

APPLICATIONS OF MONOLITHIC BRIDGE DRIVERS

High power monolithic bridge drivers are an attractive replacement for discrete transistors and half bridges in applications such as DC motor and stepper motor driving. This application guide describes three such devices – the L293, L293E and L298 – and presents practical examples of their application.

The L293, L293E and L298 each contain four push-pull power drivers which can be used independently or, more commonly, as two full bridges. Each driver is controlled by a TTL-level logic input and each pair of drivers is equipped with an enable input which controls a whole bridge. All three devices feature a separate logic supply input so that the logic can be run on a lower supply voltage, reducing dissipation. This logic supply is internally regulated.

Additionally, the L293E and L298 are provided with external connections to the lower emitters of

each bridge to allow the connection of current sense resistors. The L293E has separate emitter connections for each channel; the L298 has two, one for each bridge.

Figure 1 shows the internal structure of the L293, L293E and L298. The L293 and L293E are represented as four push pull drivers while the internal schematic is given for the L298. Though they are drawn differently the L293E and L298 are identical in structure; the L293 differs in that it does not have external emitter connections.

Fig. 1 – The L293, L293E and L298 contain four push pull drivers. Each driver is controlled by a logic input and each pair (a bridge) is controlled by an enable input. Additionally, the L293E has external emitter connections for each driver and the L298 has emitter connections for each bridge.

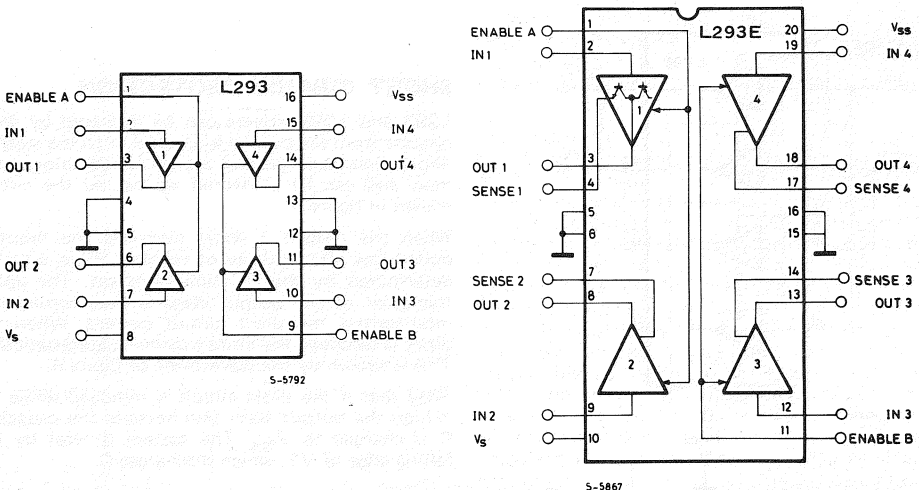
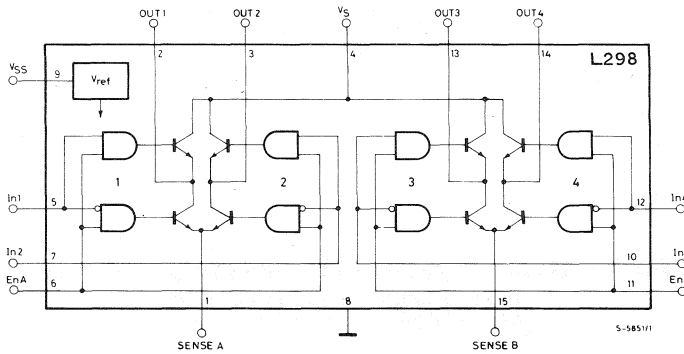


Fig. 1 (continued)

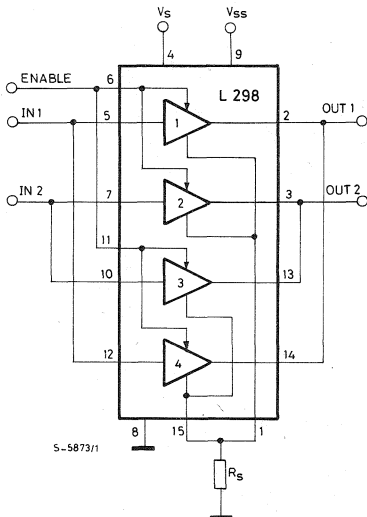


The L293 is packaged in a 12 + 4 lead POWERDIP package (a 16-pin DIP with the four center leads used to conduct heat to the PC board copper) and handles 1A per channel (1.5 peak) at voltages up to 36V.

