Thick Film Hybrid IC

No. 4874

STK6877

Reversible Brush-Type DC Motor Driver (output current: 8 A)

Overview

The STK6877 is an H bridge power pack reversible brush-type DC motor driver that uses Sanyo's unique insulated metal substrate technology (IMST) substrate. This technology provides superlative thermal dissipation characteristics. By adopting MOSFET devices as its power elements, this hybrid IC realizes reduced loss and increased current outputs as compared to our earlier STK6860H series.

Applications

- Plain paper copier drum and scanner motors
- LBP drum motors
- Printer head carriage motors
- All types of DC motor application equipment

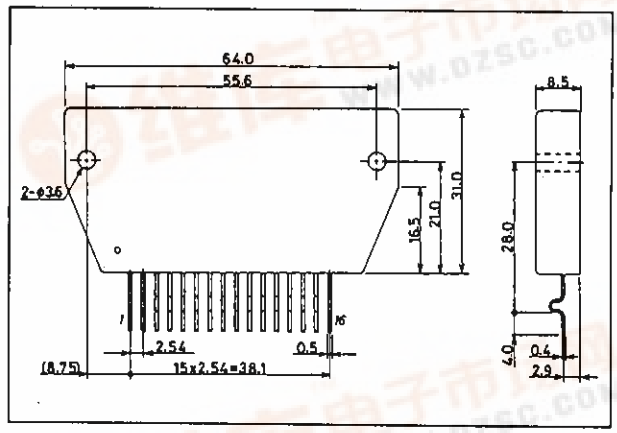
Features

- Increased margins with respect to rush currents due to the adoption of MOSFET elements
- TTL level compatible inputs
- Support for both two pin control saturation operation and three pin control PWM control
- A braking function is provided.
- Wide operating power supply voltage range ($V_{CC}1$ = 12 to 42 V)
- Few required external components (Operation is possible with only two external bootstrap capacitors.)

Package Dimensions

unit: mm

4148



Specifications

Absolute Maximum Ratings at Ta = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Maximum supply voltage 1	$V_{CC}1$ max	No signal	50	V
Maximum supply voltage 2	$V_{CC}2$ max	No signal	7	V
Maximum motor rush current	I_O peak	Period = 100 ms, duty ≤ 1% $V_{CC}2$ = 5.0 V	18	A
Operating substrate temperature	Tc max		105	°C
Junction temperature	Tj max		150	°C
Storage temperature range	T_{stg}		–40 to +125	°C

