ICH8510/8520/8530 Power Operational Amplifier

GENERAL DESCRIPTION

The ICH8510/8520/8530 is a family of hybrid power amplifiers that have been specifically designed to drive linear and rotary actuators, electronic valves, push-pull solenoids, and DC & AC motors.

There are three models available for up to +30V power supply operation: 2.7 amps @ 24 volt output levels, 2 amps @ 24V and 1 amp @ 24V. All amplifiers are protected against shorts to ground by the addition of 2 external protection resistors. For a device operating at lower voltages, see the ICH8515 data sheet.

The design uses a conventional 741 operational amplifier, a special monolithic driver chip (BL8063), NPN & PNP power transistors, and internal frequency compensating capacitors. The chips are mounted on a beryllium oxide substrate for optimum heat transfer to the metal package. This substrate also provides electrical isolation between amplifiers and metal package.

The I.C. power driver chip has built-in regulators that provide the 741 with typically a ±13V supply.

FEATURES

- Delivers Up to 2.7 Amps @ 24-28V DC (30V Supplies)
- Protected Against Inductive Kick Back With Internal Power Limiting
- Programmable Current Limiting (Short Circuit Protection)
- Package is Electrically Isolated (Allowing Easy Heat Sinking)
- Open Loop DC Gain > 100dB
- 20mA Typical Standy Quiescent Current
- Popular 8 Pin TO-3 Package
- Internal Frequency Compensation
- Can Drive Up to 0.1 Horsepower Motors

ORDERING INFORMATION

ICH85X0 M KA

- KA — Package: KA = 8 lead TO-3 can
- M — Temperature Range: M = Military −55°C to +125°C; I = Industrial −20°C to +85°C
- ICH85X0 — Basic Part Number: 8510 = 1A output; 8520 = 2A output; 8530 = 2.7A output

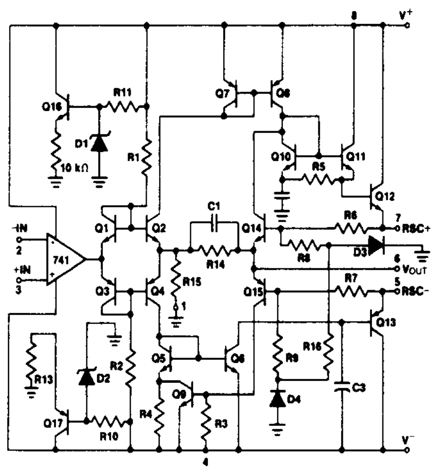


Figure 1: Functional Diagram

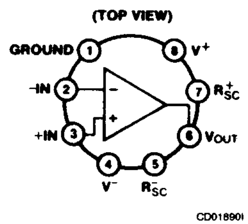


Figure 2: Pin Configuration

Note: All typical values have been guaranteed by characterization and are not tested.

ICH8510/8520/8530

ABSOLUTE MAXIMUM RATINGS @ $T_A = 25°C$

Supply Voltage .... ±32V
Power Dissipation, Safe Operating Area ...... See Curves
Differential Input Voltage .... ±30V
Input Voltage .... ±15V (Note 1)
Peak Output Current .... See Curves (Note 2)
Output Short Circuit Duration
(to ground) .... Continuous (Note 2)

Operating Temperature Range M ...... −55°C → +125°C
I .... −20°C → +85°C
Storage Temperature Range .... −65°C to +150°C
Lead Temperature (Soldering, 10sec) .... 300°C
Max Case Temperature .... 150°C

Note 1: Rating applies to supply voltages of ±15V. For lower supply voltages, $V_{INMAX} = V_{SUPP}$.

Note 2: Ratings apply as long as package dissipation is not exceeded. Device must be mounted on heat sink, see Figures 12 and 16.