The L293E, also rated at 1A/36V, is mounted in a 16 + 4 lead POWERDIP package. A 15-lead MULTIWATT plastic power package is used for the L298 which handles up to 2A per channel at voltages to 46V.

All three devices includes on-chip thermal protection and feature high noise immunity. The high switching speed makes them particularly suitable for switch mode control.

Fig. 2 - For higher currents outputs can be paralleled. Take care to parallel channel 1 with channel 4 and channel 2 with channel 3.



PARALLELING OUTPUTS

Higher output currents can be obtained by paralleling the outputs of both bridges. For example, the outputs of an L298 can be connected in parallel to make a single 3.5A bridge. To ensure that the current is fairly divided between the bridges they must be connected as shown in figure 2. In other words, channel one should be paralleled with channel four and channel two paralleled with channel three. Apart from this rule the connection is very straightforward — the inputs, enables, outputs and emitters are simply connected together.

The outputs of an L293 or L293E can also be paralleled — in this case too channel 1 must be paralleled with channel 4 and channel 2 with channel 3.

But if two bridges are needed this is not a good idea because an L298 may be used. However, if only one bridge is required an L293 connected as a single bridge may be cheaper than an underutilized L298.

SHORT CIRCUIT PROTECTION

L293 and L298 drivers can be damaged by short circuits from the output to ground or to the supply. Short circuits to ground are by far the most common and can be protected against by the circuit shown in figure 3.

When the output is short circuited the input is pulled low after a delay of roughly $10 \mu\text{s}$, a period determined by the RC time constant. The upper transistor of the output stage is thus turned off, interrupting the short circuit current. When the short is removed the circuit recovers automatically. This is shown by the waveforms of figure 4.

Note that if the short circuit is removed while V1 is high the output stays low because the capacitor C is charged to V_{IH} . The system is reset by the falling edge of V1, which discharges C.

Fig. 3 - This circuit protects a driver from output short circuits to ground.

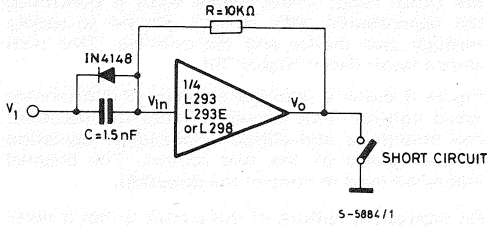
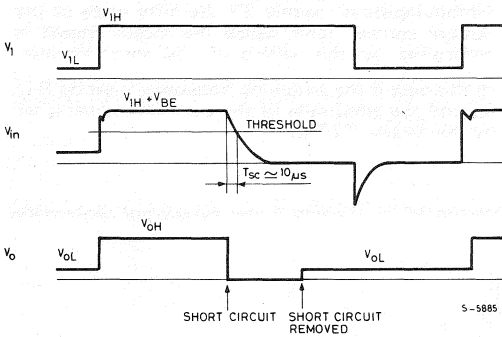


Fig. 4 - Waveforms illustrating the short circuit protection provided by the circuit of fig. 3.



DC MOTOR DRIVING

In applications where rotation is always in the same sense a single driver (half bridge) can be used to drive a small DC motor. The motor may be connected either to supply or to ground as shown in figure 5.

The only difference between these two alternatives is that the control logic is inverted - a useful fact to remember when minimising control logic.

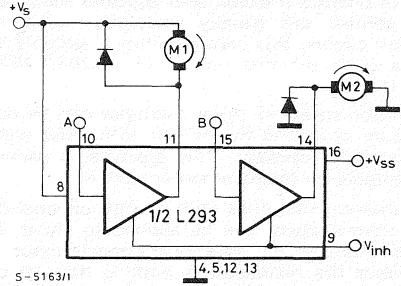
Each device can drive four motors connected in this way. The maximum motor current is 1A for the L293 and 2A for the L298. However, if several motors are driven continuously care should be taken to avoid exceeding the maximum power dissipation of the package.

Each motor in this configuration is controlled by its own logic input which gives two alternatives: run and fast stop (the motor shorted by one of the transistors).

The enable/inhibit inputs also allow a free running motor stop by turning off both transistors of the driver. Since these inputs are common to two channels (one bridge) this feature can only be used when both channels are disabled together.

