PBL 3771
Precision Stepper
Motor Driver

Description

The PBL 3771 is a switch-mode, constant-current driver IC (chopper) with two channels, one for each winding of a two-phase stepper motor. The circuit is especially developed for use in microstepping applications in conjunction with the matching dual DAC (Digital-to-Analog Converter) PBM 3960. A complete driver system consists of these two ICs, a few passive components and a microprocessor for generation of the proper control and data codes required for microstepping.

The PBL 3771 contains a clock oscillator, which is common for both driver channels; a set of comparators and flip-flops implementing the switching control; and two H-bridges with internal recirculation diodes. Voltage supply requirements are +5 V for logic and +10 to +45 V for the motor. Maximum output current is 650 mA per channel.

A special logic function is used to select slow or fast current decay in the output stage for improved high-speed microstepping.

The close match between the two driver channels guarantees consistent output current ratios and motor positioning accuracy.

Key Features

- Dual chopper driver in a single package.

- 650 mA output current per channel.

- Close matching between channels for high microstepping accuracy.

- Selectable slow/fast current decay for improved high-speed microstepping.

- Improved low-level linearity.

- Specially matched to Dual DAC PBM 3960.

- Selection of packages, 22-pin "batwing" DIP or 28-lead PLCC with lead-frame for heat-sinking through PC board copper.
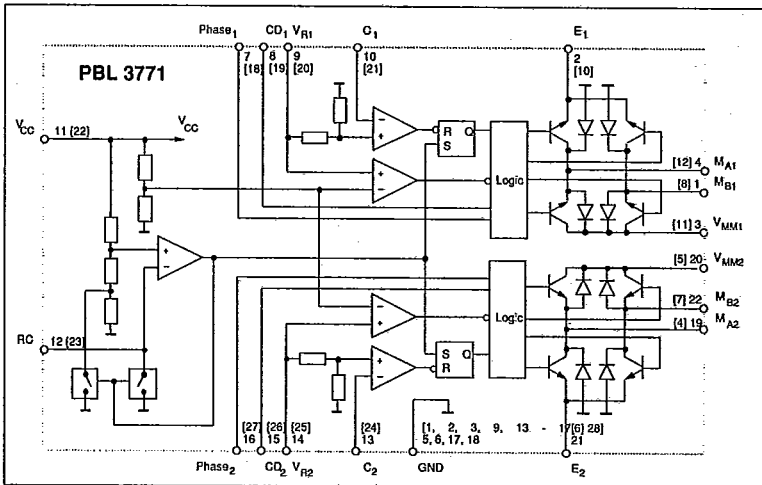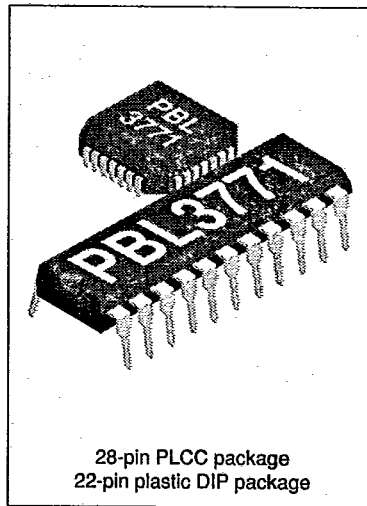

Figure 1. Block diagram.

28-pin PLCC package
22-pin plastic DIP package

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Maximum Ratings

Parameter	Pin no. *	Symbol	Min	Max	Unit
Voltage					
Logic supply	11 [22]	V_{CC}	0	7	V
Motor supply	3, 20 [5, 11]	V_{MM}	0	45	V
Logic inputs	7, 8, 15, 16 [18-19, 26-27]	V_I	-0.3	6	V
Comparator inputs	10, 13 [21, 24]	V_C	-0.3	V_{CC}	V
Reference inputs	9, 14 [20, 25]	V_R	-0.3	7.5	V
Current					
Motor output current	1, 4, 19, 22 [4, 7, 8, 12]	I_M	-700	+700	mA
Logic inputs	7, 8, 15, 16 [18, 19, 26, 27]	I_I	-10		mA
Analog inputs	10, 13 [21, 24]	I_A	-10		mA
Oscillator charging current	12 [23]	I_{RC}		5	mA
Temperature					
Junction temperature		T_j		+150	°C
Operating ambient temperature		T_a	0	+70	°C
Storage temperature		T_s	-55	+150	°C

* [no] refers to PLCC package pin no.

