

Features

- No crossover distortion
- Low output offset current
- Maximum output swing
- Programmable park voltage
- Programmable transconductance
- Programmable bandwidth
- Chip enable function
- Drive low cost bipolar transistors
- Single sense resistor
- Minimum external components
- EL3036C short circuit protected
- Current sensing amplifier in the EL3038C

Applications

- Voice coil motor servo systems
- Winchester disk drives
- Optical disk drives
- Super floppy drives
- DC motor control

Ordering Information

Part No.	Temp. Range	Package	Outline #
EL3036CM	0°C to +75°C	SOL-20	MDP0027
EL3037CM	0°C to +75°C	SOL-20	MDP0027
EL3038CM	0°C to +75°C	SOL-20	MDP0027

Manufactured under U.S. Patent Nos. 4,910,477, 4,878,034, 4,935,704 and 4,963,802.

General Description

These three IC's are servo motor driver circuits designed to drive voice coil motors in disk drive application. They are designed to drive an H bridge consisting of four low-cost external bipolar transistors for maximum output swing. All three achieve a new level drive capability. With typical output current drive of 45 mA they are suitable for very low resistance voice coils. Crossover distortion is eliminated by Class AB biasing of the output devices with a unique temperature stable circuit which never needs adjustment.

System accuracy is maximized by using only 1 external sense resistor in series with the motor. Compared to conventional grounded resistor circuits they have inherent positive to negative gain matching and no gain error due to transistor alpha. All three critical bias voltages in the main loop use the same V_{REF} voltage. This reduces the output offset current to less than 5 mA.

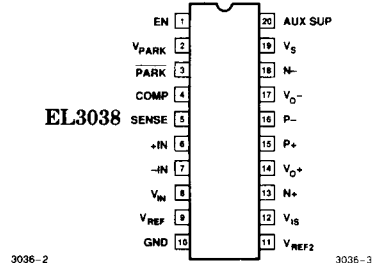
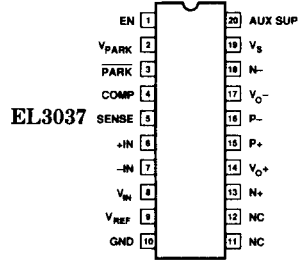
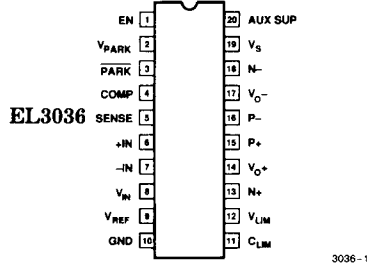
All three have an internal low power supply voltage detection which automatically initiates parking of the heads when V_S falls below about 6V. The power for this function comes from a separate supply generated by the back EMF of the spindle motor used as a generator. The EL3037C requires a minimum back EMF of 3.5V while the EL3036C and the EL3038C require only 2.5V. Parking can also be commanded by a logic low on the PARK-BAR pin.

All three have a low power consumption disabled state controlled by the logic input pin ENABLE.

The EL3037C is the simplest of the three with no extra features. The EL3036C protects the output transistors from short circuits by powering down for a programmable delay time when a fault occurs. When the fault is removed the circuit returns to normal operation. This type of short circuit protection eliminates excessive power dissipation during faults and prevents overheating.

The EL3038C has a motor current sensing amplifier for use in the system level servo loop. The amplifier multiplies the voltage across the sense resistor by 2 and references it to a reference voltage independent of the main loop reference voltage.

Connection Diagrams



EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

EL3036C/EL3037C/EL3038C

Absolute Maximum Ratings

V_S	Supply Voltage, Pin 19	-0.3V to +15V	T_A	Operating Temperature Range	-25°C to +85°C
V_{AUX}	Auxiliary Supply Voltage, Pin 20	$V_S - 1V$ to +15V		Lead Temperature	
V_{LIM}	Short Circuit Limit Sense Voltage	$V_S - 0.3V$ to +15V		SOL Package	
V_{IN}	Logic Inputs, Pins 1 and 3	-0.3V to +15V		Vapor Phase (60 seconds)	215°C
	Signal Inputs, Pins 8 and 9	-0.3V to +15V		Infrared (15 seconds)	220°C
I_{IN}	Input Current, Pins 1, 3, 8, and 9	10 mA	T_{ST}	Storage Temperature	-65°C to +150°C
T_J	Junction Temperature	150°C	P_D	Power Dissipation, $T_A = 25^\circ\text{C}$	
				DIP Package	1.80W
				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 $T_A = 25^\circ\text{C}$ and QA sample tested at $T_A = 25^\circ\text{C}$, 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 $T_A = 25^\circ\text{C}$ for information purposes only.