Allowable Operating Ranges at Ta = 25°C

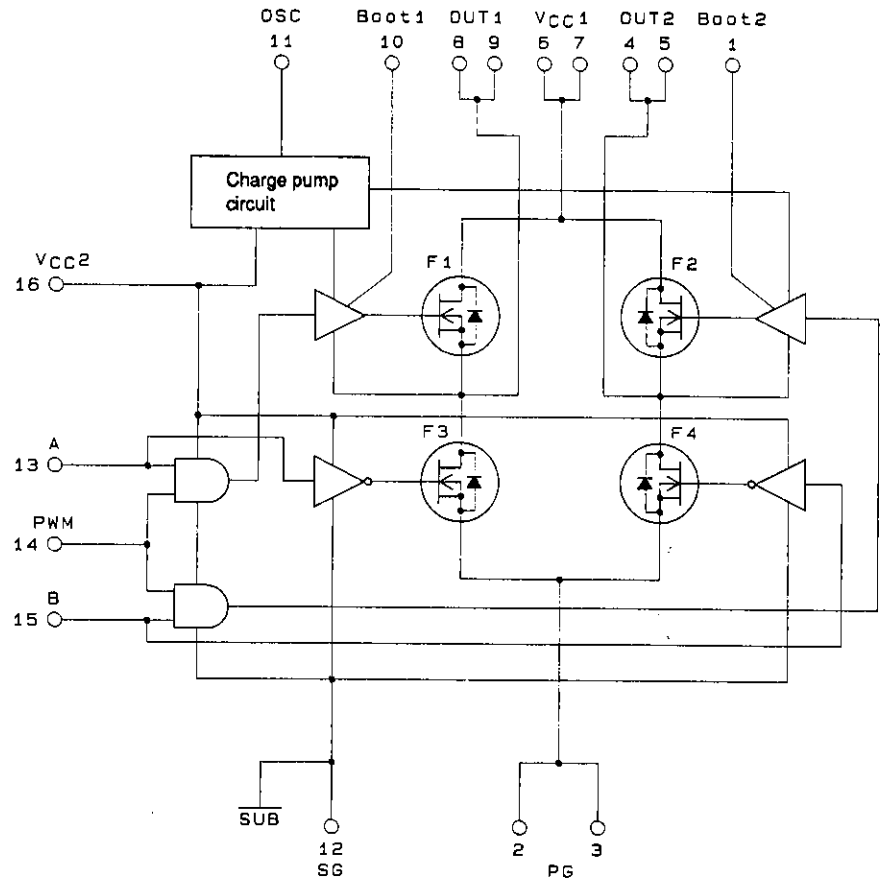
Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage 1	$V_{CC}1$	Input active	12 to 42	V
Supply voltage 2	$V_{CC}2$	Input active	5 ±5%	V
Motor output current	I_{OH} max	DC	8	A
PWM frequency	fp		1 to 30	kHz
FET withstand voltage	V_{DSS}		60	V

Operating Characteristics at Ta = 25°C, $V_{CC}1$ = 24 V, $V_{CC}2$ = 5.0 V

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Quiescent current	I_{CCO}	R_L = 2.8 Ω	30	40	50	mA
Output saturation voltage	Vst	R_L = 2.8 Ω		0.90	1.20	V
Input on voltage	V_{IH}		2.0			V
Input off voltage	V_{IL}		0		0.8	V
Input on current 1	$I_{IH}1$	V_I = 2.7 V, pin 14			20	μA
Input on current 2	$I_{IH}2$	V_I = 2.7 V, pin 13 or pin 15			0.7	mA
Input off current 1	$I_{IL}1$	V_I = 0.4 V, pin 14			−0.4	mA
Input off current 2	$I_{IL}2$	V_I = 0.4 V, pin 13 or pin 15			−0.2	mA
Diode forward voltage	Vdf	Idf = 8 A, V_{GS} = 0		1.6	2.0	V
Sensing voltage	Vsens				0.5	V

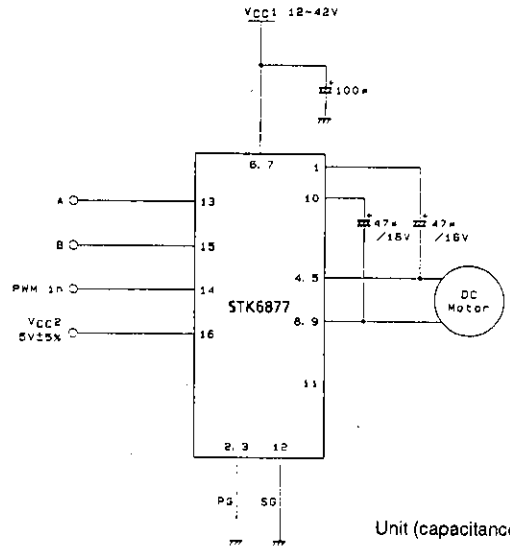
Note: Constant voltage power supplies must be used.

Equivalent Circuit



Note: 1. Boot is an abbreviation for bootstrap.
2. The OSC pin (pin 11) must be left open in operation.

Sample Application Circuit



Unit (capacitance: F)

	A	B
Forward	H	L
Reverse	L	H
Standby 1(illegal)	H	H
Standby 2	L	L

H: 5 V
L: 0 V

Note: 1. Input pin specifications
- TTL levels handled
- Maximum PWM input frequency: 30 kHz
- When used in two pin control mode, the PWM pin must be tied high.

