EL2027
Low Voltage Servo Motor Driver

Features

- +5V Supply
- Low power consumption mode
- Integral 0.4 ampere H bridge
- Bridge V_{SAT} <0.6V @ 0.25A
- Low voltage detection and retract
- Head park with low aux. supply
- 4:1 gain switch input
- Low crossover distortion
- Input amplifier/filter
- Only one sense resistor needed
- Voltage reference included
- Surface mount SOL package

Applications

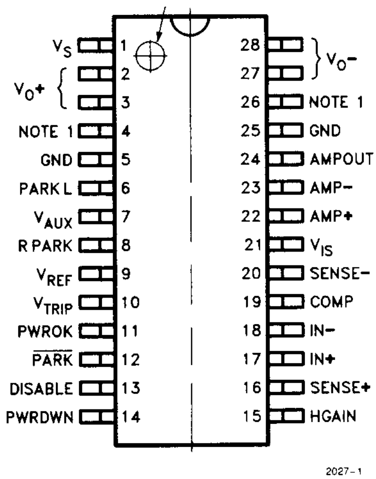
- 2.5", 3.5" Disk head positioning

Ordering Information

Part No.	Temp. Range	Package	Outline #
EL2027CM	0°C to +75°C	SOL	MDP0027

Connection Diagram

28-Pin SOL Package



Top View

Note 1: Pins 4 and 26 must be open.

General Description

The EL2027 is a servo motor driver designed to drive voice coil motors in disk drive applications. This circuit operates on +5V supply only, consumes minimum amount of quiescent current and has a power down mode to conserve battery power in portable computers. The EL2027 contains an H bridge consisting of bipolar power transistors and protection diodes and a patented low saturation voltage drive circuit.

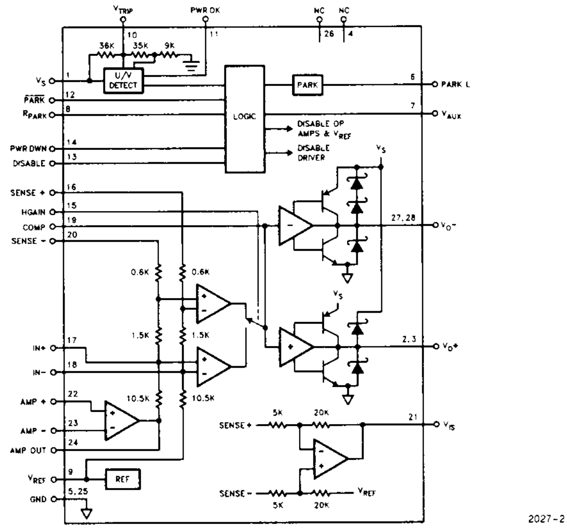
The EL2027 contains gain resistors and the transconductance can be changed (via the HGAIN logic input) by a factor of 4 to optimize the track and seek performance. The input signal amplifier can be configured to low pass or notch filter the input signal. Crossover distortion is eliminated by Class AB biasing of the output transistors with a patented temperature stable adjustment free circuit.

System accuracy is improved by using one current sense resistor in series with the motor. All of the critical bias voltages use the same internally generated voltage reference. This reduces the output offset current. The reference voltage can source or sink current to bias external DAC, PWM or other circuitry.

The undervoltage detector or a logic input triggers the Park circuit. The Park circuit forces a programmable voltage across the motor and disables all inputs. The park circuit operates from the back EMF of the spindle motor (down to 1.5V at the chip) when the main supply is removed.

The EL2027 is manufactured under U.S. patents 4,910,477 and 4,935,704.

Block Diagram



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Absolute Maximum Ratings

V_S	Supply Voltage, Pin 1	−0.3V to +7V
V_{AUX}	Auxiliary Supply Voltage, Pin 8	V_S −1 to +7V
V_{IN}	Logic Inputs, Pins 12, 13, 14, 15	−0.3 to +7V
	Signal Inputs	−0.3 to +7V
I_{OUT}	Output Current, Pins 27, 28, and 2, 3	500 mA
	Amplifier Output Current, Pins 21, 24	5 mA
	Reference Output Current, Pin 9	5 mA
T_J	Junction Temperature	150°C
T_A	Operating Temperature Range	0°C to +75°C
	Lead Temperature	
	SOL Package	
	Vapor Phase (60 seconds)	215°C
	Infrared (15 seconds)	220°C
T_{ST}	Storage Temperature	−65°C to +150°C
P_D	Power Dissipation, T_A = 25°C	
	SOL Package	1.50W

Important Note:
All parameters having Min/Max specifications are guaranteed. The Test Level column indicates the specific device testing actually performed during production and Quality inspection. Elantec performs most electrical tests using modern high-speed automatic test equipment, specifically the LTX77 Series system. Unless otherwise noted, all tests are pulsed tests, therefore $T_J = T_C = T_A$.