Recommended Operating Conditions

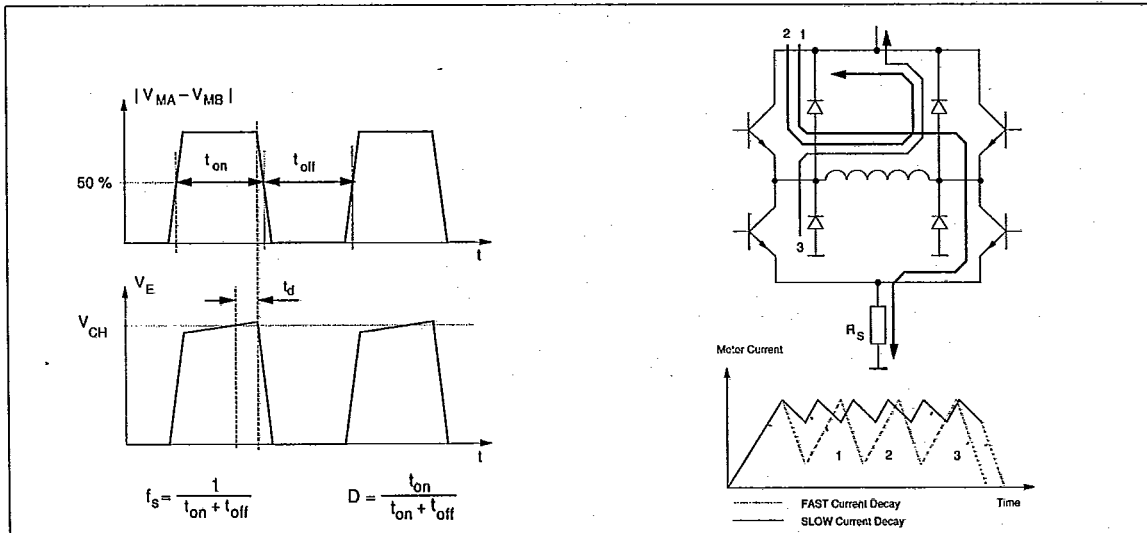| Parameter	Symbol	Min	Typ	Max	Unit
Logic supply voltage	V_{CC}	4.75	5	5.25	V
Motor supply voltage	V_{MM}	10		40	V
Motor output current **	I_M	-650		650	mA
Ambient temperature	T_a	0		70	°C
Rise time logic inputs	t_r			2	μs
Fall time logic inputs	t_f			2	μs
Oscillator timing resistor	R_T	2	15	20	kohms

** In microstepping mode, "sine/cosine" drive where $I_1 = 650 \cdot \cos(\theta)$ and $I_2 = 650 \cdot \sin(\theta)$ mA, otherwise 500 mA per channel both fully on.

$$f_s = \frac{1}{t_{on} + t_{off}} \qquad D = \frac{t_{on}}{t_{on} + t_{off}}$$

Motor Current

------ FAST Current Decay   Time
——— SLOW Current Decay

Figure 2. Definitions.

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Electrical Characteristics

Electrical characteristics over recommended operating conditions.