A full bridge configuration is used to drive DC motors in both directions (figure 6). Using the logic inputs of the two channels the motor can be

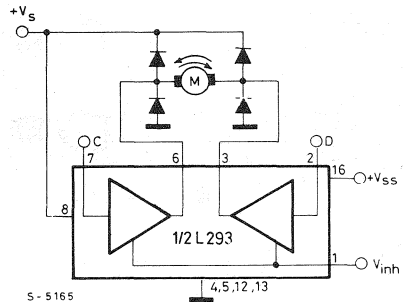
Fig. 5 - For rotation in one direction DC motors are driven by one channel and can be connected to supply or ground.



V _{inh}	A	M1	B	M2
H	H	Fast motor stop	H	Run
H	L	Run	L	Fast motor stop
L	X	Free running motor stop	X	Free running motor stop

L = Low H = High X = Don't care

Fig. 6 - A bridge is used for bidirectional drive of DC motors.



INPUTS		FUNCTION
V _{inh} = H	C = H; D = L	Turn right
	C = L; D = H	Turn left
	C = D	Fast motor stop
V _{inh} = L	C = X; D = X	Free running motor stop

L = Low H = High X = Don't care

made to run clockwise, run anticlockwise or stop rapidly.

Again, the enable/inhibit input is used for a free running stop - it turns off all four transistors of

the bridge when low. A very rapid stop may be achieved by reversing the current, though this requires more careful design to stop the motor dead. In practice a tachometer dynamo and closed loop control are usually necessary. Like the previous circuit, this configuration is suitable for motors with currents up to 1A (L293/L293E) or 2A (L298).

The motor speed in these examples can be controlled by switching the drivers with pulse width modulated squarewaves. This approach is particularly suitable for microcomputer control.

For unidirectional drive with a single channel the PWM control signal can be applied to either the channel input or the appropriate enable input. In both cases the recirculation path is through the suppression diode and motor, giving a fairly slow decay. From a practical point of view it is preferable to control the channel input because the circuit response is faster. This is very convenient because each channel has an independent input.

The situation is different for bidirectional motors driven by a bridge. In this case the two alternatives have different effects. If the channel inputs are driven by the PWM signal, with suitable logic, the

recirculation path is through a diode, the motor and a transistor (figure 7a), giving a slow decay. On the other hand, if the enable input is controlled the recirculation path is from ground to supply through two diodes and the winding. This path gives a faster decay (figure 7b).

Figure 8 shows a practical example of PWM motor speed control. This circuit includes the oscillator and modulator and allows independent regulation of the speeds of the two motors. The channel inputs are used to control the direction.

An interesting feature of this circuit is that it takes advantage of the threshold of the enable/inhibit input to economise on comparators. The TBA820M audio amplifier generates triangle waves, the DC level of which is varied from 0 to 5V by means of P1 and P2.

Since the switching threshold of the L293's enable/inhibit inputs is roughly 2V the duty cycle of the output current (and hence the motor speed) is controlled by the setting of the potentiometer.

In this circuit the switching frequency is set by R1/C1 and the amplitude of the oscillator signal is set by the divider R2/R3.

Fig. 7a - If the current shown by the solid line is interrupted by bringing A low the current recirculates round the dotted path. Decay is slow.

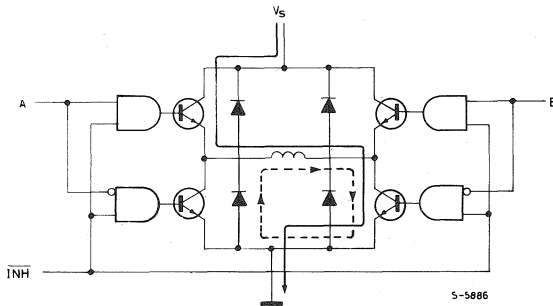


Fig. 7b - If the enable input is brought low to interrupt the current indicated by the solid line the current recirculates from ground to V_s and the decay is faster.