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 $T_A = +25°C$. $V_{SUPPLY} = ±30V$ (unless otherwise stated)

SYMBOL	DESCRIPTION	TEST CONDITIONS	ICH8510I		ICH8510M		ICH8520I		ICH8520M		ICH8530I		ICH8530M		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$\Delta V_{OS}/\Delta Pd$	Input Offset Voltage Change with Power Dissipation	Mtd on Wakefield 403 Heat Sink		4 (Typ.)		2 (Typ.)		4 (Typ.)		2 (Typ.)		4 (Typ.)		2 (Typ.)	mV/W
V_{OS}	Input Offset Voltage	$R_S < 10k\Omega$ $Pd < 1W$	−6	+6	−3	+3	−6	+6	−3	+3	−6	+6	−3	+3	mV
I_{BIAS}	Input Bias Current	$R_S < 10k\Omega$ $P_d < 1W$		500		250		500		250		500		250	nA
I_{OS}	Input Offset Current	$R_S < 10k\Omega$ $P_d < 1W$		200		100		200		100		200		100	nA
A_{VOL}	Large Signal Voltage Gain	$R_L = 20\Omega$ $V_O > 2/3\ V_{SUPP}$	100 (Typ.)		100 (Typ.)		100 (Typ.)		100 (Typ.)		100 (Typ.)		100 (Typ.)		dB
V_{CMR}	Input Voltage Range	Typical	−10	+10	−10	+10	−10	+10	−10	+10	−10	+10	−10	+10	V
CMRR	Common Mode Rejection Ratio	$R_S = 10k\Omega$	70 (Typ.)		70 (Typ.)		70 (Typ.)		70 (Typ.)		70 (Typ.)		70 (Typ.)		dB
PSRR	Power Supply Rejection Ratio	$R_S = 10k\Omega$	77 (Typ.)		77 (Typ.)		77 (Typ.)		77 (Typ.)		77 (Typ.)		77 (Typ.)		dB
SR	Slew Rate	$C_L = 3\,pF$, $A_v = 1$ $R_L = 10\Omega$ $V_O = 2/3\ V_{SUPP}$	0.5 (Typ.)		0.5 (Typ.)		0.5 (Typ.)		0.5 (Typ.)		0.5 (Typ.)		0.5 (Typ.)		V/μs
V_{OMAX}	Output Voltage Swing	$R_L = 20\Omega$ $A_v = 10$	($R_L = 30\Omega$) ±26V		($R_L = 30\Omega$ ±26V		±26V		±26V		±25V		±25V		V
I_{MAX}	Output Current (3)	$R_L = 8\Omega$ $A_v = 10$	1.0		1.0		2.0		2.0		2.7		2.7		A
I_Q	Power Supply Quiescent Current	$R_L = \infty$ $V_{IN} = 0V$		125		100		125		100		125		100	mA

NOTE 2: See Figure 7 if Power Suplies are less than ±30V.

ELECTRICAL SPECIFICATIONS $T_A = -55°C$. to $+125°C$.(M) or $T_A = -20°C$. to $+85°C$ (I).

SYMBOL	DESCRIPTION	TEST CONDITIONS	ICH8510I		ICH8510M		ICH8520I		ICH8520M		ICH8530I		ICH8530M		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
V_{0s}	Input Offset Voltage	Pd < 1W	−10	+10	−9	+9	−10	+10	−9	+9	−10	+10	−9	+9	MV
I_{BIAS}	Input Bias Current	Pd < 1W		1500		750		1500		750		1500		750	nA
I_{OS}	Input Offset Current			500		200		500		200		500		200	nA
A_{VOL}	Large Signal Voltage Gain	$R_L = 20\Omega$ $\Delta V_O = 2/3\ V_{SUPP}$	90 (Typ.)		90 (Typ.)		90 (Typ.)		90 (Typ.)		90 (Typ.)		90 (Typ.)		dB
V_{OMAX}	Output Voltage Swing	$R_L = 20\Omega$, $A_V = 10$	±24		±24		±24		±24		±24		±24		V
$R_{\theta JA}$	Thermal Resistance Junction to Ambient	Without Heat Sink		40 (Typ.)		40		40		40		40		40	°C/W
$R_{\theta JC}$	Thermal Resistance Junction to Case			2.5 (Typ.)		2.5 (Typ.)		2.5 (Typ.)		2.5 (Typ.)		2.5 (Typ.)		2.5 (Typ.)	°C/W
$R_{\theta JA}$	Thermal Resistance Junction to Ambient	Mtd. on Wakefield 403 Heat Sink		(Typ.) 4.0		(Typ.) 4.0		(Typ.) 4.0		(Typ.) 4.0		(Typ.) 4.0		(Typ.) 4.0	°C/W
V_{SUPP}	Supply Voltage Range		±20	±30	±20	±30	±20	±30	±20	±30	±20	±30	±20	±30	V

Note: All typical values have been guaranteed by characterization and are not tested.