Electrical Characteristics

$T_A = T_J = 25^\circ\text{C}$, $V_S = 12V$, $V_{REF} = 5V$, $R_s = 0.25\Omega$, Load = 10 Ω . See test circuits

Parameter	Description	Min	Typ	Max	Test Level	Units
Enabled Mode, Pin 1 = H. Pin 3 = H. (Note 1)						
I_{OS}	Output Offset Current	-5	0.6	5	I	mA
G_{M1}	Transconductance, $I_{OUT} = \pm 100\text{ mA}$	0.95	1	1.05	I	A/V
G_{M2}	Transconductance, $I_{OUT} = \pm 1A$	0.93	1	1.07	I	A/V
I_{ST}	Quiescent Supply Current, Total		20		V	mA
I_{Q1}	Quiescent Supply Current, Pin 12 + 19		9	12	I	mA
I_{Q2}	Auxiliary Supply Quiescent Current, Pin 20	4	5	7	I	mA
I_{QE}	External Transistor Quiescent Current	1	8	12	I	mA
I_{DN}	NPN Drive Current, Pin 13 or 18	35	45		I	mA
I_{DP}	PNP Drive Current, Pin 15 or 16	40	55		I	mA
I_{IB}	Input Bias Current. $V_{IN} = V_{REF} = 2.5V, 6.5V$	-250	50	250	I	μA
I_{IA}	Active Input Current. $V_{IN} = 0.5V, V_{REF} = 2.5V$	-1.5			I	mA
I_{IA}	Active Input Current. $V_{IN} = 4.5V, V_{REF} = 2.5V$		0.4	0.7	I	mA
I_{RB}	Reference Bias Current. $V_{IN} = V_{REF} = 2.5V, 6.5V$	-250	100	250	I	μA
I_{RA}	Active Reference Current. $V_{IN} = 0.5V, V_{REF} = 2.5V$	-1.0	-0.5		I	mA
I_{RA}	Active Reference Current. $V_{IN} = 4.5V, V_{REF} = 2.5V$	-1.5	-0.9	0.5	I	mA
V_S	Supply Voltage Range, Pin 19	11	12	13	IV	V
VRR	Reference Voltage Range, Pin 9	2.5		6.5	I	V
RRR	Reference Voltage Rejection, 2.5V to 6.5V	-1	-0.3	1	I	mA/V
PSR	Power Supply Rejection, 11V to 13V	-1	0.3	1	I	mA/V
THD	Total Harmonic Distortion, $V_{IN} = 20\text{ mV}_{PP}$, 1 kHz		0.5	1	I	%

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EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

Electrical Characteristics

$T_A = T_J = 25^\circ\text{C}$, $V_S = 12\text{V}$, $V_{REF} = 5\text{V}$, $R_s = 0.25\Omega$, Load = 10 Ω . See test circuits — Contd.

Parameter	Description	Min	Typ	Max	Test Level	Units
Park Mode. Pin 1 = H. Pin 3 = L. Aux Supply (Pin 20) = 6V (Note 1) $R_{PARK} = 1.5k$, EL3036C, $R_{PARK} = 3k$, EL3037C						
V_{PI}	$V_{OUT} (V_{O+} - V_{O-})$ (EL3036/38) $R_{PARK} = 1.5k$	-0.30	-0.45	-0.55	I	V
V_{PI}	$V_{OUT} (V_{O+} - V_{O-})$ (EL3037) $R_{PARK} = 3k$	-0.40	-0.50	-0.60	I	V
V_{AR}	Aux Supply Range, EL3036/38C ($-0.25\text{V} \leq V_{OUT} \leq -0.65\text{V}$)	2.5	6	12	I	V
V_{AR}	Aux Supply Range, EL3037C ($-0.25\text{V} \leq V_{OUT} \leq -0.65\text{V}$)	3.5	6	12	I	V
I_{PD}	NPN Drive. Pin 13	2	3		I	mA
I_{AUX}	Short Circuit Maximum Current (Pin 17 = 0V)		250		V	mA

Disabled Mode. Pin 1 = L. Pin 3 = H. (Note 1)

I_{OD}	Output Current	-100	10	+100	I	μA
R_{OD}	Output Resistance. $I_{OUT} \pm 1\text{mA}$	2	4		I	$k\Omega$
I_{SD}	Total Supply Current, Pin 12, 19, and 20 + Transistors		6	10	I	mA

Short Circuit Protection (EL3036C Only)

V_{TR}	Trip Voltage. Pin 12-Pin 19	340	425	510	I	mV
I_C	Capacitor Charging Current	20	35	50	I	μA
I_D	Capacitor Discharge Current	1	3	10	I	mA
V_C	Capacitor Quiescent Voltage	7	8	9	I	V

Motor Current Sense Amplifier (EL3038 Only)

A_{VIS}	Voltage Gain	1.85		2.15	I	V/V
V_{VIS}	Output Voltage Range	1		9	I	V
V_{OS}	Output Offset Voltage, $V_{O-} = \text{Sense} = V_{REF}$	-10		+10	I	mV

Logic Inputs

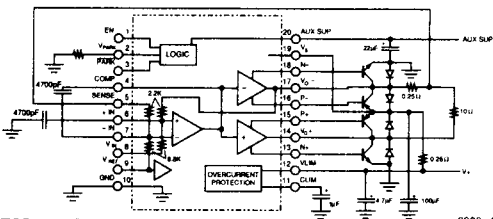
V_{IL}	Low Level Input Voltage for a Valid Low			0.8	I	V
I_{IL}	Low Level Input Current, Logic = 0V	-30	-10	0	I	μA
V_{IH}	High Level Input Voltage for a Valid High	2			I	V
I_{IH}	High Level Input Current, Logic = 5V	0	10	150	I	μA

Individual Amplifiers

A_V	Power Amplifier Voltage Gain	10.5	11.5	12.5	I	V/V
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Note 1: Logic Level L = 0.8V, Logic Level H = 2.0V

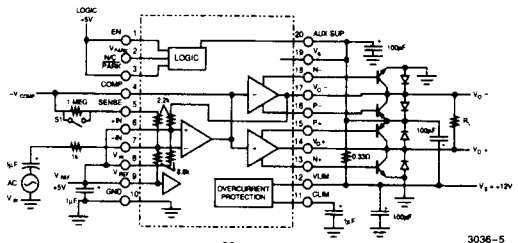
DC and Closed Loop AC Test Circuit (EL3036)



NPNs are MJE200.
PNPs are MJE210.
Diodes are 1 Amp IN4000.

