

PBL 3774 Dual Stepper Motor Driver

Description

The PBL 3774 is a switch-mode (chopper), constant-current driver IC with two channels, one for each winding of a two-phase stepper motor. The circuit is similar to Ericsson's PBL 3771 and PBL 3772. While all Dual stepper motor drivers are optimized for microstepping applications, the PBL 3774 is equipped with a TTL level compatible Disable input to simplify half-stepping operation.

The circuit is well suited for microstepping applications together 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.

In full/halfstepping applications, Ericsson Component's PBD 3517/1 can be used as a phase generator (translator) to derive the necessary signals for the PBL 3774.

The PBL 3774 contains a clock oscillator, which is common for both driver channels, a set of comparators and flip-flops implementing the switching control, and two output H-bridges.

Voltage supply requirements are +5 V for logic and +10 to +45 V for the motor.

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.
- Operation at -40 °C.
- 1000 mA continuous output current per channel.
- Low power dissipation, 2.6 W at 2 x 750 mA output current.
- Close matching between channels for high microstepping accuracy.
- Specially matched to the Dual DAC PBM 3960.
- Plastic 22-pin batwing DIP package or 28-pin power PLCC package with lead-frame for heatsinking through PC board copper.

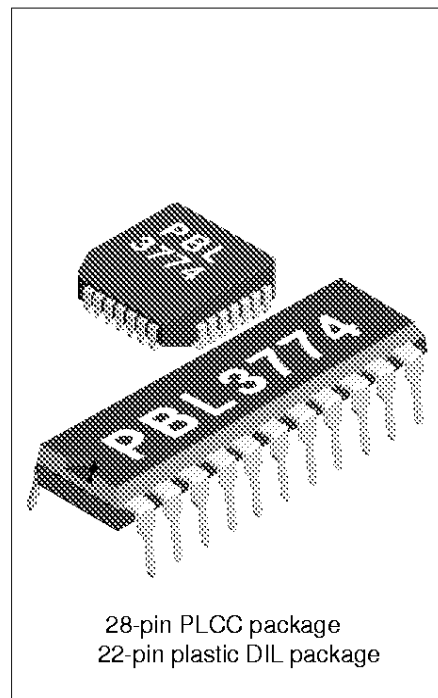
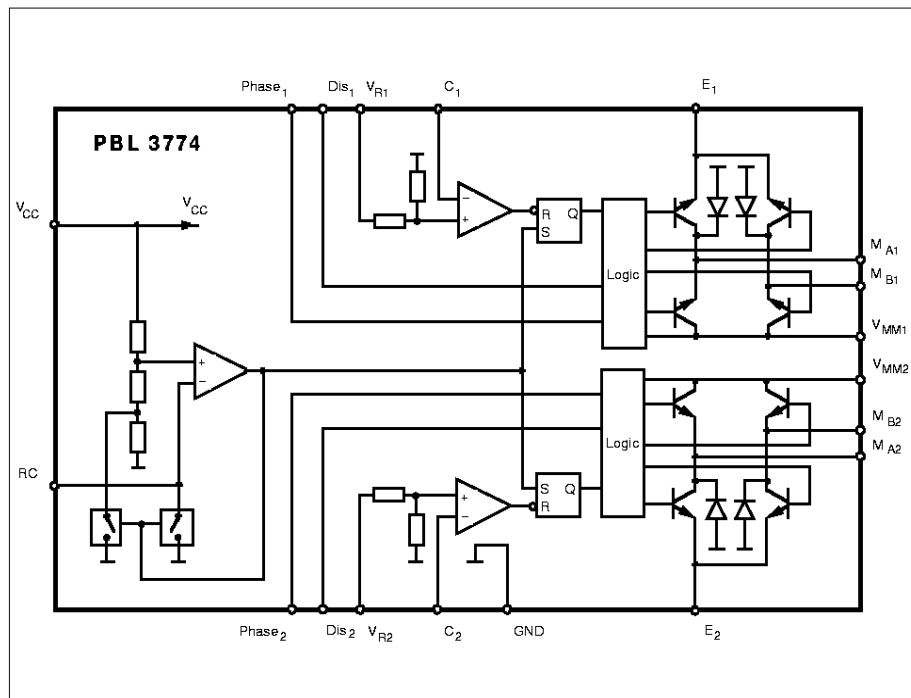


Figure 1. Block diagram.