2. Since the OSC pin (pin 11) is a monitor pin, it should be left open in normal operation.

Thermal Design

1. Heat Sink Thermal Resistance (θc-a) Derivation

The size of the heat sink required for the hybrid IC is determined by the motor output current (I_{OH}), the electrical characteristics of the motor and the chopping frequency, and the frequency of current application.
The thermal resistance (θc-a) of the heat sink is derived from the following formula.

$$\theta c\text{-}a = \frac{Tc\ max - Ta}{Pd} \quad (°C/W)$$

Tc max: Hybrid IC case temperature (°C)
Ta: Ambient temperature within the set (°C)
Pd: Average internal power dissipation within the hybrid IC (W)

As an example, Figure 2 can be used to derive the required area for a 2 mm aluminum plate heat sink. Since the ambient temperature within a set varies greatly with the set internal air circulation conditions, the size of the heat sink must be determined taking into account the constraint that the temperature of the back surface of the IC (the aluminum plate side) must never under any conditions exceed 105°C.

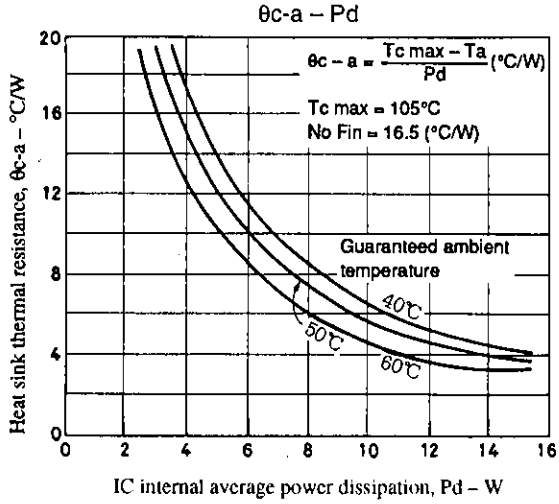


Figure 1 θc-a vs. Pd

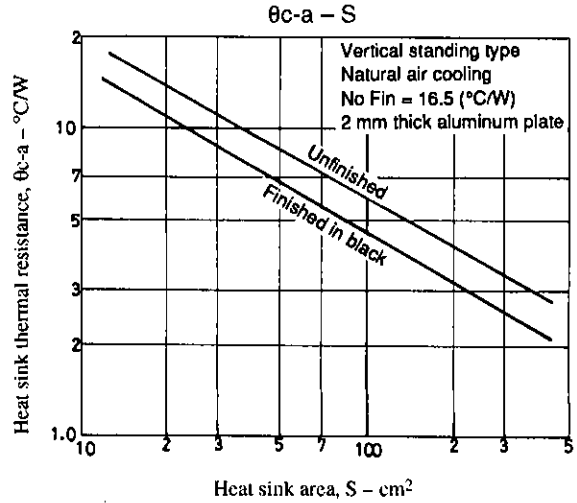


Figure 2 θc-a vs. S

2. Hybrid IC Internal Average Power Dissipation (Pd)

Of the power dissipations within the hybrid IC, the following components have large power dissipations: the FETs that are the upper PWM elements in the H bridge structure, the lower FETs that form the motor direction reversing loop, and the flywheel FET body diode. This can be expressed as shown below from experiment (from the output current waveform in the figure below).

Pd = upper FETs + lower FETs + body diode losses
$= Vst \times I_M \times fp \times t_{ON} + Vst \times I_M + Vdf \times I_M \times fp \times t_{OFF}$

Vst: FET saturation voltage (V)
I_M: Motor output current (A)
Vdf: FET body diode forward voltage (V)
fp: Chopping frequency (Hz)