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Open Loop AC Test Circuit (EL3036)



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Op Amp Gain—S1 Open, $A_V = \frac{V_{COMP}}{V_{IN}}$

Power Amp Gain—S1 Closed, $A_V = \frac{(V_{O+}) - (V_{O-})}{V_{COMP}}$

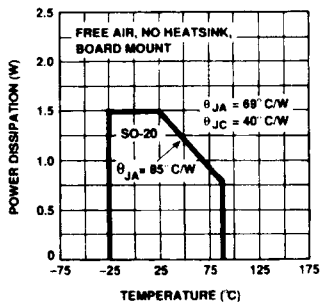
EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

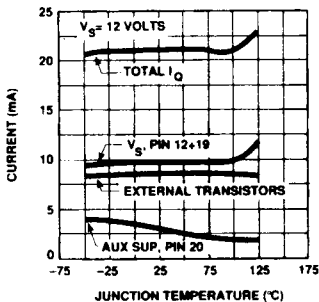
EL3036C/EL3037C/EL3038C

Typical Performance Curves

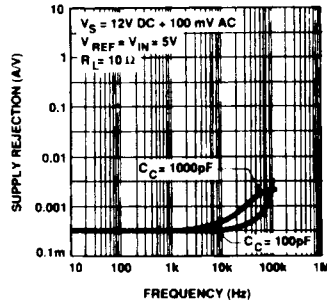
Maximum Power Dissipation vs Ambient Temperature



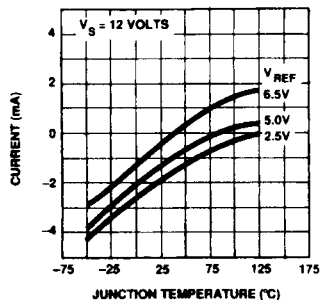
Quiescent Current vs Temperature



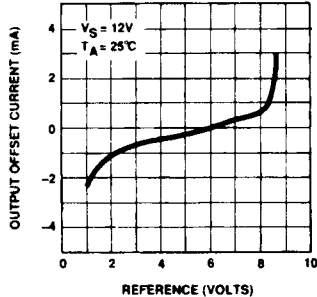
Supply Rejection vs Frequency



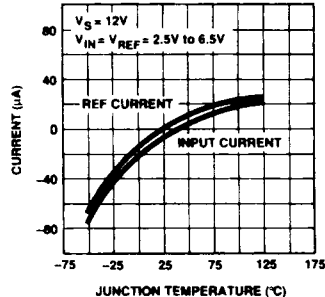
Output Offset Current vs Temperature



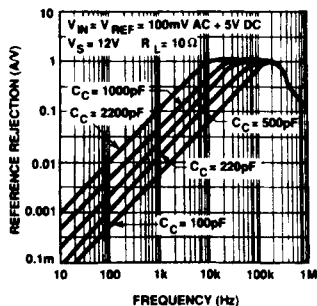
Output Offset Current vs Reference Voltage—Typical Unit



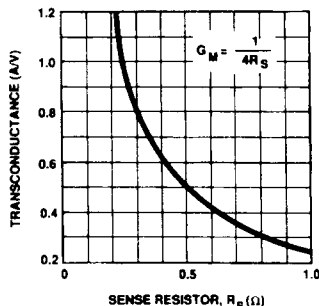
Reference and Input Bias Current vs Temperature



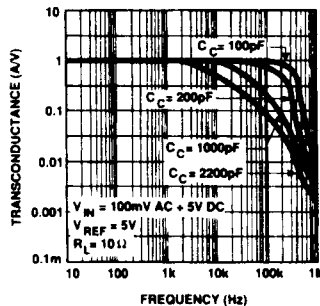
Reference Voltage Rejection vs Frequency