ICH8510/8520/8530

How To Set The Externally Programmable, Current Limiting Resistors:

The maximum output current is set by the addition of two external resistors, $R_{SC(+)}$ and $R_{SC(-)}$. Due to the current limiting circuitry, maximum output current is available only when V_O is close to either power supply. As V_O moves away from V_{SUPPLY}, the maximum output current decreases in proportion to output voltage. The curve on the next page shows maximum output current versus output voltage.

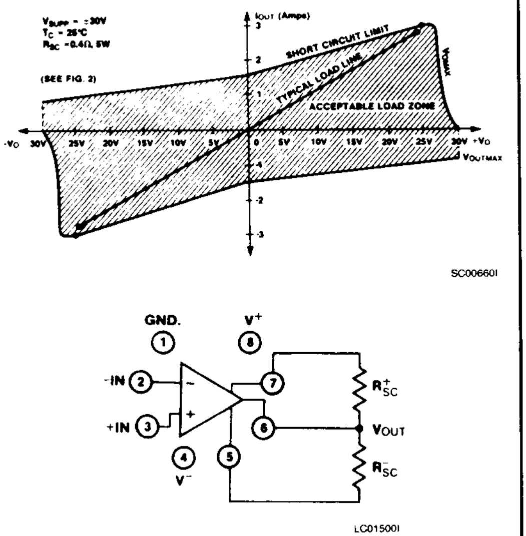


Figure 3: Maximum Output Current for Given R_{SC}

In general, for a given V_O, I_{SC} limit, and case temperature T_C, R_{SC} can be calculated from the equation below for V_O positive, I_{OUT} positive.

$$R_{SC} = \frac{(20.6V_O)^* + 680 - 2.2(T_C - 25°C)}{I_{SC(LIMIT)}}$$

*For V_O negative, replace this term with 10.3 (V_O – 1.2)

For example, for I_O = 1.5A @ V_O = 25V and T_C = 25°C,

$$R_{SC} = \frac{1195}{1500} = 0.797$$

Therefore for this application, $R_{SC} = 0.82\Omega$ (closest standard value)

When 0.82Ω is used, I_{SC} @ V_O = 0V will be reduced to about 1A. Except for small changes in the "$\pm V_{O(max)}$ Limit" area, the effects of changing R_{SC} on the I_{OUT} vs V_{OUT} characteristics can be determined by merely changing the I_{OUT} scale on Figure 3 to correspond to the new value. Changes in T_C move the limit curve bodily up and down.

This internal current limiting circuitry however does not at all restrict the normal use of the driver. For any normal load, the static load line will be similar to that shown in Figure 3.

Clearly, as V_O decreases, the I_O requirement falls also, more steeply than the I_O available. For reactive loads, the dynamic load lines are more complex. Two typical operating point loci are sketched here:

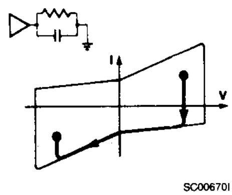


Figure 4: Capacitive Load

Thus the limiting circuitry protects the load and avoids needless damage to the driver during abnormal conditions. For any 24-28VDC motor/actuator, the R_{SC} resistors must be calculated to get proper power delivered to the motor (up to a maximum of 2.7A) and V_{SUPP} set at ±30V. For lower supply and/or output voltages, the maximum output current will follow graphs.

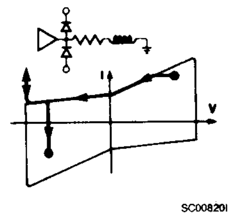


Figure 5: Inductive Load (Note catch diode)

NOTE ON AMPLIFIER POWER DISSIPATION

The steady state power dissipation limit is given by

$$P_D = \frac{T_{J(MAX)} - T_A}{R_{\theta JC} + R_{\theta CH} + R_{\theta HA}}$$

where:

T_J = Maximum junction temperature

T_A = Ambient temperature

$R_{\theta JC}$ = Thermal resistance from transistor junction to case of package

$R_{\theta CH}$ = Thermal resistance from case to heat sink

$R_{\theta HA}$ = Thermal resistance from heat sink to ambient air

And since

T_J = 200°C for silicon transistors

$R_{\theta JC} \cong$ 2.0°C/W for a steel bottom TO-3 package with die attachment to beryllia substrate header

$R_{\theta CH}$ = .045°C/W for 1 mil thickness of Wakefield type 120 thermal joint compound
.09°C/W for 2 mil thickness of type 120
.13°C/W for 3 mil thickness of type 120
.17°C/W for 4 mil thickness for type 120
.21°C/W for 5 mil thickness of type 120
.24°C/W for 6 mil thickness of type 120

4

Note: All typical values have been guaranteed by characterization and are not tested.

