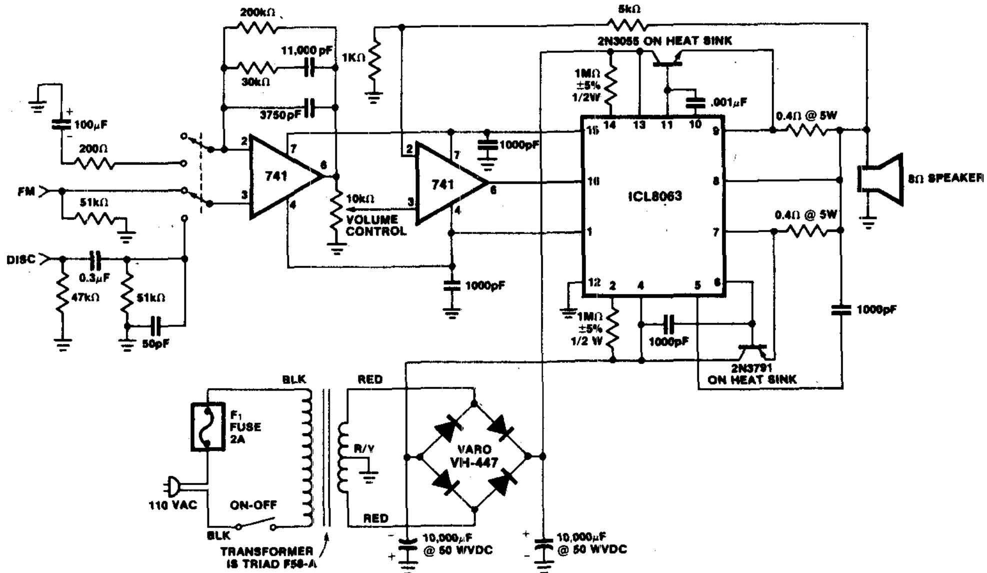


Figure 16: Hi Fi Amplifier

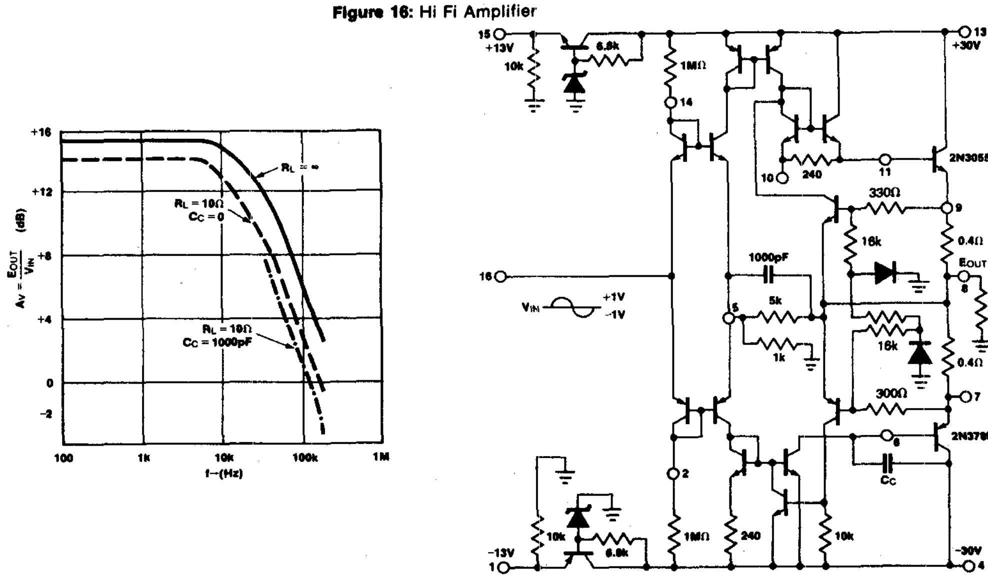
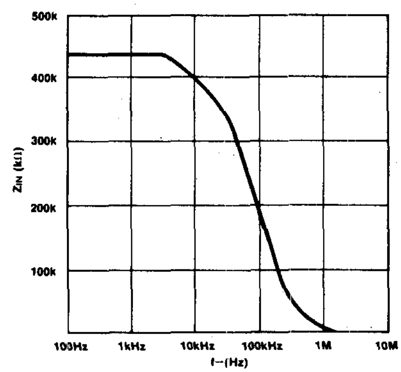


Figure 17: Typical Performance Curve of $\frac{E_{OUT}}{V_{IN}}$ vs. Frequency For Typical Circuit Shown



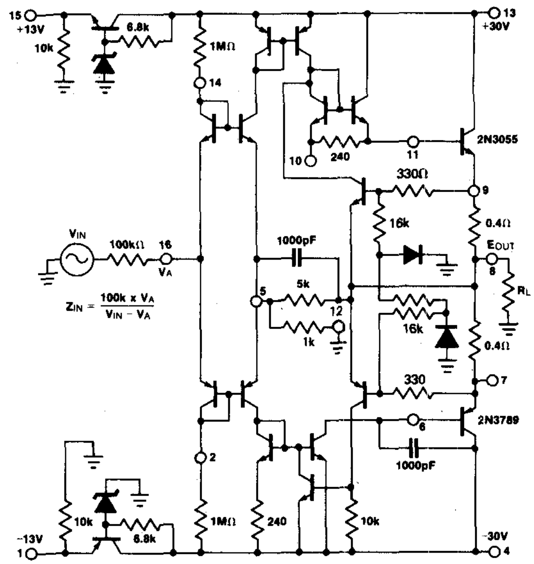
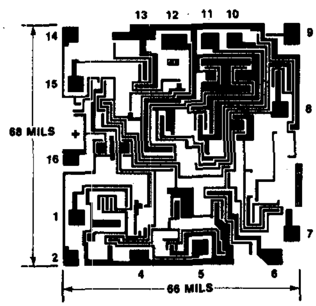


Figure 18: Typical Performance Curve of Input Impedance Versus Frequency for Typical Circuit Shown

CHIP TOPOGRAPHY



Note: Intersil offers a hybrid power amplifier similar to that shown in fig. 9. See ICH8510/8520/8530 data sheet for details.