Maximum Ratings

Parameter	Pin no. [DIL-package]	Symbol	Min	Max	Unit
Voltage					
Logic supply	22	V_{CC}	0	7	V
Motor supply	9, 14	V_{MM}	0	45	V
Logic inputs	4, 7, 16, 19	V_I	-0.3	6	V
Comparator inputs	2, 21	V_C	-0.3	V_{CC}	V
Reference inputs	3, 20	V_R	-0.3	7.5	V
Current					
Motor output current	8, 11, 12, 15	I_M	-1200	+1200	mA
Logic inputs	4, 7, 16, 19	I_I	-10		mA
Analog inputs	2, 3, 20, 21	I_A	-10		mA
Temperature					
Operating Junction temperature		T_J	-40	+150	°C
Storage temperature		T_S	-55	+150	°C
Power Dissipation (Package Data)					
Power dissipation at $T_{BW} = +25^\circ\text{C}$, DIP and PLCC package		P_D		5	W
Power dissipation at $T_{BW} = +125^\circ\text{C}$, DIP package		P_D		2.2	W
Power dissipation at $T_{BW} = +125^\circ\text{C}$, PLCC package		P_D		2.6	W

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	-1000		+1000	mA
Operating Junction temperature	T_J	-20		+125	°C
Rise and fall time, logic inputs	t_r, t_f			2	μs
Oscillator timing resistor	R_T	2	15	20	k Ω

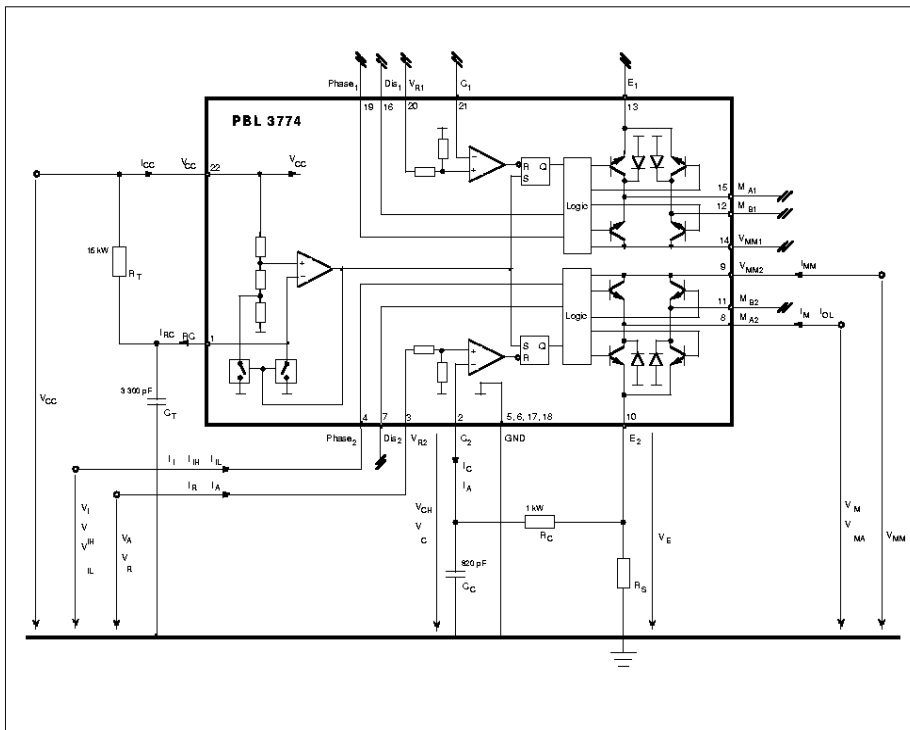


Figure 2. Definition of symbols.

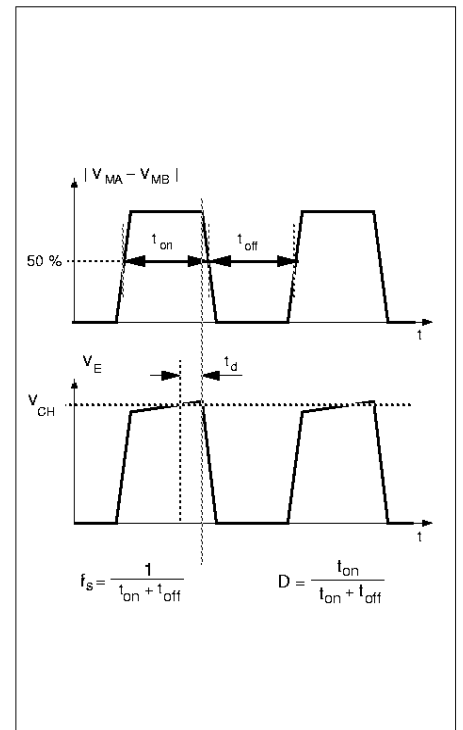


Figure 3. Definition of terms.