Test Level	Test Procedure
I	100% production tested and QA sample tested per QA test plan QCX0002.
II	100% production tested at T_A = 25°C and QA sample tested at T_A = 25°C, T_{MAX} and T_{MIN} per QA test plan QCX0002.
III	QA sample tested per QA test plan QCX0002.
IV	Parameter is guaranteed (but not tested) by Design and Characterization Data.
V	Parameter is typical value at T_A = 25°C for information purposes only.

Electrical Characteristics $T_A = T_J = 25°C, V_S = V_{AUX} = 5V, R_S = 1\Omega, R_L = 16\Omega$

Parameter	Description	Limits			Test Level	Units
		Min	Typ	Max		
Enabled Mode, Pin 13 = L, Pin 14 = L, Pin 12 = H, Pin 15 = H						
G_{MH}	Transconductance, I_{OUT} = ±200 mA	180	200	220	I	mA/V
G_{ML}	Transconductance, I_{OUT} = ±50 mA, Pin 15 = L	47	50	53	I	mA/V
G_{RATIO}	G_{MH}/G_{ML}	3.8		4.2	I	
V_{CM}	Voltage @ V_O-, V_O+	1.8	2.2	2.6	I	V
I_{OSP1}	Output Offset Current, Pin 22 Driven, Pin 15 = L	−2		+2	I	mA
I_{OSP2}	Output Offset Current, Pin 22 Driven, Pin 15 = H		0.6		V	mA
THD	Total Harmonic Distortion, V_{IN} = ±20 mV, Pin 22 Driven		0.3	1	I	%
I_{SE}	Total Quiescient Supply Current, Pins 7 and 1			18	I	mA
I_{SA}	Auxiliary Quiescent Supply Current, Pin 7		2.8	4	I	mA
PSR	Motor Current Supply Rejection, V_S and V_{AUX} = 4.5V, 5.5V, Pin 15 = L		0.2	1	IV	mA/V
V_{OP}	Differential Voltage Swing	±4.25	4.55		I	V
I_{OM}	Output Current	±250			I	mA
I_{OH1}	ParkL Output Leakage High, $V_{ParkL} = V_S$		0	1	IV	µA
Park Mode, Pin 13 = L, Pin 14 = L, Pin 12 = L, Pin 15 = H						
V_{RPARK}	Voltage at R_{PARK}, R_L = 3.0k	0.46		0.69	I	V
I_{AR}	Auxiliary Supply Range, R_L = 3.0 kΩ ($0.4 \le (V_O- - V_O+) \le 0.69$)	1.6		6	I	V
I_{SAP}	Short Circuit Maximum Current (V_O- = 0V)	100	175		I	mA
V_{OL1}	ParkL Output Low Voltage (I = 1.6 mA)			0.8	I	V
I_{OH2}	PwrOK Output Current High (V = 2.0V)	0.5			I	mA

Electrical Characteristics $T_A = T_J = 25°C, V_S = V_{AUX} = 5V, R_S = 1\Omega, R_L = 16\Omega$ — Contd.