$R_{\theta HA}$ = The choice of heat sink that a user selects depends upon the amount of room available to mount the heat sink. A sample calculation follows: by choosing a Wakefield 403 heat sink, with free air, natural convection (no fan). $R_{\theta HA} \cong 2.0°C/W$. Using 4 mil joint compound,

$$P_D = \frac{200°C - T_A}{(2.0 + 0.17 + 2.0)°C/W} = \frac{200°C - T_A}{4.17°C/W}$$

or @ $T_A = 25°C$,

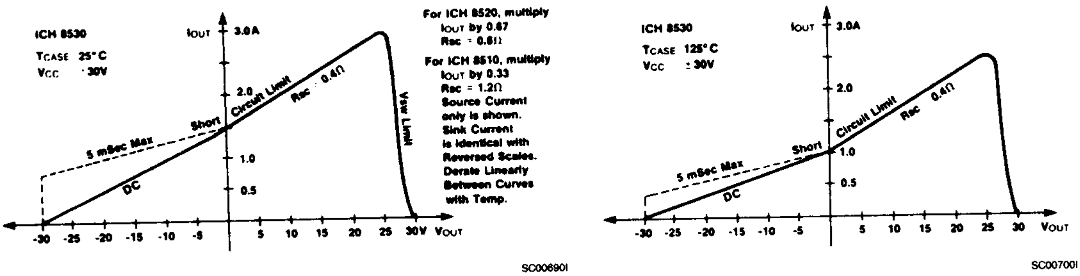
$$\frac{200°C - 25°C}{4.17°C/W} = 42W$$

and @ $T_A = 125°C$,

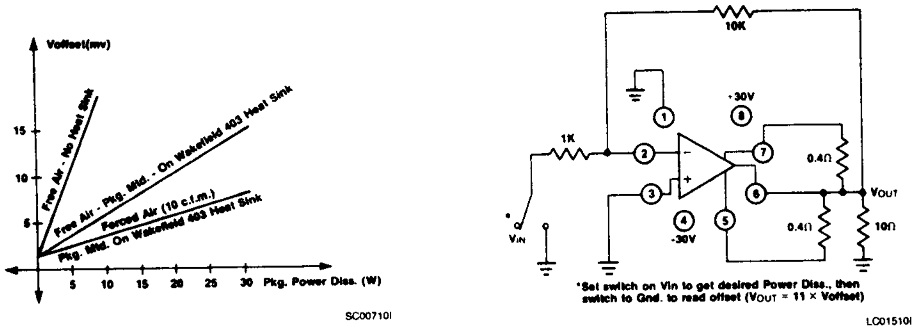
$$\frac{200°C - 125°C}{4.17°C/W} = 18W$$

From Figure 6 the worst case steady state power dissipation for an IH8520 ($R_{SC} = 0.62\Omega$) is about 30W and 18W respectively. Thus this heat sink is adequate.

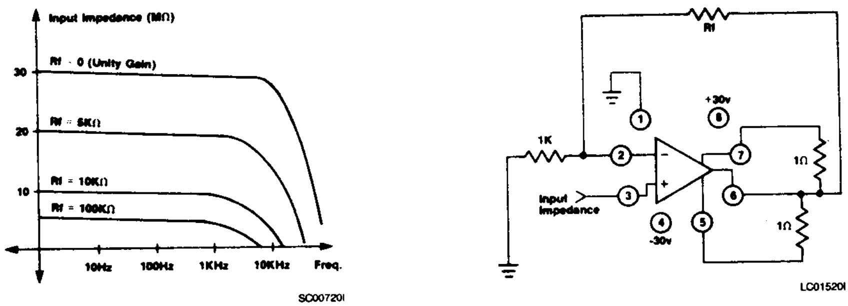
TYPICAL PERFORMANCE CHARACTERISTICS



Safe Operating Area; I_{OUT} vs V_{OUT} vs T_C



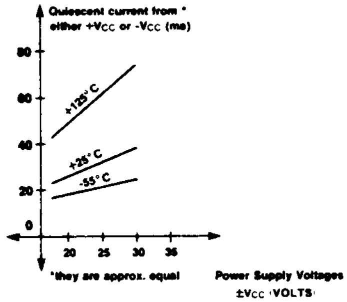
Input Offset Voltage vs Power Dissipation



Input Impedance vs Gain vs Frequency

Note: All typical values have been guaranteed by characterization and are not tested.

TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)



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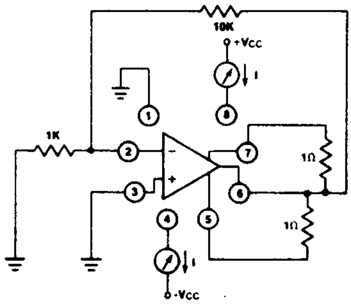

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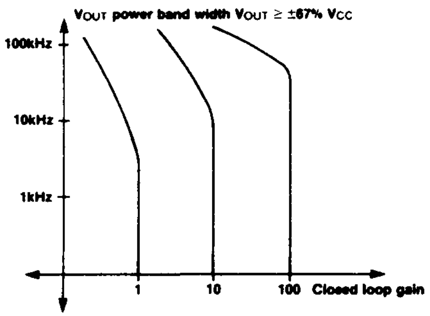
Quiescent Current vs Power Supply Voltage



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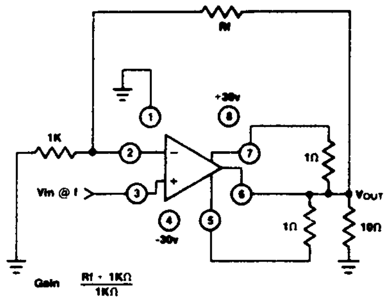
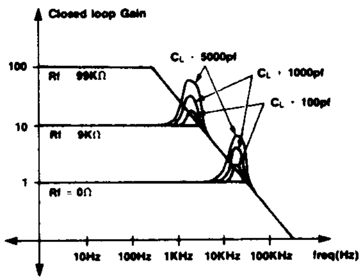


LC01540I

Large Signal Power Bandwidth



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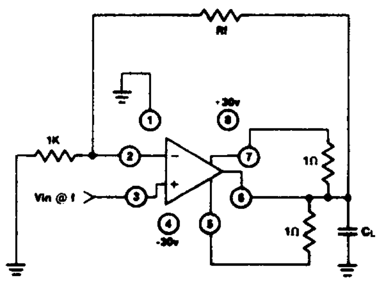


LC01550I

Small Signal Frequency Response

Note: All typical values have been guaranteed by characterization and are not tested.

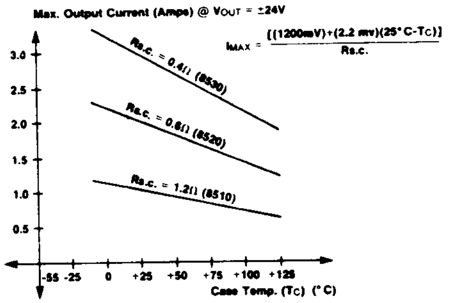


Figure 6: Maximum Output Current vs. Case Temperature

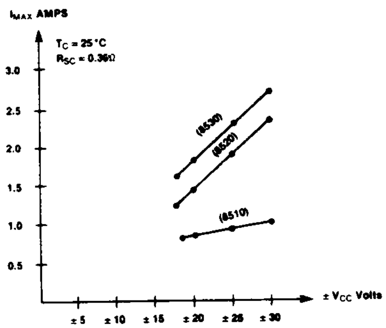


Figure 7: Maximum Output Current vs. V_{SUPPLY}

APPLICATION NOTES

The maximum input voltage range, for $V_{SUPPLY} < \pm15V$, is substantially less than the available output voltage swing. Thus non-inverting amplifiers, as in Figure 8, should always be set up with a gain greater than about 2.5, (with ±30V supplies), so that the full output swing is available without hazard to the input. At first sight, it would seem that no restrictions would apply to inverting amplifiers, since the inputs are virtual ground and ground. However, under fault (output short-circuited) or high slew conditions, the input can be substantially removed from ground. Thus for inverting amplifiers with gains less than about 5, some protection should be provided at this input. A suitable resistor from the input to ground will provide protection, but also increases the effect of input offset voltage at the output. A pair of diodes, as shown in Figure 10, has no effect on normal operation, but gives excellent protection.