Electrical Characteristics

Electrical characteristics over recommended operating conditions unless otherwise noted, $-20^{\circ}\text{C} \leq T_J \leq +125^{\circ}\text{C}$.

Parameter	Symbol	Ref. fig.	Conditions	Min	Typ	Max	Unit
General							
Supply current	I_{CC}	2	Note 4.		60	75	mA
Total power dissipation	P_D		$V_{MM} = 12\text{ V}$, $I_{M1} = I_{M2} = 750\text{ mA}$. Notes 2, 3, 4.		2.6	2.9	W
Total power dissipation	P_D		$V_{MM} = 12\text{ V}$, $I_{M1} = 1000\text{ mA}$, $I_{M2} = 0\text{ mA}$. Notes 2, 3, 4.		2.6	2.9	W
Thermal shutdown junction temperature					160		$^{\circ}\text{C}$
Turn-off delay	t_d	3	$T_A = +25^{\circ}\text{C}$, $dV_C/dt \geq 50\text{ mV}/\mu\text{s}$. $I_M = 100\text{ mA}$. Note 3.		1.4	2.0	μs
Logic Inputs							
Logic HIGH input voltage	V_{IH}	2		2.0			V
Logic LOW input voltage	V_{IL}	2				0.8	V
Logic HIGH input current	I_{IH}	2	$V_I = 2.4\text{ V}$			20	μA
Logic LOW input current	I_{IL}	2	$V_I = 0.4\text{ V}$	-0.4			mA
Comparator Inputs							
Threshold voltage	V_{CH}	2	$R_C = 1\text{ kohm}$, $V_R = 2.50\text{ V}$	430	450	470	mV
$ V_{CH1} - V_{CH2} $ mismatch	$V_{CH,diff}$	2	$R_C = 1\text{ kohm}$		1		mV
Input current	I_C	2		-10		1	μA
Reference Inputs							
Input resistance	R_R	2	$T_A = +25^{\circ}\text{C}$		5		kohm
Input current	I_R	2	$V_R = 2.5\text{ V}$		0.5	1.0	mA
Motor Outputs							
Lower transistor saturation voltage		10	$I_M = 750\text{ mA}$		0.6	0.9	V
Lower transistor leakage current		2	$V_{MM} = 41\text{ V}$, $V_E = V_R = 0\text{ V}$, $V_C = V_{CC}$			700	μA
Lower diode forward voltage drop		11	$I_M = 750\text{ mA}$		1.2	1.5	V
Upper transistor saturation voltage		12	$I_M = 750\text{ mA}$.		1.1	1.4	V
Upper transistor leakage current		2	$V_{MM} = 41\text{ V}$, $V_E = V_R = 0\text{ V}$, $V_C = V_{CC}$			700	μA
Chopper Oscillator							
Chopping frequency	f_s	3	$C_T = 3300\text{ pF}$, $R_T = 15\text{ kohm}$	25.0	26.5	28.0	kHz

Thermal Characteristics

Parameter	Symbol	Ref. fig.	Conditions	Min	Typ	Max	Unit
Thermal resistance	$R_{th_{J-BW}}$		DIP package.		11		$^{\circ}\text{C}/\text{W}$
	$R_{th_{J-A}}$	13	DIP package. Note 2.		40		$^{\circ}\text{C}/\text{W}$
	$R_{th_{J-BW}}$		PLCC package.		9		$^{\circ}\text{C}/\text{W}$
	$R_{th_{J-A}}$	13	PLCC package. Note 2.		35		$^{\circ}\text{C}/\text{W}$

Notes

- All voltages are with respect to ground. Currents are positive into, negative out of specified terminal.
- All ground pins soldered onto a 20 cm^2 PCB copper area with free air convection, $T_A = +25^{\circ}\text{C}$.
- Not covered by final test program.
- Switching duty cycle $D = 30\%$, $f_s = 26.5\text{ kHz}$.