Transconductance vs Sense Resistor



Transconductance vs Frequency

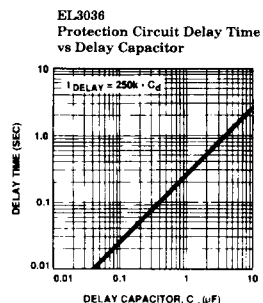
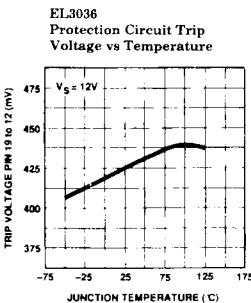
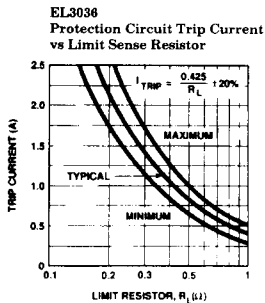
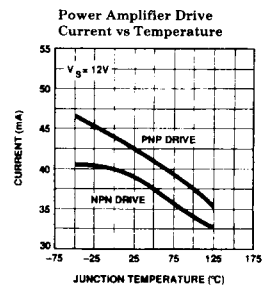
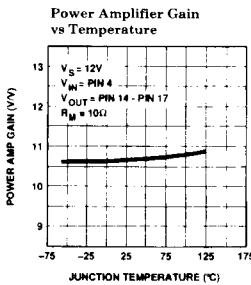
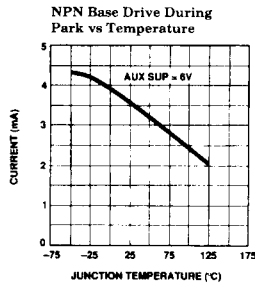
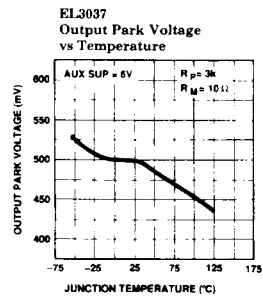
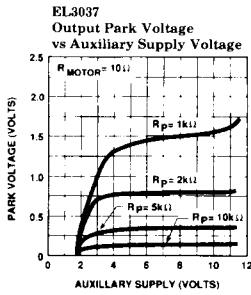
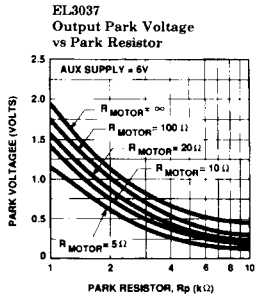
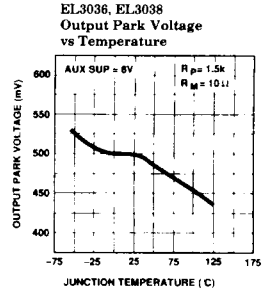
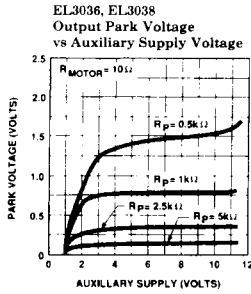
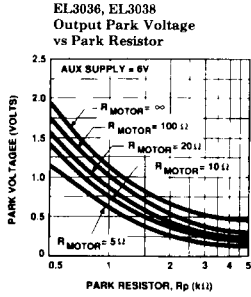


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EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

Typical Performance Curves — Contd.

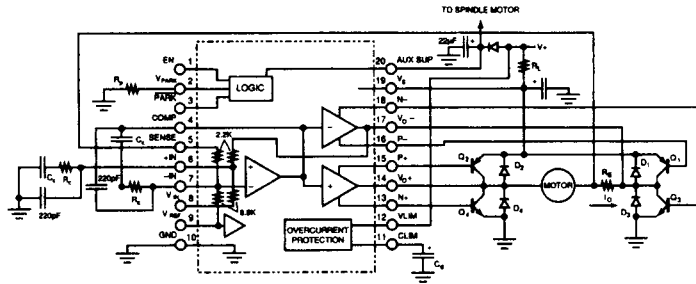


EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

EL3036C/EL3037C/EL3038C

Typical Application (EL3036C)



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External Components

Parameter	Description	Min	Typ	Max	Units	Typical ± % Tolerance
R _P	Sets the Motor Voltage During PARK Mode, EL3036, EL3038C	0.5k	1.5k	Open	Ω	5
R _P	Sets the Motor Voltage During PARK Mode, EL3037C	1k	3k	Open	Ω	5
R _s	Current Sense Resistor	0.1	0.25	1	Ω	2
C _c	Loop Compensation. Sets dominant pole	100	2000	0.1 μF	pF	5
R _c	Loop Compensation. Makes a Zero, Equal to Motor Pole	0	10	200	kΩ	5
R ₁	Short Circuit Sense Resistor	0	0.33	3	Ω	5
C _d	Short Circuit Delay Capacitor	0.05	1	100	μF	10
D1-4	Catch diodes, 1 amp	1N4000				
Q1, 2	PNP Power Transistors. Min H _{FE} = 60	MJE210 or D45H11				
Q3, 4	NPN Power Transistors. Min H _{FE} = 60	MJE200 or D44H11				
	R ₁ = 0.425/Trip current					
	C _d = Delay/250k					
	R _s = 1/(4*DC transimpedance)					

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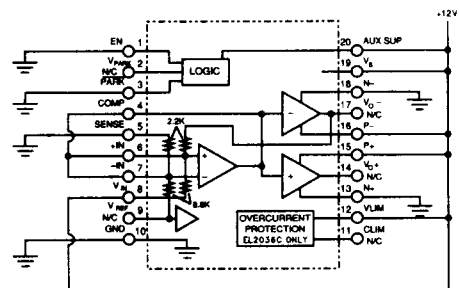
Truth Table

Enable (Pin 1)	Park (Pin 3)	V12 to V19 (EL3036C)	Output
> 2.0V	> 2.0V	< 0.34V	Normal Operation
< 0.8V	> 2.0V	< 0.34V	Disabled
X	< 0.8V	< 0.34V	Parking Mode
X	X	> 0.52V	Disabled for Delay

$$C_c = \frac{4 R_s}{800 (R_m + R_s) 2 \text{ pBandwidth}}$$

$$R_c = \frac{L_m}{C_c (R_m + R_s)}$$

Burn-In Circuit (EL3036C)



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EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

Circuit Description

Common Functions

There are 4 circuit blocks common to the EL3036, the EL3037, and the EL3038. They are a low offset voltage operational amplifier, a single-ended input to differential output power amplifier, a logic circuit, and a parking circuit. The operational amplifier and power amplifier together with four well-matched internal resistors make the basic transconductance amplifier. The logic circuit enables or disables the amplifiers or the park circuit. The park circuit provides a constant voltage across the motor.