Parameter	Symbol	Ref. fig.	Conditions	Min	Typ	Max	Unit
General							
Supply current	I_{CC}				38	50	mA
Total power dissipation	P_D		$V_{MM} = 40$ V, $I_{M1} = 450$ mA, $I_{M2} = 0$ mA. Notes 2, 3.	1.4	1.6	W	
			$V_{MM} = 40$ V, $I_{M1} = I_{M2} = 318$ mA. Notes 2, 3.	1.6		1.8	W
Turn-off delay	t_d	2	$T_a = +25°C$, $dV_C/dt \geq 50$ mV/μs. Note 3.		1.0	1.5	μs
Logic Inputs							
Logic HIGH input voltage	V_{IH}			2.0			V
Logic LOW input voltage	V_{IL}					0.8	V
Logic HIGH input current	I_{IH}		$V_I = 0.4$ V	-0.4			mA
Logic LOW input current	I_{IL}		$V_I = 2.4$ V			20	μA
Reference Inputs							
Input resistance	R_R		$T_a = +25°C$		5		kohms
Input current	I_R		$T_a = +25°C$, $V_R = 2.5$ V.		0.5	1.0	mA
Turn-off voltage	V_{TO}			20	29	38	mV
Comparator Inputs							
Threshold voltage	V_{CH}		$R_C = 1$ kohms, $V_R = 2.5$ V	430	450	470	mV
$\mid V_{CH1} - V_{CH2} \mid$ mismatch	$V_{CH,diff}$		$R_C = 1$ kohms		1		mV
Input current	I_C			-10		1	μA
Motor Outputs							
Lower transistor saturation voltage			$I_M = 500$ mA		1.0	1.20	V
Lower transistor leakage current			$V_{MM} = 41$ V, $V_E = V_R = 0$ V, $V_C = V_{CC}$			300	μA
Lower diode forward voltage drop			$I_M = 500$ mA		1.1	1.25	V
Upper transistor saturation voltage			$I_M = 500$ mA		1.2	1.35	V
Upper transistor leakage current			$V_{MM} = 41$ V, $V_E = V_R = 0$ V, $V_C = V_{CC}$			300	μA
Upper diode forward voltage drop			$I_M = 500$ mA		1.0	1.25	V
Chopper Oscillator							
Chopping frequency	f_s	2	$C_T = 3300$ pF, $R_T = 15$ kohms	25.0	26.5	28.0	kHz

Thermal Characteristics

Parameter	Symbol	Ref. fig.	Conditions	Min	Typ	Max	Unit
Thermal resistance	Rth_{j-c}		DIP package.		11		°C/W
	Rth_{j-a}	5	DIP package. Note 2.		40		°C/W
	Rth_{j-c}		PLCC package.		9		°C/W
	Rth_{j-a}	5	PLCC package. Note 2.		35		°C/W

Notes

1. All voltages are with respect to ground. Currents are positive into, negative out of specified terminal.
2. All ground pins soldered onto a 20 cm² PCB copper area with free air convection.
3. Not covered by final test program.
4. Swtching duty cycle D = 30%, $f_S = 26.5$ kHz.

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Pin Description

Refer to figure 3.

| DIP	PLCC	Symbol	Description
1	8	M_{B1}	Motor output B, channel 1. Motor current flows from M_{A1} to M_{B1} when Phase is HIGH.
2	10	E_1	Common emitter, channel 1. This pin connects to a sensing resistor to ground.
3	11	V_{MM1}	Motor supply voltage, channel 1, 10 to 40 V. V_{MM1} and V_{MM2} should be connected together.
4	12	M_{A1}	Motor output A, channel 1. Motor current flows from M_{A1} to M_{B1} when Phase is HIGH.
5, 17 6, 18	1, 2, 3, 9 13, 14 15, 16 17, 28		Ground and negative supply. Note: these pins are used thermally for heat-sinking. Make sure that all ground pins are soldered onto a suitably large copper ground plane for efficient heat sinking.
7	18	$Phase_1$	Controls the direction of motor current at outputs M_{A1} and M_{B1}. Motor current flows from M_{A1} to M_{B1} when $Phase_1$ is HIGH.
8	19	CD_1	Current decay control, channel 1. A logic HIGH on this input results in *slow* current decay, a LOW results in *fast* current decay, see "Functional Description."
9	20	V_{R1}	Reference voltage, channel 1. Controls the threshold voltage for the comparator and hence the output current. Input resistance is typically 2.5 kohms, ±20%.
10	21	C_1	Comparator input 1. This input senses the instantaneous voltage across the sensing resistor, filtered by an RC network. The threshold voltage for the comparator is $(0.450 / 2.5) \cdot V_{R1}$, i.e. 450 mV at V_{R1} = 2.5 V.
11	22	V_{cc}	Logic voltage supply, nominally +5 V.
12	23	RC	Clock oscillator RC pin. Connect a 15 kohm resistor to V_{cc} and a 3300 pF capacitor to ground to obtain the nominal switching frequency of 26.5 kHz.
13	24	C_2	Comparator input 2. This input senses the instantaneous voltage across the sensing resistor, filtered by an RC network. The threshold voltage for the comparator is $(0.450 / 2.5) \cdot V_{R1}$, i.e. 450 mV at V_{R1} = 2.5 V.
14	25	V_{R2}	Reference voltage, channel 2. Controls the threshold voltage for the comparator and hence the output current. Input resistance is typically 2.5 kohms, ±20%.
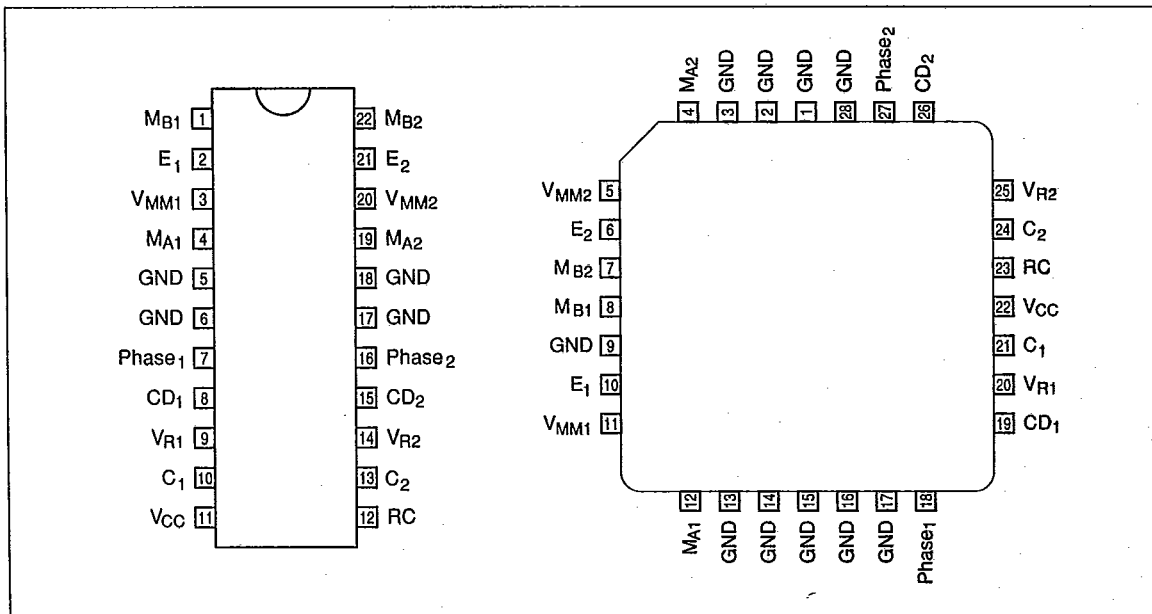
Figure 3. Pin configuration.