Parameter	Description	Limits Min	Limits Typ	Limits Max	Test Level	Units
Disable Mode, Pin 13 = H, Pin 14 = L, Pin 12 = H, Pin 15 = H						
I_{OD}	Motor Leakage Current		±1	±200	I	μA
R_{OD}	Output Resistance, $I_{OUT} = \pm 1$ mA		3		V	kΩ
I_{SD}	Total Supply Current, Pins 1 and 7			8	I	mA
Power Down Mode, Pin 13 = H, Pin 14 = H, Pin 12 = H, Pin 15 = H						
I_{OP}	Motor Leakage Current			±200	I	μA
R_{OP}	Output Resistance, $I_{OUT} = \pm 1$ mA		3		V	kΩ
I_{SP}	Total Supply Current, Pins 1 and 7		1.75	3.0	I	mA
Input Amplifier						
V_{OS1}	Offset Voltage	−2		2	IV	mV
I_{OS1}	Offset Current	−100	0	+100	IV	nA
I_{B1}	Bias Current	−500	0	+500	IV	nA
V_{BUF}	Output Voltage Range	0.9		3.5	I	V
A_{VOL}	Open Loop Gain	4	6		IV	V/mV
Voltage Reference						
V_{REF}	Reference Voltage Value	2.1		2.3	I	V
R_{VR}	Reference Voltage Regulation $I_L = \pm 1$ mA		3		V	mV/mA
Power Amplifier						
A_{VP}	Power Amplifier Voltage Gain	6.5	7.5	8.5	I	V/V
Undervoltage Detector						
V_{STF}	Trip Point, VS Falling	3.7		4.3	I	V
V_{HYS}	Trip Point Hysteresis	200		500	I	mV
I_{OL1}	PowerOK Output Leakage Current Low			10	I	μA
V_{OL2}	ParkL Output Voltage Low, $I_{ParkL} = 1.6$ mA			0.8	I	V
Motor Current Sense Amp						
A_{VIS}	Voltage Gain, Pin 22 Driven	3.9		4.1	I	V/V
V_{VIS}	Output Voltage Range	0.9		3.5	I	V
V_{OS2}	Output Offset Voltage, Sense+ = Sense− = V_{REF}			±10	I	mV
Logic Inputs Hgain, PwrDwn, Disable, $\overline{PARK}$						
V_{IL}	Low Level Voltage to a Valid Low			0.8	I	V
I_{IL}	Low Level Input Current, $V_{IN} = 0V$		30	100	IV	μA
V_{IH}	High Level Input for a Valid High	2			I	V
I_{IH}	High Level Input Current, $V_{IN} = 5V$		0	+1	IV	μA

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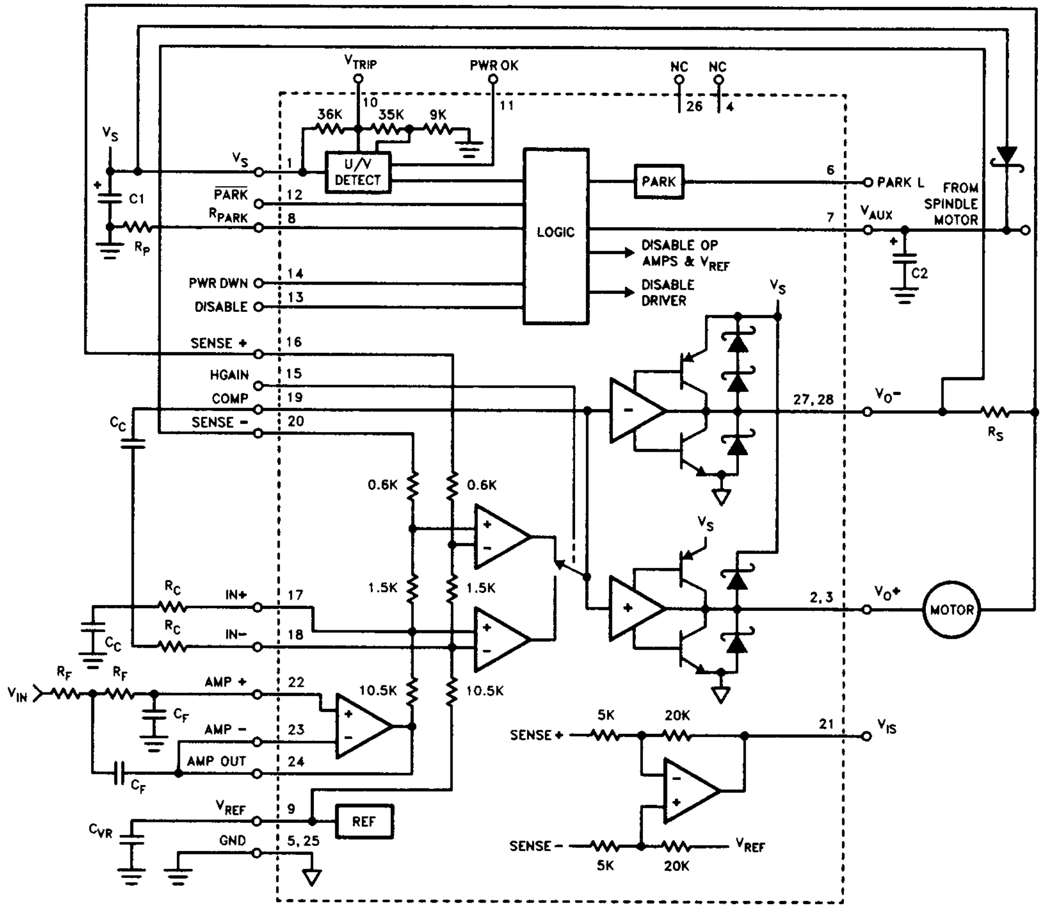
Typical Application