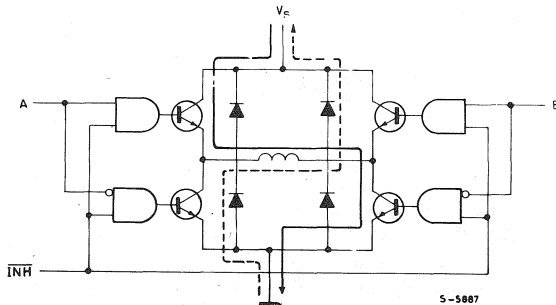
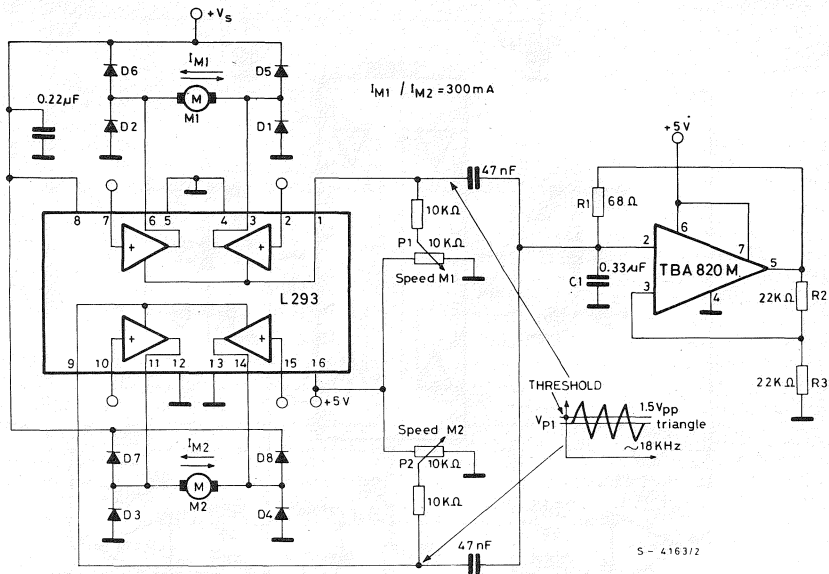


Fig. 8 - This circuit illustrates PWM control of the motor speed. The speed of each motor is controlled independently.



STEPPER MOTOR DRIVING

Monolithic bridge drivers are extremely useful for stepper motor driving because they simplify the use of bipolar motors. This is an important point since a bipolar stepper motor costs less than an equivalent unipolar motor (it has fewer windings) and gives more torque per unit volume, other things being equal.

The basic configuration for bipolar stepper motor driving is shown in figure 9. In this example it is assumed that a suitable translator (phase sequence generator) is connected to the four channel inputs.

Either an L293 or an L298 can be used in this circuit; an L293E would be wasted compared to an L293 because load current regulation, and hence the sense resistor connection, is not used.

But load current regulation is highly desirable to exploit the performance characteristics of the motor. Using an L293E or L298 this can be implemented by adding an LM339 quad comparator as shown in figure 10.

This is another circuit that requires an external translator but it provides independent PWM chopper regulation of the current in each winding.

Looking at motor phase one, the comparator output is initially high, enabling the bridge through pin 1.

The current in the motor winding rises until the voltage across the sensing resistor R2 produces a voltage at the inverting input of the comparator equal to the voltage on the non-inverting input (370 mV). This value is produced by the divider R10/R11 and by the hysteresis determined by R6 and R8.

At this point the comparator switches, disabling the bridge. The current in the winding recirculates through D5 and D6 until the voltage across R2 falls below the lower threshold of the comparator. The comparator then switches again and the cycle repeats.

Fig. 9 - A single device can be used to drive a two phase bipolar stepper motor.

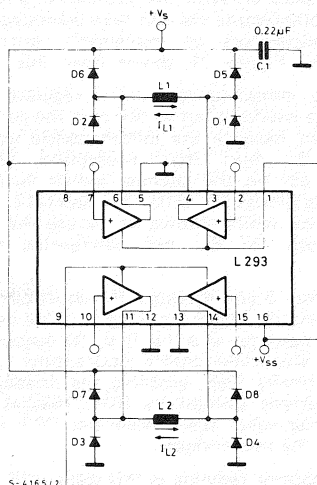
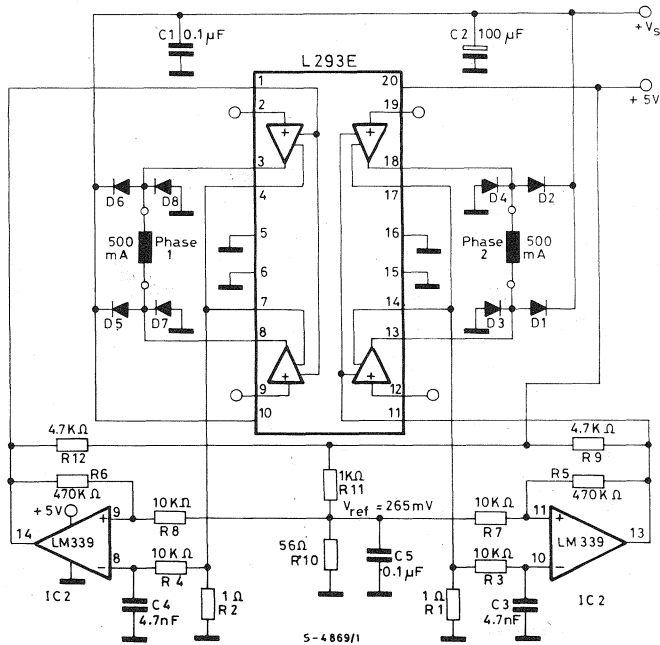


