ERICSSON

September 1988

T-52-13-01

PBD 3545/1 Universal Sink Driver

Description

PBD 3545/1 is a bipolar universal high-current highly-protected driver with transparent input and 2A continuous-current sink capability (low side switch). A high-level input activates the output. A special feature is a load-check function with ERROR output, which enhances the serviceability and diagnosis possibilities.

Extensive electrical protection makes the driver almost indestructible when driving loads such as solenoids, relays, or resistive loads.

Key Features

- 2A continuous-output current
- Short circuit to V_{CC} protection
- ERROR signal to host system
- Open circuit detection
- Short circuit to ground detection
- Thermal protection
- Built-in protection diodes
- LS-TTL, CMOS, and supply voltage compatible input

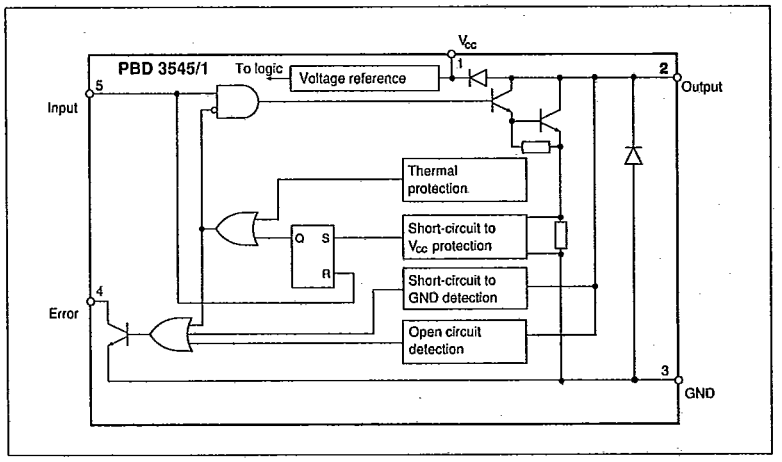
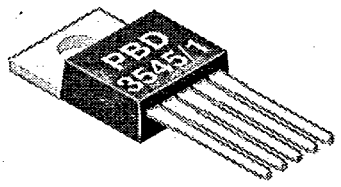


Figure 1. Block Diagram



TO-220 5-pin package

Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Supply voltage	V_{CC}	0	45	V
Logic input voltage	V_{In}	0	V_{CC}	V
Logic input current	I_{In}	-10		mA
Continuous DC Operation output current	I_{Out}		2.0	A
Power dissipation (T_{Case} = 85°C)	P_{Tot}		11	W
Operating junction temperature (internal limit)	T_j		+140	°C
Storage Temperature	T_s	-55	+150	°C
ESD tolerance (note 1)		2000		V

Thermal Data

Parameter	Symbol	Min	Max	Unit
Thermal resistance	$R_{th\,j\text{-}case}$		5	°C/W
Thermal resistance	$R_{th\,j\text{-}case}$		60	°C/W

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Supply voltage	V_{CC}	4.75		40	V
Output current	I_{Out}			2.0	A
Ambient temperature	T_{Amb}	-40		+85	°C

Electrical Characteristics

At 5V ≤ V_{CC} ≤ 40V, -40°C ≤ T_j ≤ +100°C. Typical values are given at V_{CC} = 24V, T_j = 25°C.

Parameter	Ref. fig.	Conditions	Min	Typ	Max	Unit
General						
Current consumption, I_{CC}	2	$0 \le V_{In} \le 0.8$	1.5	4	7	mA
Thermal sutdown, T_{is}			+120	+130	+140	°C
Thermal shutdown release, T_{isr}			+110	+120	+130	°C
Clamping diode forward voltage, V_f	3	I_f = 2.0A		1.5	1.8	V
Logic inputs						
High level input voltage, V_{Ih}			2.0			V
Low level input voltage, V_{Il}			0.0		0.8	V
High level input current, I_{Ih}	4	$2.0 \le V_{In} \le V_{CC}$		9	20	µA
Low level input current, I_{Il}	4	$0 \le V_{In} \le 0.8$	-400			µA
Outputs						
Error signal voltage drop, V_{Err}	5	I_{Err} = 5mA		0.2	1	V
Output voltage drop, $V_{ce\,Sat}$	6	I_{Out} = 2A		1.4	1.8	V
Output current shutdown, I_{os}	9	$2.0 \le V_{In} \le V_{CC}$	2.0	3.2	4.5	A
Output current, I_{oMin} (not detected as open circuit)		$2.0 \le V_{In} \le V_{CC}$		2	8	mA
Timing						
Propagation time	8	I_{Out} = 2A				
Output high to low (50%), t_{phl}				1.5	3.0	µs
Output low to high (50%), t_{plh}				0.5	1.0	µs
Rise time (10 to 90%), t_{Rise}	8			0.2	0.5	µs
Fall time (90 to 10%), t_{Fall}	8			0.2	0.5	µs