15	26	CD_2	Current decay control, channel 2. A logic HIGH on this input results in *slow* current decay, a LOW results in *fast* current decay, see "Functional Description."
16	27	$Phase_2$	Controls the direction of motor current at outputs M_{A2} and M_{B2}. Motor current flows from M_{A2} to M_{B2} when $Phase_2$ is HIGH.
19	4	M_{A2}	Motor output A, channel 2. Motor current flows from M_{A2} to M_{B2} when Phase is HIGH.
20	5	V_{MM2}	Motor supply voltage, channel 2, 10 to 40 V. V_{MM1} and V_{MM2} should be connected together.
21	6	E_2	Common emitter, channel 2. This pin connects to a sensing resistor to ground.
22	7	M_{B2}	Motor output B, channel 2. Motor current flows from M_{A2} to M_{B2} when Phase is HIGH.

Functional Description

Each channel of the PBL 3771 consists of the following sections: an H-bridge output stage, capable of driving up to 650 mA continuous motor current (or 500 mA, both channels driven), a logic section that controls the output transistors, an S-R flip-flop, and two comparators. The oscillator is common to both channels.

Constant current control is achieved by switching the current to the windings. This is done by sensing the (peak) voltage across a current-sensing resistor, R_S, effectively connected in series with the motor winding, and feeding that voltage back to a comparator. When the motor current reaches a threshold level, determined by the voltage at the reference input, V_R, the comparator resets the

flip-flop, which turns off the output transistors. The current decreases until the clock oscillator triggers the flip-flop, which turns on the output transistors again, and the cycle is repeated.

The current-decay rate during the turn-off portion of the switching cycle, can be selected fast or slow by the CD input.

In slow current-decay mode, only one of the lower transistors in the H-bridge (those closest to the negative supply) is switched on and off, while one of the upper transistors is held constantly on. During turn-off, the current recirculates through the upper transistor (which one depends on current direction) and the corresponding free-wheeling diode connected to V_{MM}, see figure 2.

In fast current decay mode, both the upper and lower transistors are switched.