Fig. 10 - Two comparators provide chopper current regulation in this bipolar stepper motor drive circuit.



The peak current in each winding is determined by V_{ref} (in this case it is 0.5A) and the switching rate — and hence the average current — depends on the hysteresis of the comparator and R4C4. With the component values shown the switching frequency is roughly 20 kHz.

The figure 10 circuit uses only half of the LM339 quad comparator. With the addition of a few extra passive components we can take advantage of the spare comparators to implement short circuit protection. Figure 11 shows how this is done.

As before, comparators 1 and 2 regulate the current in the windings but in this case the connection is different because the inhibit/enable inputs are used for the short circuit protection. The PWM choppers act on the channel inputs through the four clamp diodes D9, D10, D11 and D12. This is a simple trick which allows us to use the channel inputs both for the step sequencing and the choppers.

Comparators 3 and 4 realize the short circuit protection function. Again looking at phase one, comparator 3 operates as a flip flop. Its output is connected to the bridge enable inputs (pins 1 and 11) and is normally high, enabling the drivers. If the output current (sensed by RS1) reaches double the nominal value the comparator CP3 switches, inhibiting the two bridges.

The comparator remains in this state until the V_{SS}

supply (5V) is interrupted. The outputs of comparators 3 and 4 are ORed together so that a short circuit on one phase disables both bridges.

For this circuit V_A should be less than 300 mV (V_A is the voltage on the + input of CP1). From the value chosen for V_A and the desired phase current the sense resistor RS1 (and RS2) is chosen. The current ripple should be at least 30 mA to avoid spurious triggering of CP1 and CP2.

The component values indicated are for a motor with a resistance of 37 Ω /phase, inductance of 80 mH/phase and a current of 280 mA/phase. V_{ref} is 243 mV giving $V_A = 274$ mV when the output is high and 243 mV when the output is low. Since RS1 = 1 Ω the current in the winding reaches 274 mA peak and has a ripple of roughly 30 mA. The switching frequency depends on the hysteresis of the comparators and the motor characteristics. For this example the frequency is about 15 kHz.