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External Components

Parameter	Description	Min	Typ	Max	Units	Typical ± % Tolerance
R_P	Sets the Motor Voltage During PARK Mode	1.0	3.0		kΩ	5
C_{VR}	Voltage Reference Bypass Cap			0.01	μF	NA
R_S	Current Sense Resistor		1		Ω	1
C_C	Loop Compensation. Sets Dominant Pole				pF	5
R_C	Loop Compensation. Makes a Zero, Equal to Motor Pole	0	10		kΩ	5
C_F	Sets Input Low Pass Filter				Ω	5
R_F	Sets Input Low Pass Filter				μF	10

$R_P = V_P / 190\ \mu A$

$R_S = 1/(5 \times \text{DC Transimpedance (High Gain)})$

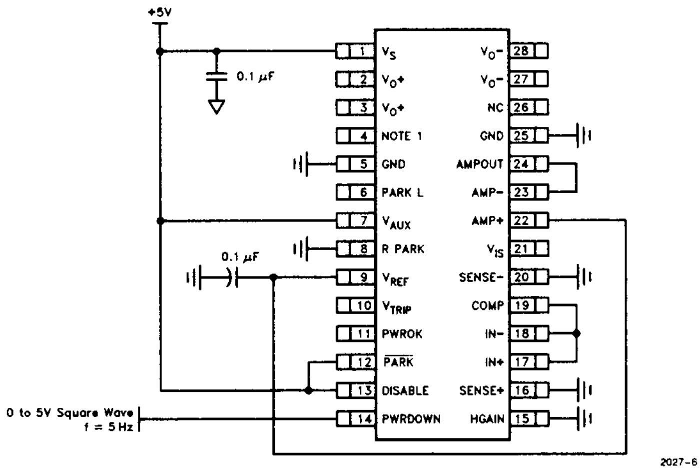
$$C_C = \frac{R_S}{X\,(R_M + R_S)\,2\pi\,BW}$$

$$R_C = \frac{L_M}{(R_M + R_S)\,C_C}$$

$X_{HG} = 300$

$X_{LG} = 85.7$

Burn-In Circuit



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Truth Table

$\overline{\text{PARK}}$	Disable	PwrDwn	H Gain	Output
<0.8V	X	X	X	Parking Mode
>2.0V	X	>2.0V	X	Disabled, Lowest PWR Consumption
>2.0V	>2.0V	<0.8V	X	Disabled/Power Amplifier Only
>2.0V	<0.8V	<0.8V	>2.0V	Normal Operation HIGH Transconductance
>2.0V	<0.8V	<0.8V	<0.8V	Normal Operation LOW Transconductance

Note: To go from park mode to normal operation PwrDwn must go HIGH then LOW, while $\overline{\text{Park}}$ is not asserted.