During the off-time, the freewheeling current is opposed by the supply voltage, causing a rapid discharge of energy in the winding.

Fast current decay may be required in half- and microstepping applications when rapid changes of motor current are necessary. Slow current decay, however, gives less current ripple, and should always be selected, if possible, to minimize core losses and switching noise.

Applications Information

Current control

The output current to the motor winding is mainly determined by the voltage at the reference input and the value of the sensing resistor, R_S.
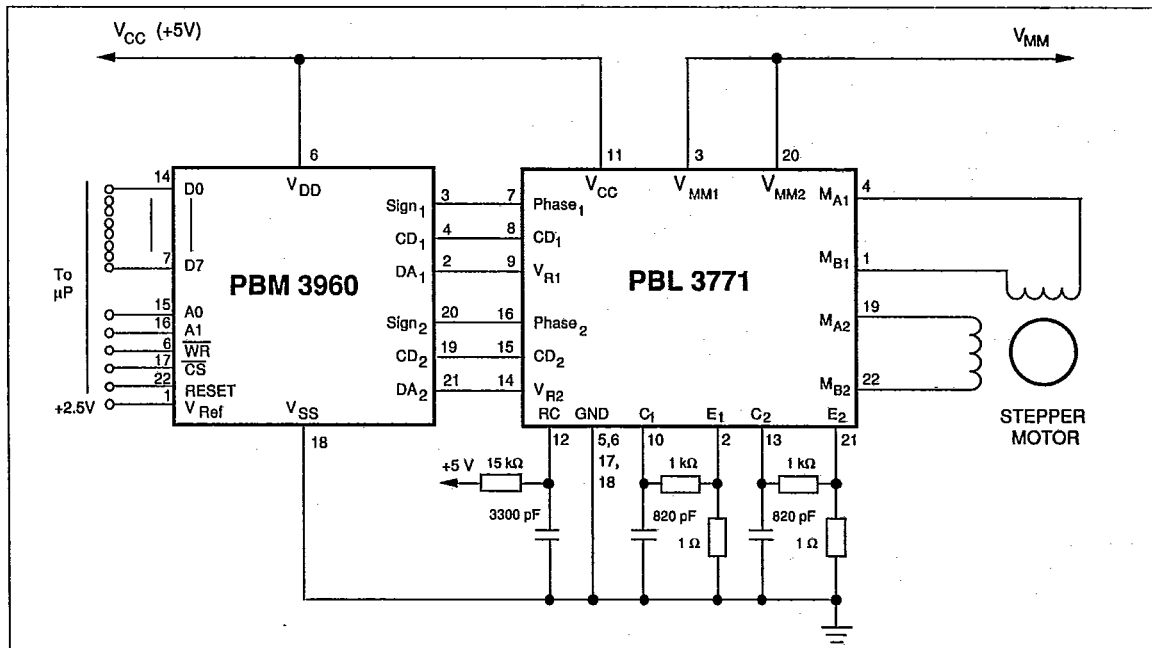

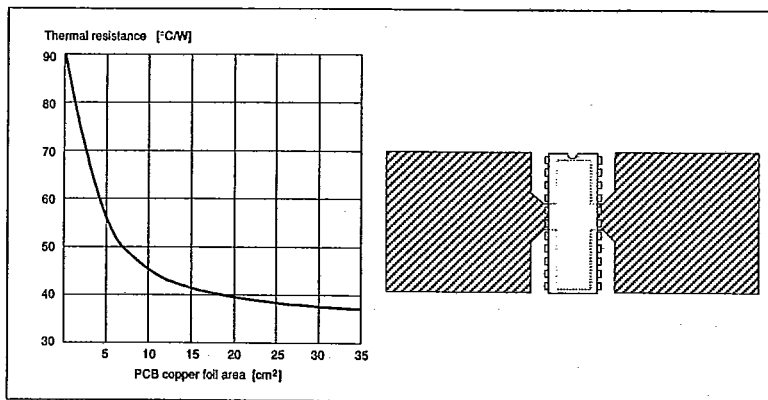Figure 4. Microstepping system with PBM 3960 and PBL 3771.