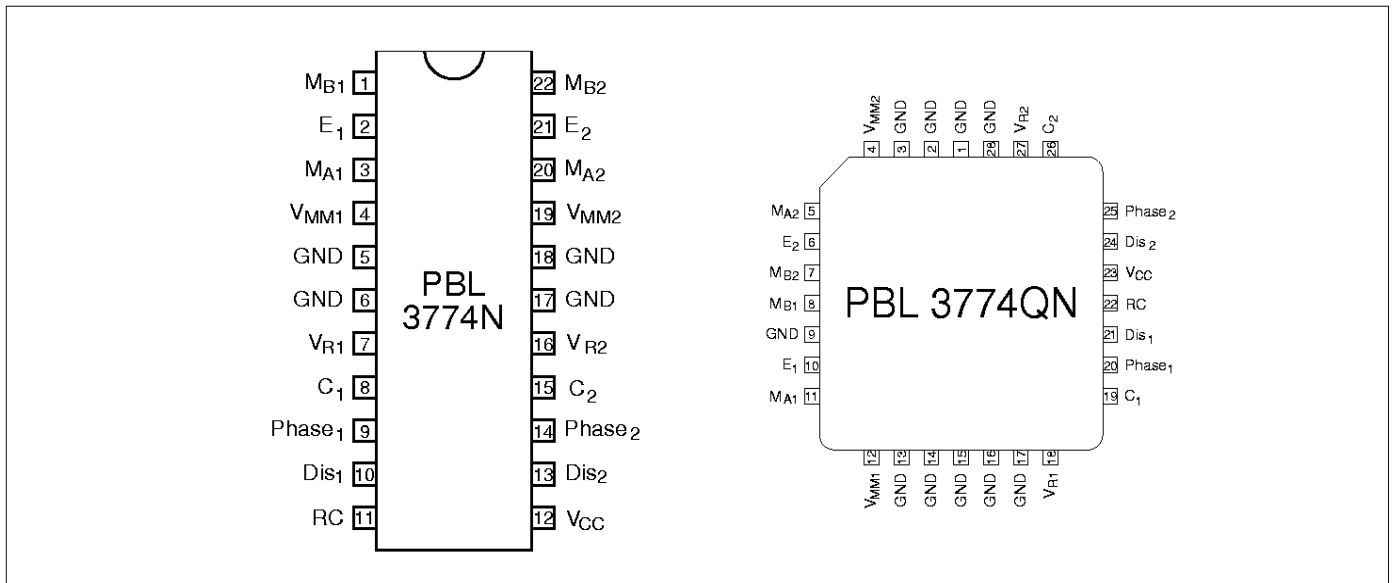


Figure 4. Pin configuration.

Pin Description

PLCC	DIP	Symbol	Description
1-3, 9, 13-17, 28	5, 6, 17, 18	GND	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.
4	8	M_{A2}	Motor output A, channel 2. Motor current flows from M_{A2} to M_{B2} when $Phase_2$ is HIGH.
5	9	V_{MM2}	Motor supply voltage, channel 2, +10 to +40 V. V_{MM1} and V_{MM2} should be connected together.
6	10	E_2	Common emitter, channel 2. This pin connects to a sensing resistor R_S to ground.
7	11	M_{B2}	Motor output B, channel 2. Motor current flows from M_{A2} to M_{B2} when $Phase_2$ is HIGH.
8	12	M_{B1}	Motor output B, channel 1. Motor current flows from M_{A1} to M_{B1} when $Phase_1$ is HIGH.
10	13	E_1	Common emitter, channel 1. This pin connects to a sensing resistor R_S to ground.
11	14	V_{MM1}	Motor supply voltage, channel 1, +10 to +40 V. V_{MM1} and V_{MM2} should be connected together.
12	15	M_{A1}	Motor output A, channel 1. Motor current flows from M_{A1} to M_{B1} when $Phase_1$ is HIGH.
18	16	Dis_1	Disable input (TTL level compatible) for channel 1. When HIGH, all four output transistors are turned off, which results in a rapidly decreasing output current to zero.
19	19	$Phase_1$	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.
20	20	V_{R1}	Ref. voltage, channel 1. Controls the threshold voltage for the comparator and hence the output current.
21	21	C_1	Comparator input channel 1. This input senses the instantaneous voltage across the sensing resistor, filtered by an RC network. The threshold voltage for the comparator is $V_{CH1} = 0.18 \cdot V_{R1}$ [V], i.e. 450 mV at $V_{R1} = 2.5$ V.
22	22	V_{CC}	Logic voltage supply, nominally +5 V.
23	1	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.
24	2	C_2	Comparator input channel 2. This input senses the instantaneous voltage across the sensing resistor, filtered by an RC network. The threshold voltage for the comparator is $V_{CH2} = 0.18 \cdot V_{R2}$ [V], i.e. 450 mV at $V_{R2} = 2.5$ V.
25	3	V_{R2}	Ref. voltage, channel 2. Controls the threshold voltage for the comparator and hence the output current.
26	4	$Phase_2$	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.
27	7	Dis_2	Disable input (TTL level compatible) for channel 2. When HIGH, all four output transistors are turned off, which results in a rapidly decreasing output current to zero.

Functional Description

Each channel of the PBL 3774 consists of the following sections: an output H-bridge with four transistors, capable of driving up to 1000mA continuous current to the motor winding; a logic section that controls the output transistors; an S-R flip-flop; and a comparator. The clock-oscillator is common to both channels.