The Operational Amplifier

The operational amplifier is a low offset design with modest gain and excellent common mode rejection over a wide range that includes ground. This ensures proper operation when the motor voltage exceeds the supply or ground and is clamped by the catch diodes. The operational amplifier is internally compensated for stable operation at all times. The gain bandwidth product is 2 MHz and the phase margin is 60° at unity gain. The operational amplifier has internal clamps to limit its output swing to about $\pm 2V$ of the reference voltage. The clamps are not shown in the simplified schematic and their only function is to prevent overcharging of the compensation capacitor during transients. The operational amplifier output is disabled by the logic circuit when either pin 1 or pin 3 is low.

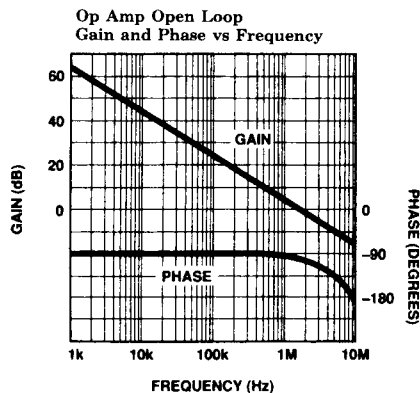


Figure 1

3036-10

The Power Amplifier

The power amplifiers of the EL3036C/EL3037C are made of two identical stages that take a single-ended input and drive the motor differentially. The outputs of both stages are biased from the buffered reference voltage to reduce output offset current. Each stage has feedback for linearity and gain accuracy. One stage operates noninverting and the other inverting, resulting in a total gain of 11. The feedback is more complicated than shown in the simplified schematic, to ensure accurate gain even when one amplifier saturates before the other. The bandwidth of the power amplifier is about 500 kHz as shown below.

External power transistors deliver the power to the motor to optimize the output swing capability and eliminate power dissipation concerns. A unique biasing circuit eliminates low-level cross-over distortion by biasing the transistors on at a few mA. The amplifier outputs are disabled when either pin 1 or pin 3 is low.

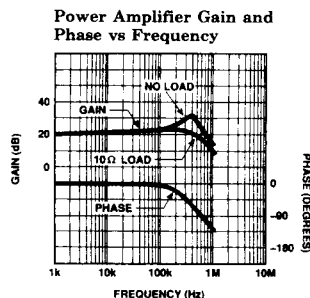


Figure 2

3036-11

The Logic Circuit

The logic circuit operates from a separate supply called the auxiliary supply. In a typical disk drive application, the auxiliary supply is usually within a diode drop of the normal supply, except when the normal supply is interrupted. Then the auxiliary supply is generated from the back EMF of the spindle motor. By having two supplies, the logic circuit can operate for a while after the main power has been removed.

EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

Circuit Description — Contd.

All the devices have two external inputs and one common internal input to the logic circuit. The external inputs are Park-Bar and Enable. The common internal input is from the low supply voltage sensor. The external inputs are TTL compatible and can be driven from CMOS sources. The park-bar input and the low supply sensor input override the Enable input. When Park-Bar is high and the supply voltage is above approximately 8V the Enable input turns the main amplifiers on or off. The EL3036 has another logic input, the short-circuit sensor. See the Short Circuit section for more details.

Park Circuit

When the Park-Bar logic input is high and the voltage on V_S is above about 8V the park circuit is disabled and has no effect on the motor. If either condition is reversed, the main amplifiers are disabled and the park circuit is activated. Like the logic circuit, the park circuit uses the auxiliary supply, not the main supply. The park circuit sets the voltage at ParkR (Pin 2) to about 0.75V (EL3036, EL3038) or 1.4V (EL3037). The value of the external resistor from ParkR to GND sets the voltage at V_O- (pin 17) according to the graph in the Typical Performance section. At the same time current is provided at N+ (pin 13) to saturate the external NPN transistor on the opposite side of the motor.

EL3036C Short Circuit Protection Circuit

The short circuit protection circuit consists of a comparator, a floating reference, a flip flop and a one-shot. An external resistor, R_1 between pins 12 and 19 senses the total supply current the amplifiers pull from the supply. The floating reference subtracts 425 mV from the voltage sensed on pin 12 and the comparator trips when the voltage on pin 19 is at the same level. The net result is that when the drop across R_1 is <425 mV, the comparator trips. The output of the comparator sets a flip flop whose output disables the amplifiers and triggers the one-shot. When the one-shot starts timing, it resets the flip flop and the one-shot keeps the amplifiers off.