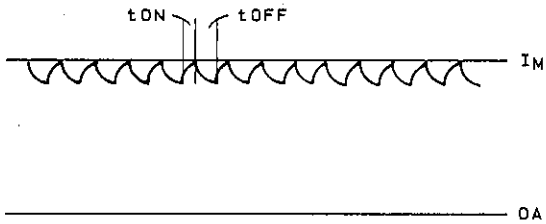


Figure 3 I_M Waveform Model

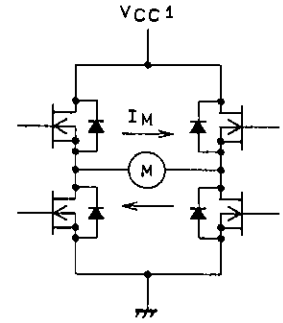


Figure 4 Model Circuit Diagram

Figures 5 and 6 show the I_O vs. Vst and I_O vs. Vdf characteristics.

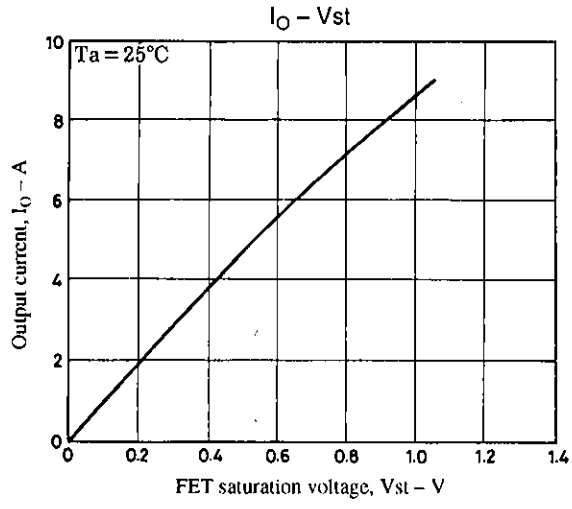


Figure 5 I_O vs. Vst

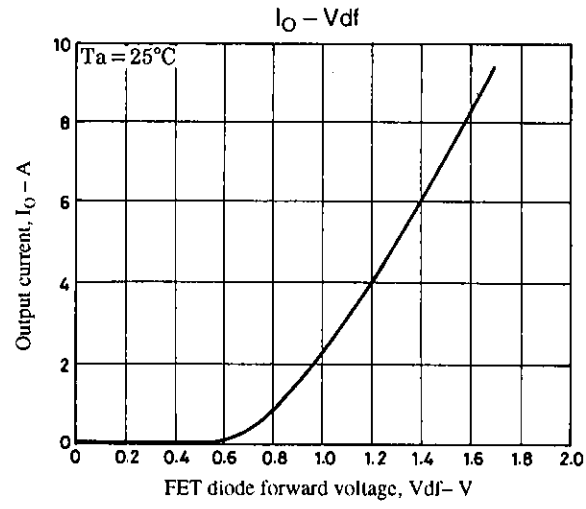


Figure 6 I_O vs. Vdf

3. Junction Temperature, Tj

The junction temperatures Tj (°C) for each element (F1, F2, F3 and F4) can be derived from the formula below from the power dissipation Pds (W) for each element and the junction thermal resistances θj-c (°C/W).

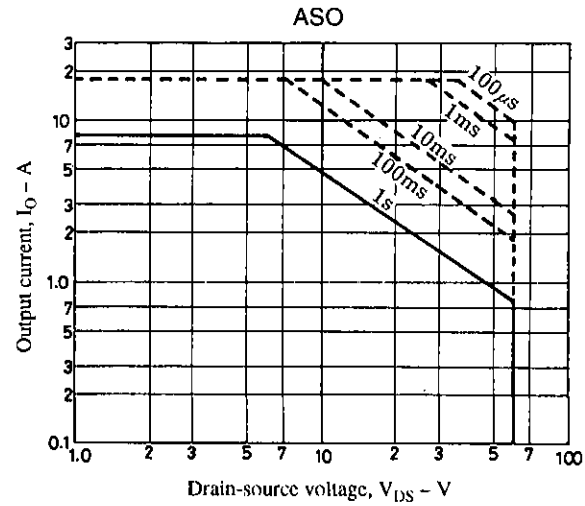
$Tj = Tc + \theta j\text{-}c \times Pds$ (°C)

Pds: Loss per element

Note that the thermal resistances for the power elements are as follows.