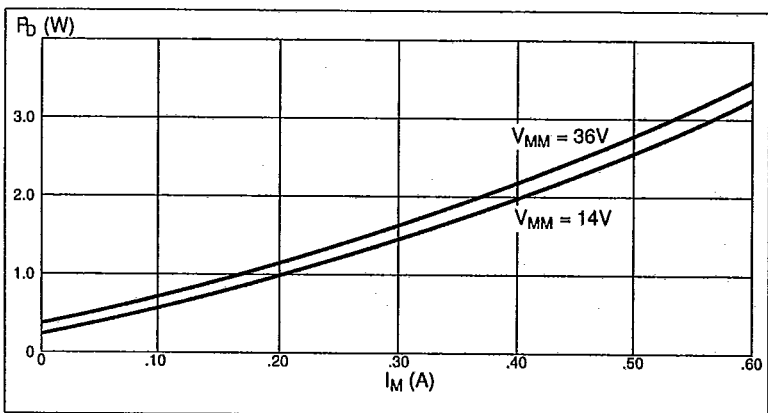Figure 5. Thermal Resistance vs. PC Board copper area and suggested layout.

Figure 6. Power dissipation vs. motor current, both channels driven, $T_a = 25°C$.
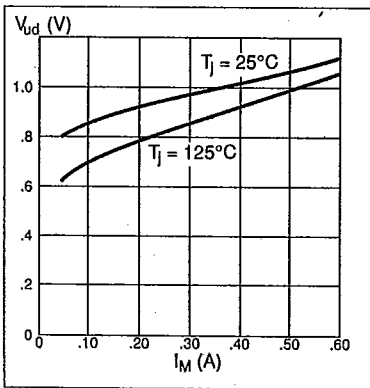

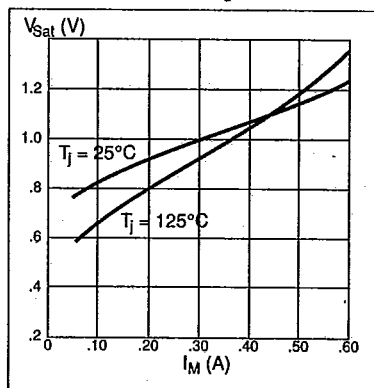Figure 7. Typical upper diode voltage drop vs. recirculating current.

Figure 8. Typical source saturation voltage vs. output current.

Chopping frequency, winding inductance, and supply voltage will affect the current level, but to much less extent. Fast current decay setting will produce somewhat lower (average) current than slow current decay. The peak current through the sensing resistor (and motor winding) can be expressed as:

$$I_{M,peak} = 0.18 \cdot (V_R / R_S) \qquad [A]$$

i.e., with a recommended value of 1 ohm for the sensing resistor, R_S, a 2.5 V reference voltage will produce an output current of approximately 450 mA. To improve noise immunity on the V_R input, the control range may be increased to 5 volts if R_S is correspondingly changed to 2 ohms.

External components

The voltage across the sensing resistor is fed back to the comparator via a low-pass filter section, to prevent erroneous switching due to switching transients. The recommended filter component values, 1 kohm and 820 pF, are suitable for a wide range of motors and operational conditions.

Since the low-pass filtering action introduces a small delay of the signal to the comparator, peak voltage across the sensing resistor, and hence the peak motor current, will reach a slightly higher level than the threshold, V_c, set by the reference voltage ($V_c = 450$ mV @ $V_R = 2.5$ V).

The time constant of the low-pass filter may therefore be reduced to minimize the delay and optimize low-current performance, especially if a low (12 V) supply voltage is used. Increasing the time constant may result in unstable switching.

The frequency of the clock oscillator is set by the R-C combination at pin RC. The recommended values give a nominal frequency of 26.5 kHz. A lower frequency will result in higher current ripple and may cause audible noise from the motor, while increasing the frequency results in higher switching losses and possibly increased iron losses in the motor.

The sensing resistor, R_S, should be selected for maximum motor current. The relationship between peak motor current, reference voltage and the value of R_S is described under "Current control" above. Be sure not to exceed the maximum output current which is 650 mA per channel (or 500 mA per channel, both

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channels fully on, see "Recommended Operating Conditions").

Motor selection

The PBL 3771 is designed for "bipolar" motors, i.e., motors that have only one winding per phase. A "unipolar" motor, having windings with a center tap, can also be used, see figure 11.