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Pin Description Table

Pin #	Name	Description
1	V_S	+ 5V supply to the op amps and power stages.
2, 3	V_O+	Positive output of the driver. When V_{IN} is higher than V_{REF} the voltage on V_O+ is higher than the V_O- voltage.
5, 25	GND	Ground.
6	ParkL	Open collector output. Normally High. Low when head is being parked.
7	V_{AUX}	V+ for reference, logic and park circuit.
8	R_{park}	Current source output. An external resistor to GND establishes the voltage to be impressed on the motor during park.
9	V_{REF}	Internally generated reference voltage tap and bypass point.
10	V_{trip}	Trip voltage of the undervoltage dectector bypass and adjustment point.
11	Power OK	Output of undervoltage detector. When under voltage is detected pin is pulled low and parking is initiated.
12	$\overline{\text{PARK}}$	TTL low signal will park the head. The park command is latched. Reset by pulling PwrDwn high then low.
13	Disable	High TTL input disables the power amplifier and H bridge.
14	PwrDwn	High TTL input disables the driver and shuts down most circuitry to minimize power consumption. When pulled high then low resets the Park circuit.
15	Hgain	TTL input sets the gain of the programmable gain amplifier. When high the driver transconductance is 200 mA/V. When low 50 mA/V (with $R_S = 1\Omega$).
16	Sense+	Positive feedback input from sense resistor.
17	In+	Non inverting input of the driver. Compensation network R_C and C_C is tied from it to ground.
18	In−	Inverting input of the driver for compensation network to Comp pin.
19	Comp	Output pin of the programmable gain amplifier. Compensation network R_C and C_C is tied from it to the inverting input of the driver.
20	Sense−	Negative feedback input from sense resistor.
21	V_{IS}	Output voltage proportional to the current in the motor ($V_{IS} = -4 \times I_M \times R_S$) + V_{REF}.
22	Amp+	Amplifier's positive input.
23	Amp−	Amplifier's negative input.
24	Amp Out	Output of input amplifier/filter.
27, 28	V_O-	Negative output of driver to the motor and its current sense resistor R_S.

Circuit Description

The EL2027 is an application specific product designed to drive and control Voice Coil Motors in 5V disk drives. It contains 8 main blocks. These are:

- Three low offset voltage operational amplifiers dedicated to specific functions.
- Single-ended to differential output power amplifier to drive the motor.
- Voltage reference.
- Undervoltage detector.
- Control logic circuit.
- Park circuit.

Operational Amplifiers

All three amplifiers share a common design but are modified to fulfill special functions. Their common characteristics are low offset, modest gain and wide common mode range (V_S − 1V to GND). They are internally compensated for stable operation at all gains. Their gain bandwidth products are 2 MHz and the phase margin is 60° at unity gain. One amplifier is used as input buffer and an active filter. One amplifier is used as main motor driver gain block. The third amplifier is used to sense the motor current. All three amplifiers have an output swing of 0.8V to V_S − 1.4V. Beyond these bounds they clip.

Power Amplifier

The power amplifier of the EL2027 is made of two identical stages, two power NPN's, two power PNP's and feedback elements. The power amplifier takes the difference between COMP and V_{REF} and drives the motor differentially. One stage operates non-inverting, the other inverting. The feedback elements set the total gain to 7. The feedback is specially designed to ensure accurate gain even when one amplifier saturates before the other. A unique patented biasing circuit for the power devices eliminates low-level crossover distortion by biasing the transistors on at a few mA.

The EL2027 will typically support more than 4.0V across a 10Ω motor (I ≤ 400 mA).

Voltage Reference

The voltage reference is a classic bandgap design with the added ability to both source and sink current. Its output is used internally as the global reference of the EL2027 and is brought to the pin V_{REF} for bypassing and external use.

The Voltage Reference is switched off when the EL2027 is switched into the power down mode. This drops the undervoltage trip point to nearly 0V making its ability to initiate parking unreliable. Thus the user should always park the motor before switching to the power down mode.

Undervoltage Detector

The undervoltage detector compares 0.55 times the main supply voltage with the 2.2V reference. When the main supply drops below this level (V_S = 4V) the undervoltage detector overrides all logic inputs and latches the IC into the park mode. The undervoltage detector has built-in hysteresis. Once triggered, park will be asserted by the undervoltage detector until 0.5 times the main supply exceeds the 2.2V voltage reference (V_S = 4.4V). The trip point of the undervoltage detector is brought out to the pin Vtrip. The trip point can be adjusted up or down by resistors to GND or the main supply or by directly forcing a voltage into the pin. The undervoltage detector has a logic output PWROK (11). When V_S is above the trip point PWROK is high. When low V_S is detected PWROK is pulled low by an internal 60 kΩ resistor. The resistor is intentionally high to reduce EL2027's supply current. If desired an external resistor to ground can be added to insure a low when driving a TTL logic input.