The one-shot delay is set by an external capacitor, C_d . When the one-shot times out, the amplifiers are enabled again. If there is still a fault condition, the supply current rises until the comparator trips and the cycle repeats. Because the circuit is much faster than the one-shot delay time, the average power dissipation is very low. The circuit responds very quickly, in a few microseconds, so any current spike through R_1 will be detected and disable the amplifier for the delay time. The protection circuit will sometimes trip when there is a large, very fast, input signal. This is because there is a short but large spike of supply current. If this is a problem, the resistor R_1 should be bypassed with a large (about 100 μ F) capacitor. Pins 11 and 12 are not connected on the EL3037C.

EL3038C Current Sense Circuit

The EL3038C has a copy of the main low offset voltage operational amplifier wired with 4 well-matched resistors to amplify the voltage across the motor current sense resistor by 2. Its output appears at the pin V_{IS} . The resistors are wired to center the amplified voltage around the user supplied voltage at pin V_{REF2} . This amplifier is active whenever the main transconductance amplifiers are active.

Applications Information

Transconductance

The DC transconductance is set by one resistor, R_s , that senses the motor current. The input voltage is the difference between the voltage on pin 8 and 9. When pin 8 is more positive than pin 9, the input is said to be positive. When the input is positive, the voltage on pin 14 is more positive than pin 17 and the motor current is said to be positive. The DC transconductance is given by the simple equation:

$$G_{MO} = \frac{1}{4R_s} = \frac{I_O}{V_{IN}-V_{REF}}$$

For a transconductance of 1 Amp per volt, the sense resistor, R_s , should equal 0.25 Ω . Because the sense resistor is very small, care should be taken to insure that the PC board trace resistance does not increase its value. The connections from pin 5 and 17 are the "sense" connections while

EL3036C/EL3037C/EL3038C

2 Amp Precision Servo Motor Drivers

Applications Information — Contd.

the motor and transistor collectors are the "force" connections. Therefore, the connections from pin 5 and pin 17 should go directly to the sense resistor.

Source Impedance

The input and reference source impedances should be low to prevent gain and offset errors. The input current is determined by the internal feedback resistors and the input and output voltages. The worst case current flows when the reference is low and the input is lower and therefore the V_O — output is high. This condition is tested and the input and reference currents are guaranteed to be less than 1.5 mA. Therefore, the input and reference should be able to sink and source 1.5 mA. For the typical case where the transconductance is 1 Amp per volt, a source impedance of less than 10Ω will generate less than 2.5 mA of additional output offset current and less than 1.5% gain error. Obviously, if the output of an operational amplifier drives the IC, there will be no errors due to source impedance. Be careful with some single supply operational amplifiers (324 and 358 types). They require output loading to ground to eliminate their high output impedance and crossover distortion.

Transistors

The IC will drive almost any pair of complementary transistors. The output transistor drive is guaranteed to be more than 40 mA for the PNPs and 35 mA for the NPNs. The required maximum output current divided by the available base drive gives the minimum H_{FE} required. For 2 Amp output current, the minimum H_{FE} is 60.

The important specifications for the output devices are:

BV_{CEO}	Minimum 15V
H_{FE}	Minimum 60 at 2 Amp
f_t	40 MHz or more
$V_{CE(SAT)}$	As low as possible

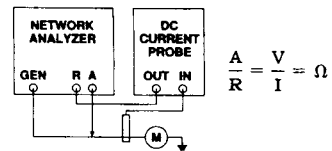
The MJE200 and MJE210 series are excellent with minimum H_{FE} of 45 and saturation voltages of only 300 mV at 1 Amp. The D44H11 and D45H11 series have even lower saturation voltages and a higher H_{FE} of 60. Both types are available in surface mount from Motorola, SGS and others.

Motor Characterization

The formulas for motor compensation are based on the electrical characteristics of the motor. For most high-performance voice coil motors, the effective impedance is a function of frequency that can not be modeled over a large frequency range with a simple resistor and inductor. Fortunately, for the compensation equations to work, it is only necessary to model the motor at the bandwidth frequency.

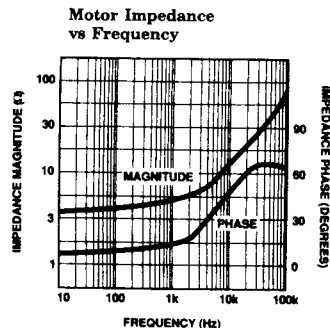
The easiest way to determine the resistance and inductance of a motor is to use an RLC meter that reads the inductance and resistance at the bandwidth frequency. If such a meter is not available, a network analyzer and a current probe will give the impedance versus frequency. From the magnitude and phase at the bandwidth frequency, the real and imaginary impedance can be calculated (and the imaginary part converted to inductance). Some network analyzers will even give the real and imaginary impedances directly.

The setup below was used to generate the following curve of impedance versus frequency on a real motor. At 10 kHz the impedance is 13Ω at 52° . This is 8Ω real and 10.25Ω reactive. Notice that the DC resistance is much less than the impedance at 10 kHz. The equivalent inductance is $163\mu H$.



3036-12

Figure 3. Motor Characterization Setup



3036-13

Figure 4

EL3036C/EL3037C/EL3038C

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Applications Information — Contd.