The chopping principle in the PBL 3771 is based on a constant frequency and a varying duty cycle. This scheme imposes certain restrictions on motor selection. Unstable chopping can occur if the chopping duty cycle exceeds approximately 50%. To avoid this, it is necessary to choose a motor with a low winding resistance. Low winding resistance means less inductance and will therefore enable higher stepping rates, however it also means less torque capability. A compromise has to be made.

Choose a motor with the lowest possible winding resistance that still gives the required torque and use as high supply voltage as possible without exceeding the maximum recommended 40 V. Check that the chopping duty cycle does not exceed 50% at maximum current.

Since the PBL 3771 produces a regulated, constant output current it is not necessary to use a motor that is rated at the same voltage as the actual supply voltage. Only rated current needs to be considered. Typical motors to be used together with the PBL 3771 have voltage ratings of 5 to 12 V, while the supply voltage usually ranges from 24 to 40 V.

General

Phase inputs. A logic HIGH on a SIGN input gives positive current flowing out from M_A into M_B. A logic LOW gives a current in the opposite direction.

Slow/fast current decay. A logic HIGH on the CD input gives slow current decay, a logic LOW gives fast current decay.

Heat sinking. Soldering the four center pins onto a free PCB copper area of 20 cm² (approx. 1.8" × 1.8", copper foil thickness = 35 μm) permits the circuit to operate with a maximum of 320 mA output current, both channels driving, at ambient temperatures up to +70°C. Consult figures 5 and 6 in order to
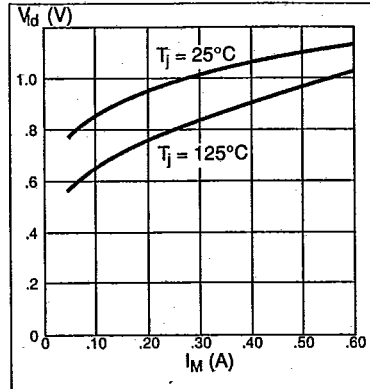

Figure 9. Typical lower diode voltage drop vs. recirculating current.
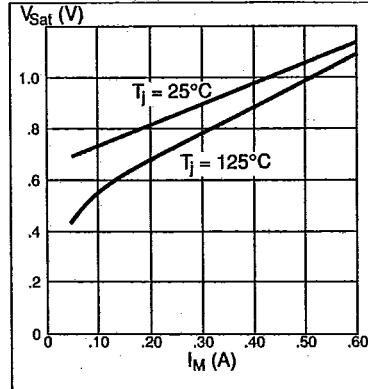

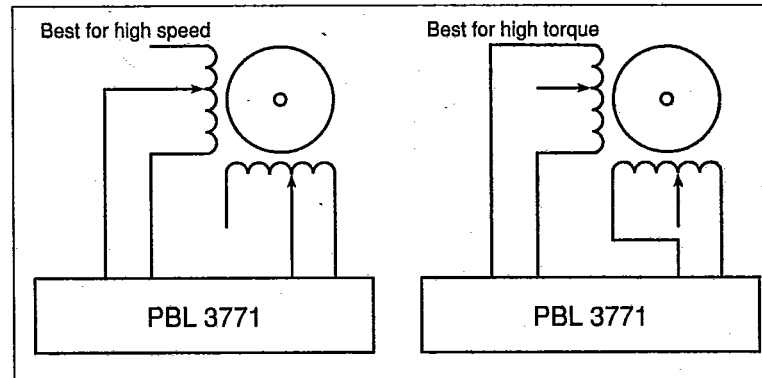Figure 10. Typical sink saturation voltage vs. output current.

Figure 11. Connection of unipolar motors.

Description	DIP	PLCC
Rth$_{j-c}$, Junction to Case (Case = ground pin)	11°C/W	9°C/W
Rth$_{j-a}$, Junction to Ambient*	40°C/W	35°C/W

* For the DIP, the four ground pins soldered to a 20 cm² ground plane according to figure 5. For the PLCC, all ground pins are soldered to a 20 cm² ground plane located as close as possible to the device and on both sides of a double sided PCB.

Table 1. Thermal resistance . Thermal resistance values are heavily dependant on location and shape of heatsinks.

determine the necessary copper area for heat sinking if higher currents are required.

Thermal shutdown. The circuit is equipped with a thermal shutdown function that reduces the output current at chip temperatures above +160°C.

Ordering Information

Package	Temp. range	Part No.
Plastic DIP	0 to 70°C	PBL3771N
PLCC	0 to 70°C	PBL3771QN