Constant current control is achieved by switching the output current to the windings. This is done by sensing the peak current through the winding via a resistor, R_S , effectively connected in series with the motor winding during the turn-on period. As the current increases, a voltage develops across the resistor, and is fed back to the comparator. At the predetermined level defined by the voltage at the reference input V_R , the comparator resets the flip-flop, turning off the output transistors. The current decreases until the clock oscillator triggers the flip-flop, turning on the output transistors, and the cycle is repeated.

The current paths during turn-on, turn-off and phase shift are shown in figure 5. Note that the upper recirculation diodes are connected to the circuit externally.

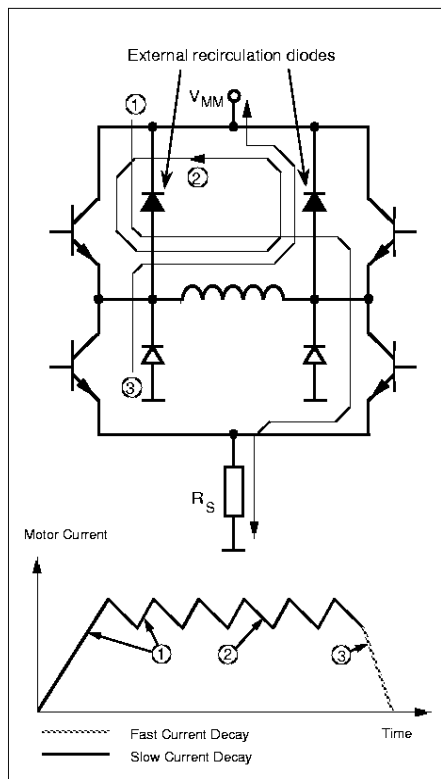


Figure 5. Output stage with current paths during turn-on, turn-off and phase shift.

Applications Information

Current control

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

Chopping frequency, winding inductance and supply voltage also affect the current, but to much less extent. The output current can be switched off completely by a HIGH input level at the Disable input (Dis1 and Dis2 for respective channels). When Disable goes HIGH, all four transistors in the output stage are switched off, and the output current rapidly drops to zero ("fast current decay" – see figure 5).

The peak motor current through the sensing resistor and the motor winding can be expressed as:

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

A 2.5 V reference voltage and a 0.47 ohm sensing resistor will produce an output current level of approximately 960 mA.

To improve noise immunity at the V_R input, the voltage control range can be increased to 5 V if R_S is correspondingly changed (for example to 1ohm for 900 mA max output current).

External components

For the device to function properly, four external free-wheeling diodes must be connected, as in figure 6. The diodes should be of fast type with a reverse recovery time of less than 100 ns. Commonly used types are UF4001 or BYV27.

A low pass filter in series with the comparator input prevents 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 lowpass 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 what is defined by the comparator threshold, V_{CH} , set by the reference input V_R ($V_{CH} = 450$ mV at $V_R = 2.5$ V).

The time constant of the low-pass filter may therefore be reduced to minimize the delay and optimize low-current performance. Increasing the time constant may result in unstable switching. The time constant should be adjusted by changing the C_c value.