Compensation

The compensation components, C_c and R_c , are calculated to give the desired transconductance bandwidth. The equivalent motor resistance and inductance, R_m and L_m , the value of the sense resistor, R_s , and the bandwidth, BW , are used to compute C_c and R_c . Two identical networks are required for compensation. Each network is a series connection of a resistor, R_c , and a capacitor, C_c . The matching of the components is not critical, standard five percent tolerance is sufficient. The derivation of the following equations is in the AC Response Section.

$$C_c = \frac{4 R_s}{800 (R_m + R_s) 2\pi BW}$$

$$R_c = \frac{L_m}{(R_m + R_s) C_c}$$

To compensate the motor described in the previous section for a 10 kHz bandwidth and a transconductance of 1 Amp per volt we substitute

$$\begin{aligned} R_s &= 0.25 \quad L_m = 160 \mu\text{H} \\ R_m &= 8\Omega \quad BW = 10 \text{ kHz} \end{aligned}$$

into the above equations.

$$C_c = \frac{4 (0.25)}{800(8 + 0.25)(2)(3.14)(10 \text{ kHz})} = 2400 \text{ pF}$$

use 2200 pF

$$R_c = \frac{160 \text{ mH}}{(8 + 0.25)(2200 \text{ pF})} = 8800$$

use 10k.

Two 220 pF capacitors between pin 4 and pin 7, and between pin 6 and Ground (as shown in the Typical Application drawing on page 6) smooth fast rising input signals to ensure that the operational amplifier will not slew rate limit. Both capacitors can be eliminated if the slew rate of the input signal does not exceed 0.5 V/ μ s.

Park Function

The EL3036C/EL3037C will force a constant voltage across the motor when pin 3, park-bar, is open or low. The output voltage is negative; pin

14 if forced to about zero volts and pin 17 to the constant voltage determined by the resistor R_p from pin 2 to ground. This voltage drive produces a constant velocity that is used to park the heads. The power to drive the motor is supplied from an auxiliary supply (Aux Sup) on pin 20. Usually this auxiliary supply is the normal supply reduced by a diode drop. The spindle motor also is tied to the auxiliary supply. Once the normal supply drops, the spindle motor back EMF acts as a generator and holds the voltage up long enough for the drive to park the heads. An external bypass capacitor is needed on pin 20 to filter the ripple. To determine the value of the resistor required from pin 2 to ground use the curve of Output Park Voltage versus Park Resistor (page 5).

Protection Circuit (EL3036C)

The EL3036C has a protection circuit that prevents damage if either of the motor terminals is shorted to ground. The circuit senses the total supply current with a resistor, R_1 , and disables the amplifiers during over-current conditions. The curve of Protection Circuit Trip Current versus Limit Sense Resistor (page 5) should be used to select the proper resistor. For a typical 1 Amp output current the resistor should equal 0.33 Ω .

Motor Current Sensing (EL3038C)

Many servo systems require a voltage representing the actual motor current. The V_{IS} signal (Pin 12) provides this. Internally there is an OpAmp configured to amplify the voltage across the motor current sense resistor by 2 and reference it to reference voltage V_{REF2} at pin 11. For example if the motor current were -1A , the sense resistor 0.25Ω and the V_{REF2} 2.5V the voltage at V_{IS} will be $2.5\text{V} + (-1 \times 0.25 \times 2)$ or 1.5V. The internal OpAmp is a copy of the OpAmp used in the main motor current amplifier and has the same characteristics of low offset and good gain. But its output swing is limited to $+1\text{V}$ to $+8\text{V}$ ($V_S = 12\text{V}$). Consequently with some combinations of reference voltage and motor current sense resistor the signal at V_{IS} will be clipped. The OpAmp and gain setting resistors are guaranteed to have an offset voltage less than 10 mV. So in a typical application the ultimate accuracy of the V_{IS} signal is $\pm 10 \text{ mA}$.

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AC Response

The AC response is set by the motor electrical time constant and the compensation impedance $Z(s)$. The actual circuit is quite difficult to analyze due to the differential techniques used to improve accuracy. To simplify the analysis, a single-ended system can be modeled with a summer, a forward path, the motor electrical elements and a feedback path. The forward path has a gain that includes the compensation components, and the feedback includes the current sense resistor, R_S . In this way we can solve for the response in terms of the actual external component values.

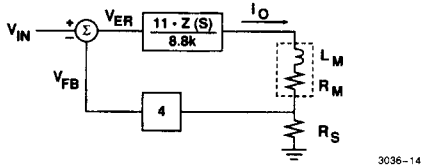


Figure 5. The Servo Motor Loop Equivalent Circuit

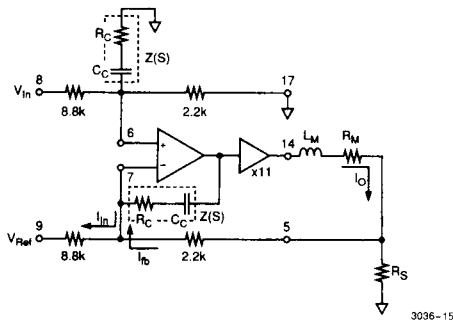


Figure 6. The Servo Motor Control Equivalent Circuit

The forward path gain of this circuit is the output current divided by the input voltage without any feedback.