Note three facts when using the EL2027. First, the Voltage Reference draws its power from V_{AUX}. When V_{AUX} is below 3.4V V_{REF} follows V_{AUX} and the undervoltage trip voltage moves accordingly. Second, the logic circuit stops operating at about 2.4V on V_{AUX}. Third the park circuit is self sustaining. The logic circuit must hold off parking action during normal operation. So if V_S drops very slowly and V_{AUX} follows it, the undervoltage detector will not trip until V_S reaches about 2.7V. At this time, if the back EMF of the motor does not hold V_{AUX} above 2.4V the park signal will not latch. But parking will be initiated anyway because the logic circuit will not be holding off the park circuit. So the collapse of the Voltage Reference and the logic circuit does not interfere with parking even if V_S drops slowly and the back EMF if low. But, if the power is immediately restored and V_S rises very quickly the parking action may be aborted because the park signal was not latched. If it is desired to avoid this and also to initiate parking at power on, a capacitor should be placed on the V_{TRIP} pin. The trip point divider is made with large resistors ($\approx$36k) so a 0.1 μF capacitor will slow the voltage rise on V_{TRIP} compared to the voltage rise on V_{REF} and will result in a park signal.

Logic Circuit

The logic circuit operates from a separate supply called the Auxiliary Supply (V_{AUX}, 7). In a typical disk drive application the Auxiliary Supply is usually within a diode drop of the main supply, except when the main supply is interrupted. Then the Auxiliary Supply is generated by the back EMF of the spindle motor. By having two supplies the logic circuit can operate for a finite time after the main power has been removed.

There are four external inputs and one internal input to the logic circuit. The external inputs are Highgain (Hgain, 15), Disable (Disable, 13), Powerdown (PwrDwn, 14), and Park-bar ($\overline{\text{PARK}}$, 12). The internal input is from the undervoltage detector and activates parking regardless of the level at $\overline{\text{PARK}}$. The external inputs are TTL compatible and can be driven by CMOS gates. The action of the four external inputs is shown in the truth table (page 6). Hgain switches the EL2027's transconductance by a factor of four. Powerdown and Disable set the operating mode of the EL2027. When both are low the EL2027 is fully operational. When Disable is high the transconductance amplifier is off. When PwrDwn is high maximum power savings is achieved by disabling all circuitry except the logic, park, and undervoltage sections. PwrDwn also serves as the reset input for the park function. Once Park has been asserted by $\overline{\text{Park}}$ or the undervoltage detector the EL2027 will stay in the parking mode until PwrDwn has been set high then low while Park is not asserted.

The Park Circuit

The Park Circuit is activated by the park latch in the logic circuit or by removing power from the EL2027. When activated the Park circuit forces a constant voltage on the pin V_O- and provides base current to saturate the power NPN transistor on pin V_O+. The voltage at V_O- is programmed by pin RPARK. The park circuit sources 190 μA $\pm$20% at pin RPARK. A resistor to ground at this pin establishes the voltage at RPARK. Alternately a voltage can be forced at pin RPARK with external circuitry. The Park circuit has an output impedance of approximately 1.75Ω which should be taken into account when computing the actual voltage between V_O- and V_O+. The lowest nominal voltage which can be programmed at RPARK is 0.25V.

The park circuit uses the Auxiliary Supply (V_{AUX}, 7) for power not the main supply. The park circuit has been especially designed to operate at a very low auxiliary supply voltage. With only 1.6V at V_{AUX} the park circuit provides 0.6V to park the motor. The park circuit needs V_{AUX} of about 1.1V above the programmed parking voltage to operate properly. As the voltage drops below this the parking voltage quickly drops to zero. The park circuit also has an output ParkL (6). It is an open collector output which sinks current when the park circuit is activated.

Applications Information

Transconductance

The DC transconductance of the EL2027 is set by the state of Hgain (15) and one resistor R_S that senses the motor current. The input voltage is the difference between the voltages on pins AMPOUT (24) and V_{REF} (9). When pin 24 is more positive than pin 9 the input is said to be positive. When the input is positive the voltage on V_O+ (2, 3) is more positive than V_O- (27, 28) and the motor current is said to be positive. The DC transconductance is given by the equation

$$G_{MO} = \frac{G}{R_S} = \frac{I_O}{V_{IN}-V_{REF}}$$

where G = 0.2 when Hgain is high or 0.05 when Hgain is low.