F1, F2, F3, F4 θj-c = 4 (°C/W)

F1, F2, F3, F4, ASO
Ta = 25°C
1 pulse



Usage Notes

1. Drive Circuit Start-up Procedure

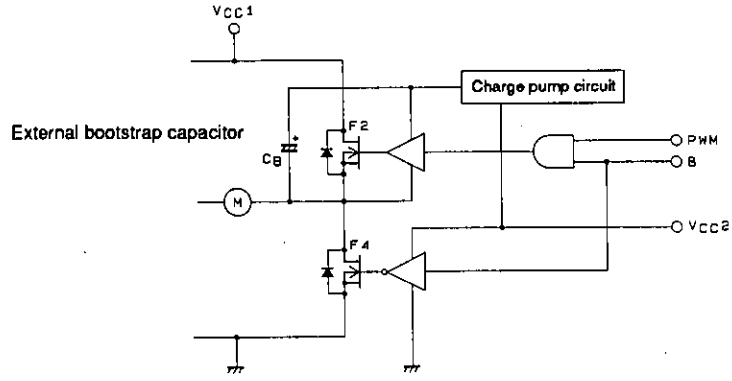


Figure 7 Upper and Lower MOSFET Drive Circuits

When starting (applying power to) the driver circuit (STK6877), the external control signals must be set to standby mode, i.e., pins A and B both set to low (setting both these pins high is an illegal mode). Then, after the specified power supply voltages ($V_{CC}1$ and $V_{CC}2$) have been input to the driver circuit, the circuit can be driven by inputting external control signals.

2. Illegal Input Mode with both the A and B Phase Signals (pins 13 and 15) High

Since the circuit operation problems described below occur when the input signal mode with both signals high is used, this mode should be avoided.

2-1 If used in the standby state, the voltage (Vch) charged on the external bootstrap capacitor (47 μF/16 V) will drop to an inadequate level. As a result, when the STK6877 driver circuit is switched to the start-up state, an insufficient drive voltage state for the upper FETs (F1 and F2) will occur.

2-2 If the A and B phase input signals are both switched to the high level in the motor start-up state (CW or CCW mode), a current loop (braking current) will be created in the upper side FETs due to the motor energy. At this point, since the upper FET drive voltage (the V_{GS} voltage) drops, an insufficient drive state will occur in the upper FETs, and they may be destroyed. However, if during this operation the charge voltages Vch across the two terminals of the bootstrap capacitors (47 μF/16 V) are monitored at the following points:

① The voltage between pin 10 and pin 8 (or 9).....Phase A .....(1)
② The voltage between pin 1 and pin 4 (or 5).....Phase B

and if both these voltages can be maintained at 4.0 V or higher, then the A and B phase pin input signals can both set to high safely. In other words, if the A and B phase pin input signal mode with both signals high is used as a motor stopping technique, care must be taken to assure that the charge voltages Vch on the external bootstrap capacitors meet this condition.

3. Handling the Hybrid IC's PG (pins 2 and 3) and SG Pins (pin 12)

Basically, the PCB pattern must be designed so that the PG and SG pins connect to a single grounding point. Also, if a current detection resistor (R_E) is inserted on the PG pin, handle the PG and SG pins as shown in Figure 8, i.e., connect them to a single grounding point, and select a value of the resistor R_E so that the voltage drop V_{RE} meets the following condition.

$V_{RE} = (I_{OH} \times R_E) \leq 0.5$ V .....(2)

I_{OH}: Motor output current (A)
R_E: Current detection resistance(Ω)
V_{RE}: Voltage drop across R_E (V)

The condition specified by formula (2) is specified in the specifications as the sensing voltage Vsens.