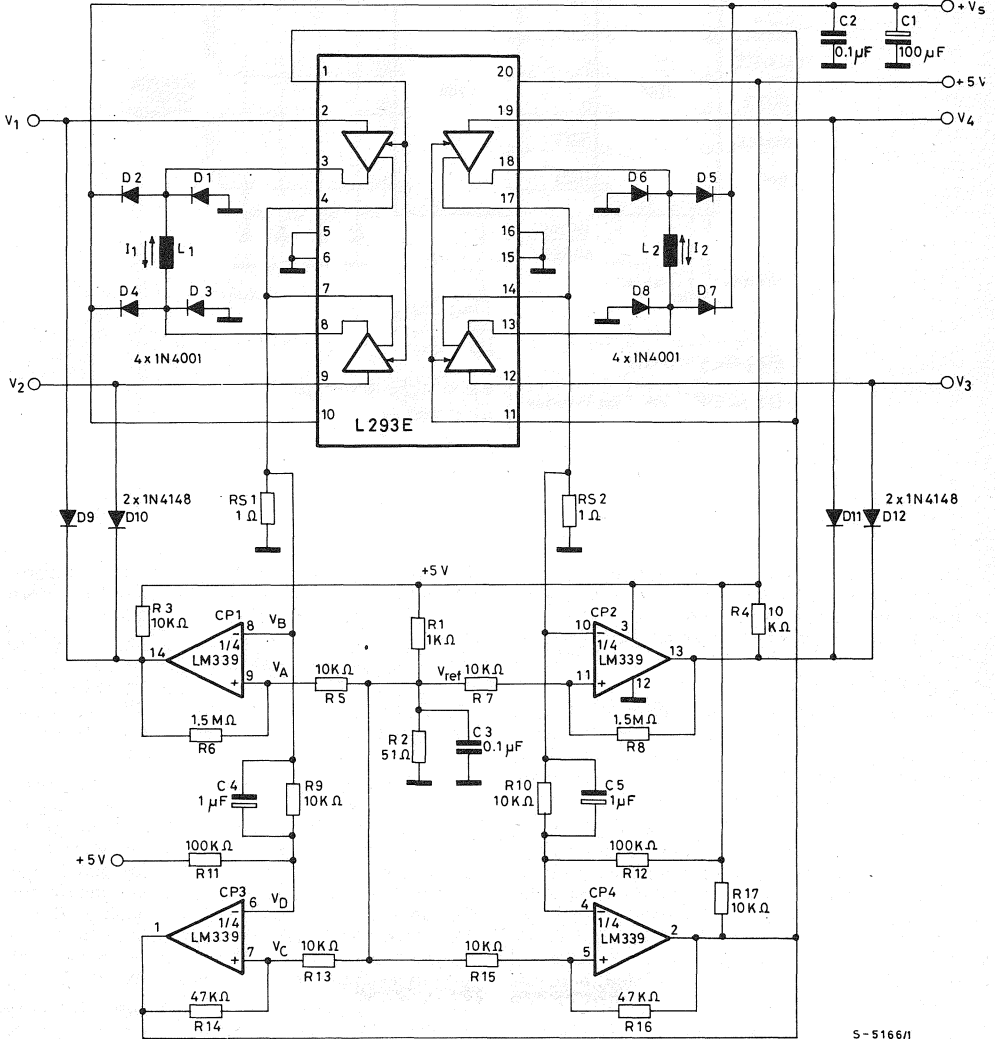
Stepper motor drive circuits can be simplified using the L297 stepper motor controller which contains a translator to generate the phase sequences plus a dual PWM chopper to regulate the phase currents.

The L297 connects directly to the L293E or L298 as shown in figure 12. This example drives a bipolar stepper motor with winding currents up to 2.5A. For lower currents an L293E is used and more powerful motors can be driven by two L298s with paralleled bridges, giving up to 3.5A.

In this configuration the motor is controlled through the L297. A step clock moves the motor one increment, the CW/CCW input controls the direction and the HALF/FULL input selects half step or normal operation. The input V_{ref} is connected to a suitable voltage reference and sets the

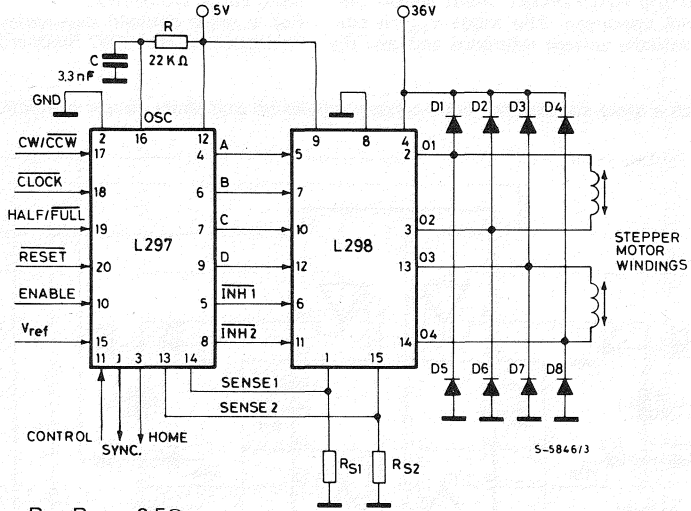
peak winding current in the motor. The choppers in the L297 can operate on the phase lines or the inhibit lines, depending on the state of the logic input called CONTROL. For a more detailed description of the L297 see "Introducing the L297 Stepper Motor Controller".

Fig. 11 - With a quad comparator both current regulation and short circuit protection can be obtained.



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Fig. 12 - An L297 stepper motor controller and a L298 driver together form a complete microprocessor-to-stepper motor interface. This circuit drives bipolar stepper motors with winding currents up to 2A.



$R_{S1} R_{S2} = 0.5\Omega$

D1 to D8 = 2A Fast Diodes $\left\{ \begin{array}{l} V_F \leq 1,2V @ I = 2A \\ t_{rr} \leq 200 \text{ ns} \end{array} \right.$