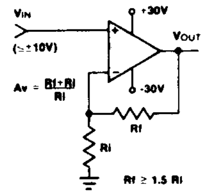


Figure 8: Non-Inverting Amplifier

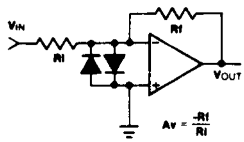


Figure 9: Inverting Amplifier

Power dissipation is another important parameter to consider. The current protection circuit protects the device against short circuits to ground, (but only for transients to the opposite supply) provided the device has adequate heat sinking. A curve of power dissipation vs V_O under short circuit conditions is given in Figure 10. The limiting circuit is more closely dependent on case temperature than (output transistor) junction temperatures. Although these operating conditions are unlikely to be attained in actual use, they do represent the limiting case a heat sink must cope with. For a fully safe design, the anticipated range of V_O values that could occur, (steady state, including faults) should be examined for the highest power dissipation, and the device provided with a heat sink that will keep the junction temperature below 200°C and the case temperature below 150°C with the worst case ambient temperature expected.

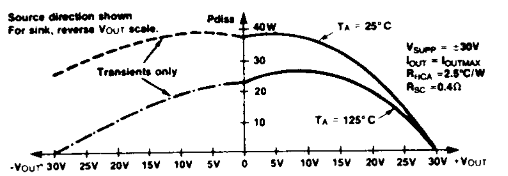


Figure 10: Power Dissipation under Short Circuit Conditions

Note: All typical values have been guaranteed by characterization and are not tested.

TYPICAL APPLICATIONS

Actuator Driving Circuit (24→28 VDC rated)

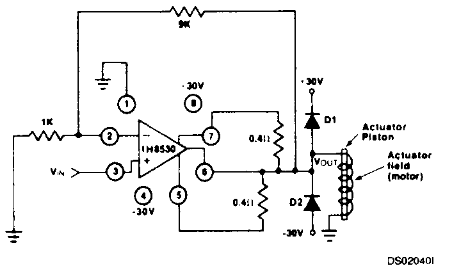


Figure 11: Power Amp Driving Actuator

The gain of the circuit is set to +10, so a V_{IN} = +2.4V will produce a +24V output (and deliver up to 2.7 amps output current). To reverse the piston travel, invert V_{IN} to −2.4V and V_{OUT} will go to −24V. Diodes D1 and D2 absorb the inductive kick of the motor during transients (turn-on or turn-off); their breakdown should exceed 60V.

Obtaining Up To 5 Amps Output Current Capability By Paralleling Amplifiers

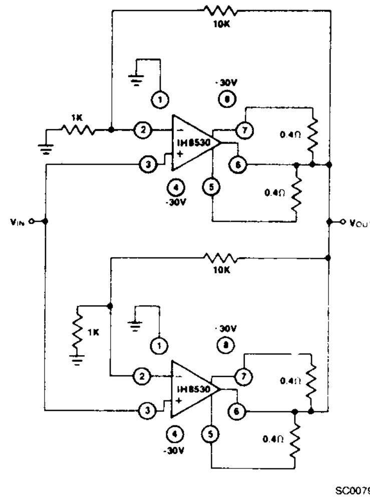


Figure 12: Paralleling Power Amps for Increased Current Capability

This paralleling procedure can be repeated to get any desired output current. However, care must be taken to provide sufficient load to avoid the amplifiers pulling against each other.

Driving A 48VDC Motor

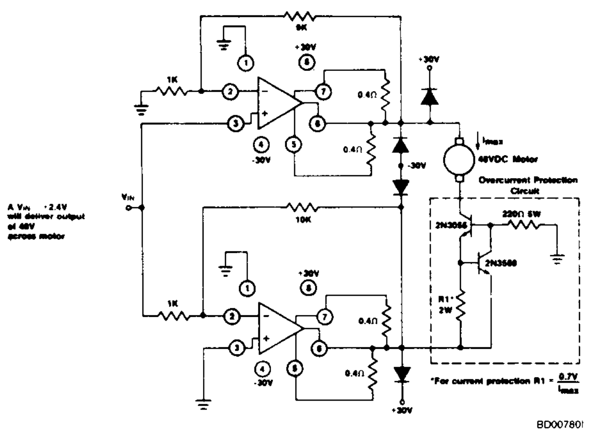


Figure 13: Power Amp Driving 48 VDC Motor

Note: All typical values have been guaranteed by characterization and are not tested.