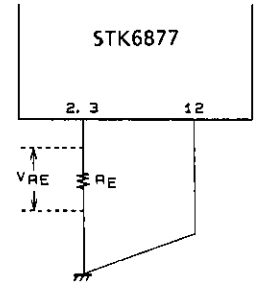


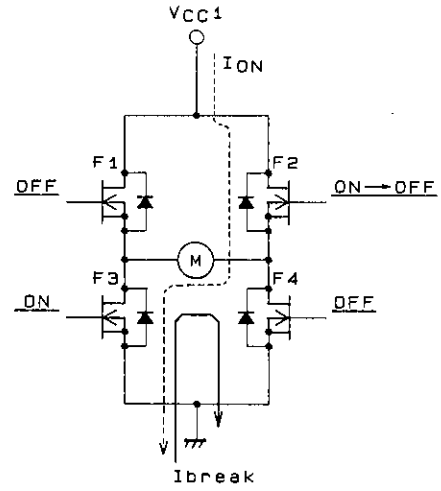
Figure 8 Handling for the PG and SG Pins

4. Braking Operation Procedures

There are three methods for applying braking to the motor.

(a) Setting both the A and B phase inputs to low. (This shorts the motor pins.)
(b) Setting the PWM input low. (This effects motor flywheel current regenerative braking.)
(c) After setting the PWM input low, setting both the A and B phase inputs to low. (This is the combination of methods (a) and (b).)

(a) When braking method (a) is used, damping is applied through the lower MOSFETs. (This stops the motor quickly.) Since this method is equivalent to shorting the motor, the braking flywheel current rises radically, and the lower MOSFETs go to the overload state. As shown in Figure 9, F3 and F4 go to the overload state, and Figure 10 shows the flywheel current that flows in this braking method. Thus if this method is to be used, the user must confirm that, under the conditions of the actual application circuit, the flywheel current that flows in the lower FETs does not exceed the maximum rated current range for the hybrid IC.



Note: (*) Braking applied during reverse motor rotation

Figure 9 Brake Method (a) Current Flow

When brake method (b) is used, the motor drive current from before braking is applied is released in the lower MOSFETS thus resulting in a motor stopping operation. (This is a free running motor stop method.) Although the MOSFETs will not be overloaded, the braking is not as fast.

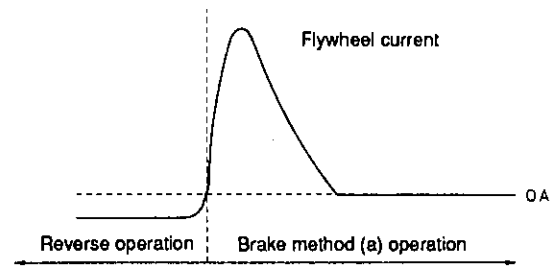
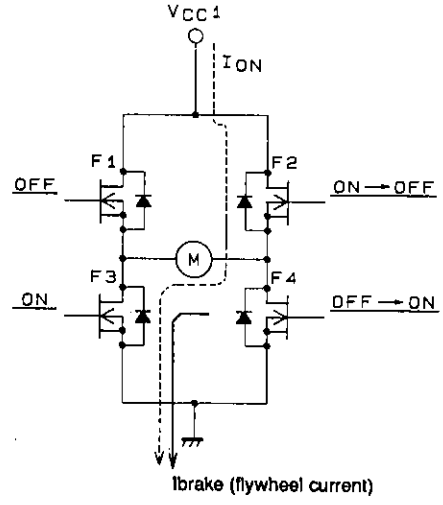


Figure 10 Flywheel Current Flowing in the Lower FET (F4)

When brake method (c) is used, first the PWM input is set to low, and the motor's rotational energy is released to a certain degree. Then full braking is applied by setting both the A and B phase inputs to low. This method allows the flywheel current that flows in the lower MOSFETs to be held to within the maximum rated range by first applying method (b) braking, and then when the motor's rotational energy has been reduced, applying method (a) braking to stop the motor.