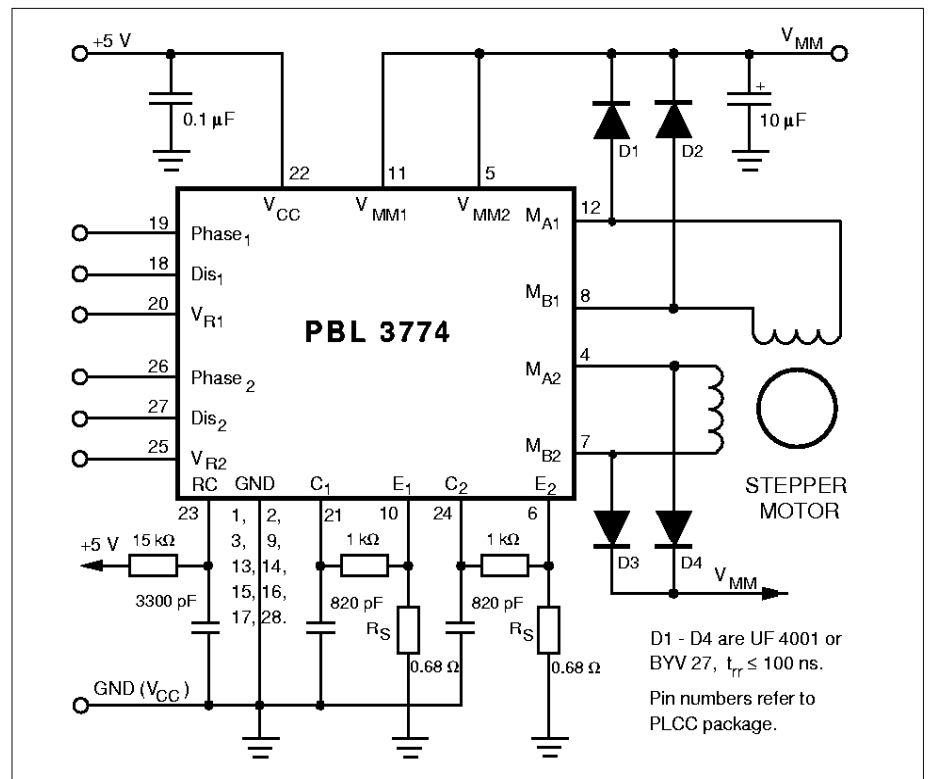


Figure 6. Typical stepper motor driver application with PBL 3774.

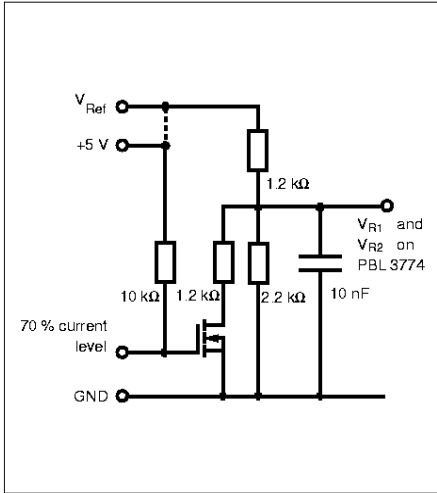


Figure 7. Reduction of reference voltage at the V_R pin of PBL 3774.

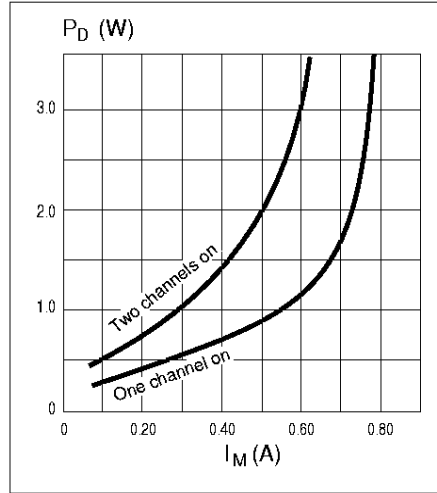


Figure 8. Power dissipation vs. motor current, $T_A = 25^\circ\text{C}$.

The frequency of the clock oscillator is set by the R_T - C_T timing components at the RC pin. The recommended values result in a clock frequency (= switching frequency) of 26.5 kHz. A lower frequency will result in higher current ripple, but may improve low-current level linearity. A higher clock frequency reduces current ripple, but increases the switching losses in the IC and possibly increased iron losses in the motor. If the clock frequency needs to be changed, the C_T capacitor value should be adjusted. The recommended R_T resistor value is 15 kohm.

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 1200mA peak when only one channel is activated. Or recommended output current, which is 1000mA peak, when both channels is activated.

Motor selection

The PBL 3774 is designed for two-phase bipolar stepper motors, i.e. motors that have only one winding per phase.

The chopping principle of the PBL 3774 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%. See figure 3 for definitions. To avoid this, it is necessary to choose a motor with a low winding resistance and inductance, i.e. windings with a few turns.

It is not possible to use a motor that is rated for the same voltage as the actual supply voltage. Only rated current needs to be considered. Typical motors to be used together with the PBL 3774 have a voltage rating of 1 to 6 V, while the supply voltage usually ranges from 12 to 40 V.

Low inductance, especially in combination with a high supply voltage, enables high stepping rates. However, to give the same torque capability at low speed, the reduced number of turns in the winding of the low resistive, low inductive motor must be compensated by a higher current. A compromise has to be made. Choose a motor with the lowest possible winding resistance and

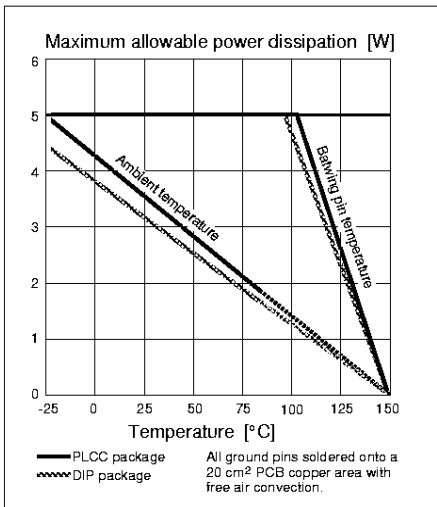


Figure 9. Maximum allowable continuous power dissipation vs. temperature.