Precise Rate Control of an Electronic Valve

There are two methods to get very fine control of the opening of an orifice driven by an electronic valve.

1. Keep the voltage constant, i.e., 24VDC or 12VDC, and vary the time the voltage is applied, i.e., if it takes five seconds to completely open an orifice at 24VDC, then applying 24V for only 2½ seconds opens it only 50%.
2. Simply vary the DC driving voltage to valve. Most valves obtain full opening as an inverse of applied voltage, i.e., valves open 100% in five seconds at 24VDC and in 10 seconds at 12VDC.

A circuit to perform the second method is shown below; the advantage of this is that digit switches can precisely set driving voltage to 0.2% accuracy (8-bit DAC), thereby controlling the rate at which the valve opens.

The circuit presented in Figure 14 is also an excellent way to get a precise power supply voltage; in fact, it is possible to build a precision variable power supply using a BCD coded DAC with BCD Thumbwheel switches.

There is great power available in the sub-systems shown in Figures 14 & 15; there the D/A converter is shown being set manually (via digit switches) to get a precise analog output (binary # x full scale voltage), then the driver amplifier multiplies this voltage to produce the final output voltage. It seems obvious that the next logical step is to let a microprocessor control the D/A converter. Then total, pre-programmable, electronic control of an actuator, electronic valve, motor, etc., is obtained. This would be used in conjunction with a transducer/multiplex system for electronic monitoring and control of any electromechanical function.

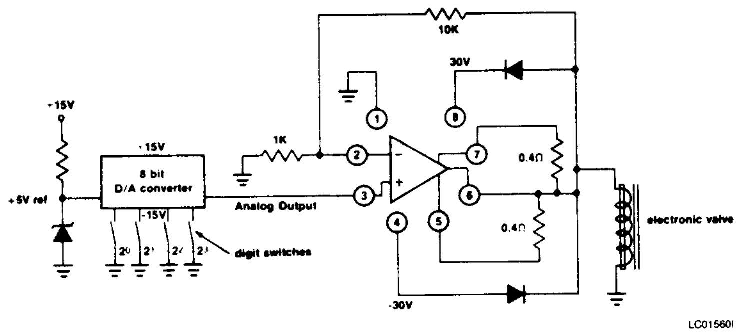
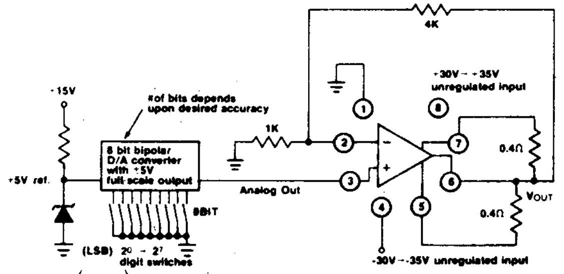


Figure 14: Digitally Controlled Electronic Value

Note: All typical values have been guaranteed by characterization and are not tested.



$V_{OUT} = \pm 5V \left(\frac{4K + 1K}{1K}\right) \times$ digital # set by Sws. and can deliver up to 3 amps.

LC015701

2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	0 BIT	V_{out}
1	1	1	1	1	1	1	1	1	+25VDC
1	1	1	1	1	1	1	1	0	-25VDC
0	1	0	1	1	0	0	1	1	+15VDC
0	1	0	1	1	0	0	1	0	-15VDC
1	0	0	0	0	0	0	0	1	+0.098VDC
1	0	0	0	0	0	0	0	0	-0.098VDC

The power supply can be set set to ±0.1VDC.

Figure 15: Digitally Programmable Power Supply

HEAT SINK INFORMATION

Heat sinks are available from Intersil. Order part number 29-0305 ($10.00 ea.) with a $R_{\theta HA}$ = 1.3°C/watt. A convenient mating connector is also available. Order part number 29-0306 ($4.50 ea.).

Note: This product contains Beryllia. If used in an application where the package integrity may be breached and the internal parts crushed or machined, avoid inhalation of the dust.

APPLICATION NOTES

For Further Applications Assistance, See:

A021 "Power D/A Converters Using The ICH8510/20/30," by Dick Wilenken
A026 "DC Servo Motor Systems Using The ICH8510/20/30," by Ken McAllister
A029 "Power Op Amp Heat Sink Kit," by Skip Osgood

Note: All typical values have been guaranteed by characterization and are not tested.