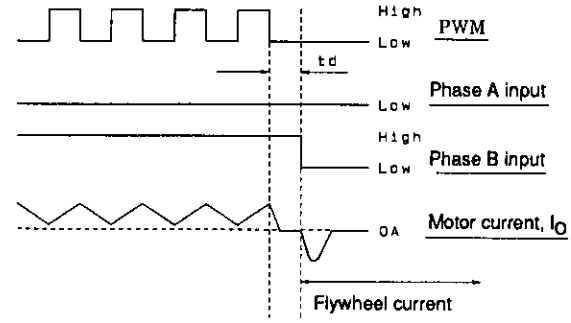
Note: (*) Braking applied during reverse motor rotation

Figure 11 Current Path in Brake Method (a)

The dead time (td) and the flywheel current must be checked with the motor actually used, since the amount of dead time (td) that must be inserted between setting the PWM input low and setting the A and B phase inputs low to assure that the flywheel current is held within the maximum rated range will vary with the conditions under which the circuit operates. (See Figure 12.)

Method (c) allows the motor to be stopped in a much shorter time than is possible with method (b). When releasing the brake it does not matter if the phase input signals or the PWM input signal is set high first.

Although we have presented three braking methods, we recommend the use of method (c) due to the speed of braking and the current levels flowing during the braking operation.



Note: (*) Braking applied during reverse motor rotation

Figure 12 Input Signal Timing Chart for Braking Method (c)

5. Upper and Lower MOSFET Shorting Currents

It is conceivable that both the upper and lower MOSFETs could be in the on state at the same time during braking operations (braking methods (a) and (c)) and release states. Taking this into consideration, the STK6877 provides two dead times (td1 and td2) of at least 1 µs with respect to the input signals in the upper and lower MOSFET drive circuits as shown in the figure below. As a result there is no need for concern about shorting currents in the upper and lower MOSFETs.

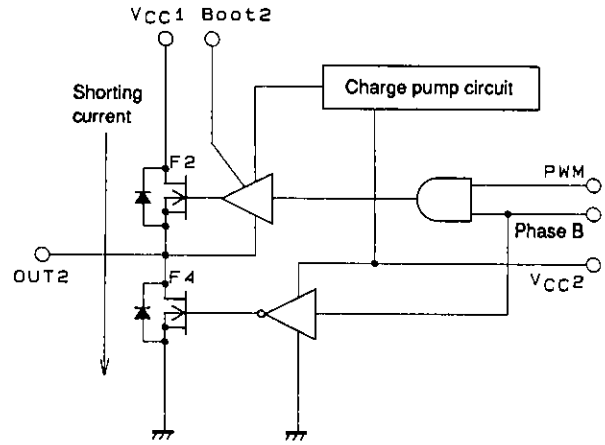
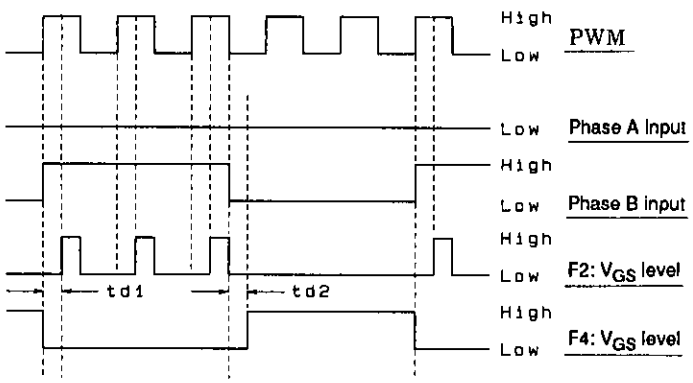


Figure 13 Upper and Lower MOSFET Equivalent Circuit



Note: td1: Dead time in the upper MOSFET drive circuit
td2: Dead time in the lower MOSFET drive circuit
(*) td1, td2 ≥ 1 µs

Figure 14 Upper and Lower MOSFET V_{GS} Voltage Timing Chart