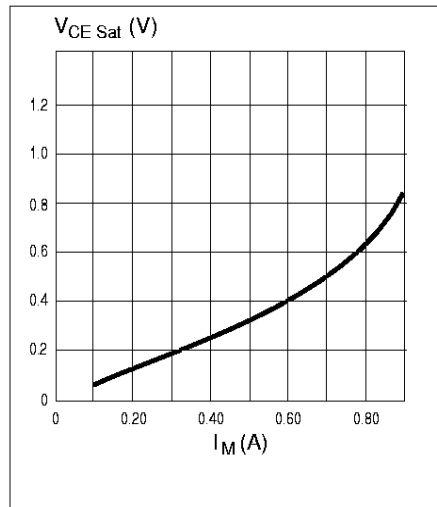


Figure 10. Typical lower transistor saturation voltage vs. output current.

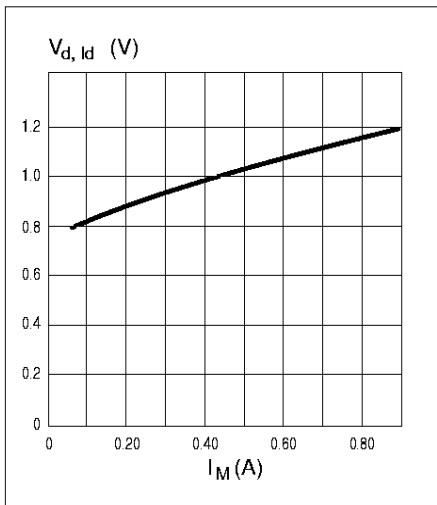


Figure 11. Typical lower diode voltage drop vs. recirculating current.

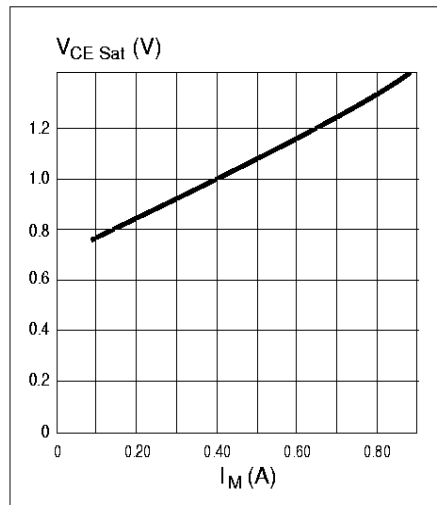


Figure 12. Typical upper transistor saturation voltage vs. output current.

inductance, 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 max. current.

General

Phase inputs. A logic HIGH on a Phase input gives a current flowing from pin M_A into M_B . A logic LOW gives a current flow in the opposite direction. A time delay prevents cross conduction in the H-bridge when changing the Phase input.

Heat sinking. Soldering the batwing ground leads onto a copper ground plane of 20 cm² (approx. 1.8" x 1.8"), copper foil thickness 35 μm, permits the circuit to operate with 650 mA output current, both channels driving, at ambient temperatures up to 70°C. Consult figures 8, 9 and 13 in order to determine the necessary copper ground plane area for heat sinking at higher current levels.

Thermal shutdown. The circuit is equipped with a thermal shutdown function that turns the output off at temperatures above 160°C. Normal operation is resumed when the temperature has decreased about 20 °C.

Programming

Figure 14 shows the different input and output sequences for full-step, half-step and modified halfstep operations.

Full-step mode. Both windings are energized at all the time with the same current, $I_{M1} = I_{M2}$. To make the motor take one step, the current direction (and the magnetic field direction) in one phase is reversed. The next step is then taken when the other phase current reverses. The current changes go through a sequence of four different states which equal four full steps until the initial state is reached again.

Half-step mode. In the half-step mode, the current in one winding is brought to zero before a complete current reversal is made. The motor will then have taken two half steps equalling one full step in rotary movement. The cycle is repeated, but on the other phase. A total of eight states are sequenced until the initial state is reached again.

Half-step mode can overcome potential resonance problems. Resonances appear as a sudden loss of torque at one or more distinct stepping rates and must be avoided so as not to loose

control of the motor's shaft position.

One disadvantage with the half-step mode is the reduced torque in the half step positions, in which current flows through one winding only. The torque in this position is approximately 70 % of the full step position torque.