$$A = \frac{I_o}{V_{IN}} = \frac{11Z(s)}{8.8K (sL_m + R_m + R_s)}$$

The feedback path is the feedback voltage divided by the output current.

$$b = \frac{V_{FB}}{I_o} = 4 R_s$$

The closed loop response is therefore:

$$A_{CL} = \frac{A}{1 + A\beta} = \frac{\frac{1}{\beta}}{1 + \frac{1}{A\beta}} = \frac{1}{4 R_s \left(1 + \frac{800}{4 R_s} \left(\frac{s L_m}{R_m + R_s} + 1 \right) \left(\frac{R_m + R_s}{Z(s)} \right) \right)}$$

The compensation network $Z(s)$ is usually a series resistor and capacitor, R_C and C_C . That is to say

$$Z(s) = R_C + \frac{1}{s C_C} = \frac{s R_C C_C + 1}{s C_C}$$

Substituting this into the closed loop equation gives

$$A_{CL} = \frac{1}{4 R_s \left(1 + \frac{800}{4 R_s} \left(\frac{s L_m}{R_m + R_s} + 1 \right) \frac{(R_m + R_s) s C_C}{(s R_C C_C + 1)} \right)}$$

There are many ways to analyze this for the desired response. Bode plots, Nyquist plots and root locus techniques can all be used to determine the values of R_C and C_C for a particular motor. The simplest way to obtain the values of R_C and C_C is to make the zero due to them equal to the motor pole.

$$R_C C_C = \frac{L_m}{R_m + R_s}$$

Substituting this constraint into the closed loop equation results in a single pole system. The equation is:

$$A_{CL} = \frac{1}{4 R_s \left(\frac{800}{4 R_s} (R_m + R_s) s C_C + 1 \right)}$$

The closed loop -3 dB bandwidth (BW) is where the magnitude of the real and imaginary parts of the denominator are equal. We therefore can say, in terms of bandwidth in Hertz, that

$$\frac{800}{4 R_s} (R_m + R_s) 2\pi \cdot BW \cdot C_C = 1$$

Solving these for C_C and R_C gives:

$$C_C = \frac{4 R_s}{800 (R_m + R_s) 2\pi BW}$$

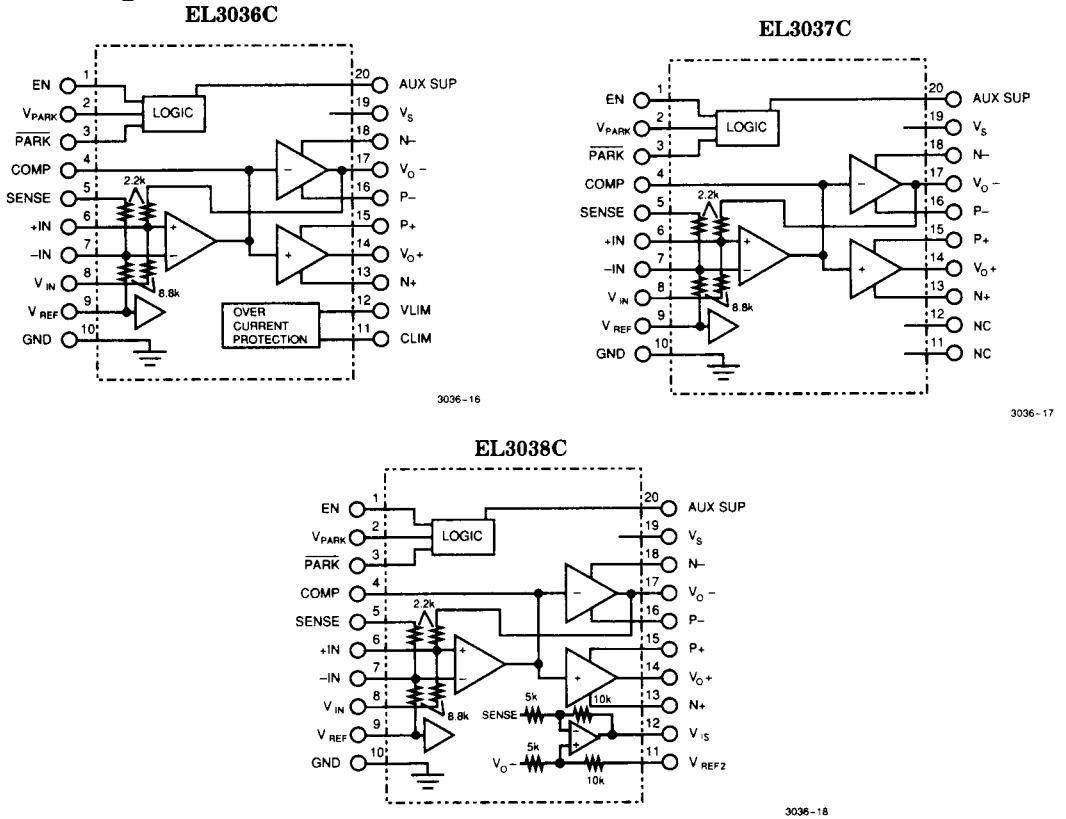
$$R_C = \frac{L_m}{(R_m + R_s) C_C}$$

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Block Diagrams



3036-16

3036-17

3036-18

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