For a transconductance of 200 mA/V and 50 mA/V R_S should equal 1Ω. Resistor R_S should be connected between V_O- and the motor for maximum accuracy at large swings. The feedback (current sensing) is provided by pins Sense− (20) and Sense+ (16) connected to V_O- and the motor side of the sense resistor respectively. Care should be taken to insure that the PC board trace resistance to pins 16 and 20 is low compared to R_S.

Motor Loop Compensation

The primary loop is compensated by components C_C and R_C. Their values are calculated to give the desired transconductance bandwidth. The equivalent motor resistance and inductance, R_M and L_M, the value for the sense resistor, R_S, and the bandwidth, BW, are used to compute C_C and R_C. The EL2027 requires two identical networks for compensation. Each network is a series connection of R_C and C_C. The matching of the components is not critical, standard 5 percent tolerance is sufficient.

The EL2027 has two transconductance settings selected by the logic input Hgain. So the loop bandwidth will assume two different values depending on the gain setting. Figure 1 shows the SPICE equivalent circuit of the feedback loop using voltage dependent voltage sources for the primary op amp (E1) and the power stage (E2). By connecting the inputs of E1 to either the right or left sides of resistors R2A and R2B both gain settings can be simulated. Figure 2 shows the results of both a high gain and a low gain simulation. R_C and C_C were selected for a bandwidth of 29 kHz at high gain. The low gain −3 dB bandwidth is about 74 kHz. This bandwidth change should be considered in any application where the gain switch is used.

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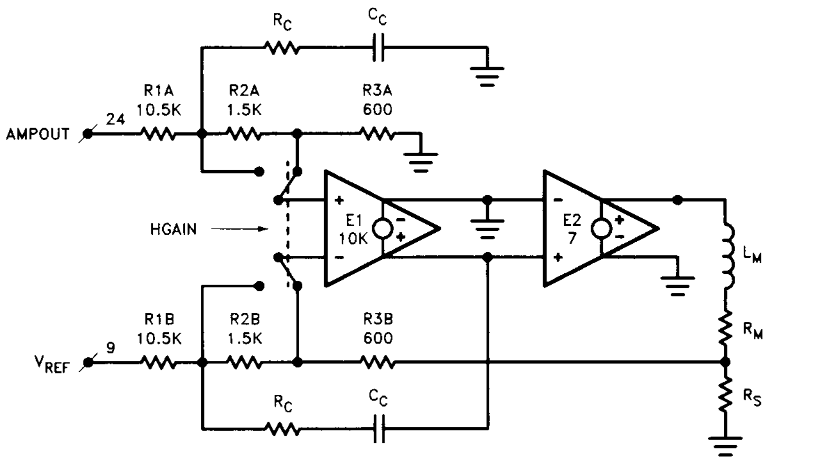

Figure 1. Servo Motor Equivalent SPICE Network Shown at Low Gain Setting

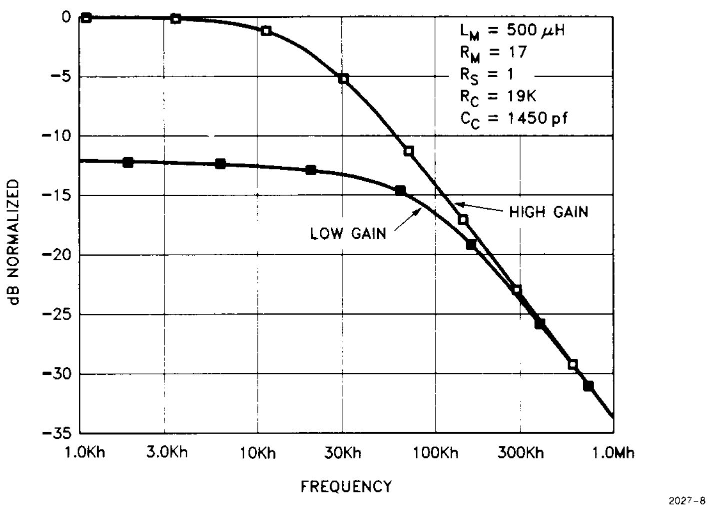

Figure 2. Simulated Transconductance vs Frequency

Use the following equations to select R_c and C_c in the high gain mode:

$$C_c = \frac{R_S}{G\,(R_M + R_S) \times 2\pi \times BW} \qquad R_C = \frac{L_M}{(R_M + R_S) \times C_C}$$

For high gain compensation G = 300

For low gain compensation G = 85.7