Modified half-step mode. The torque variations in half step mode will be eliminated if the current is increased about 1.4 times in the halfstep position. A constant torque will further reduce resonances and mechanical noise, resulting in better performance, life

expectancy and reliability of the mechanical system.

Modifying the current levels must be done by bringing the reference voltage up (or down) from its nominal value correspondingly. This can be done by using DACs or simple resistor divider networks, as shown in figure 7.

The PBL 3774 is designed to handle about 1.4 times higher current in one channel on mode, for example 700 mA per winding in the full-step position, and 1000 mA in the half-step position.

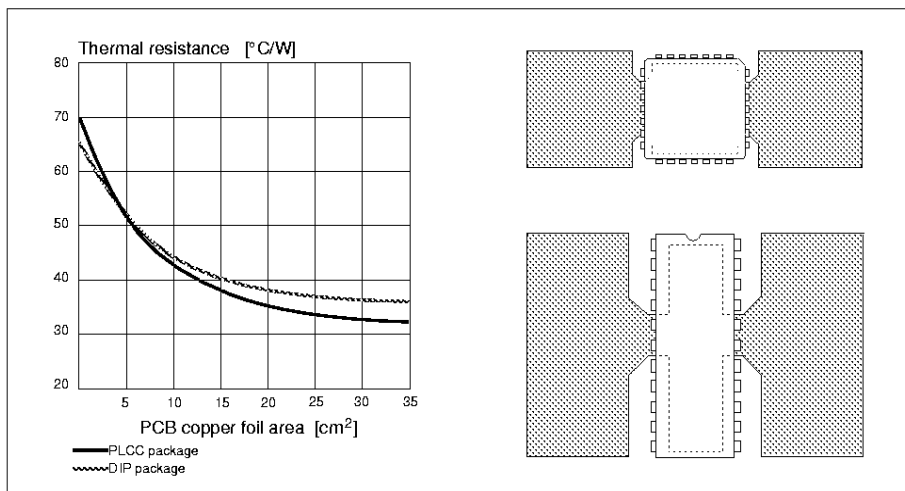


Figure 13. Typical thermal resistance vs. PC Board copper area and suggested layout.

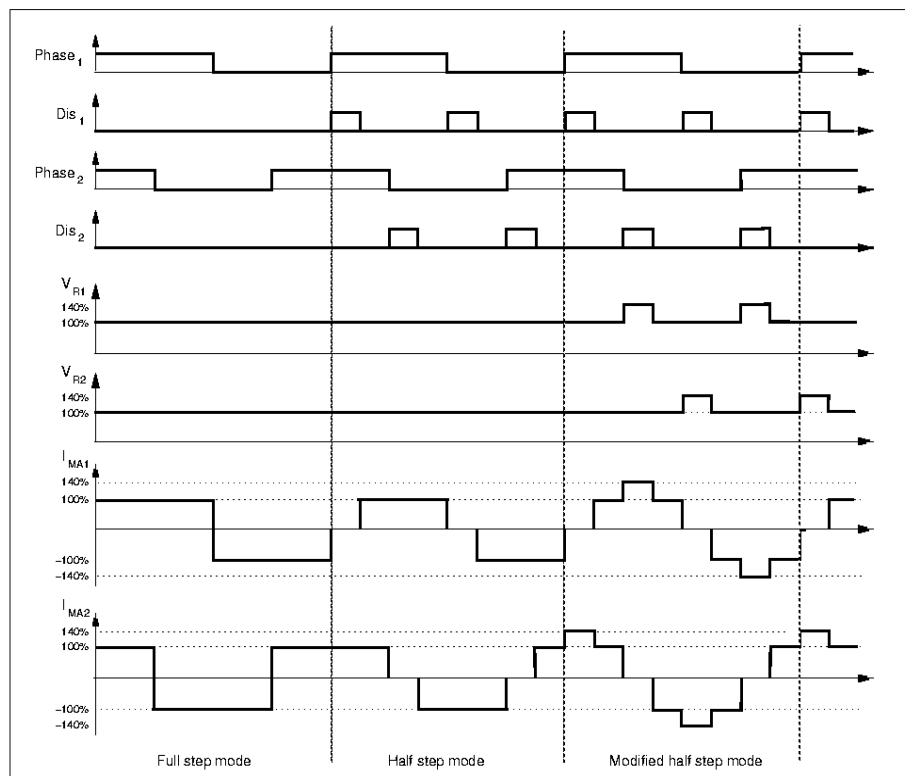


Figure 14. Stepping modes.

Ordering Information

Package	Part No.
DIP	PBL 3774N
PLCC	PBL 3774QN
PLCC Tape & Reed	PBL 3774QN:T

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