Note 1. ESD testing according to Human Body Model (C_{Zap} = 100pF, R_{Zap} = 1500Ω)
Note 2. Currents are defined positive if flowing into, and negative if flowing out of a terminal. Voltages are defined between terminal and ground.

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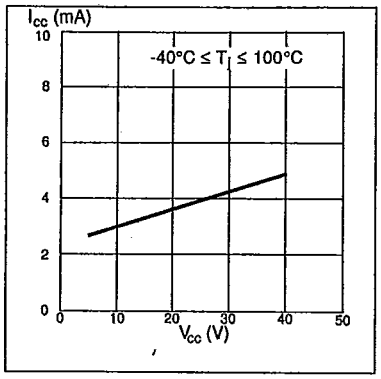

Figure 2. Typical current consumption vs. supply voltage at 0V ≤ V_{in} ≤ 0.8V.

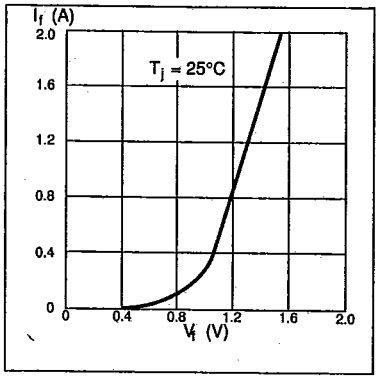

Figure 3. Typical diode forward voltage drop vs. forward current.

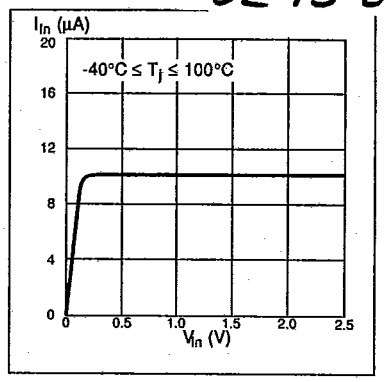

Figure 4. Typical input current vs. input voltage. 5V ≤ V_{cc} ≤ 40V.

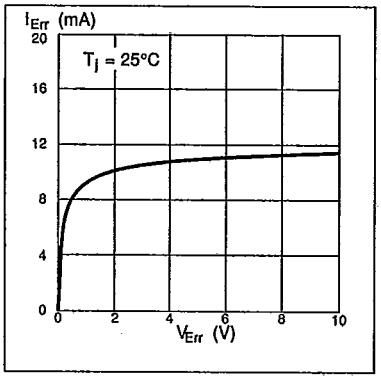

Figure 5. Typical error signal voltage drop vs. error current. V_{cc} = 24V.

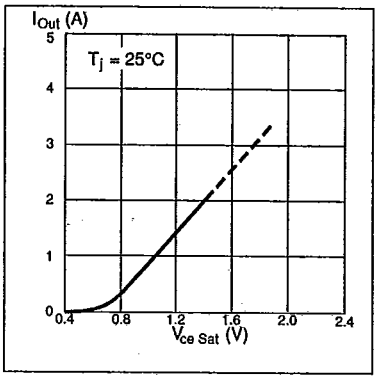

Figure 6. Typical output voltage drop vs. output current. 5V < V_{cc} < 40V.

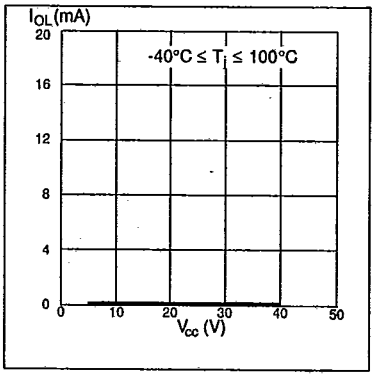

Figure 7. Typical output leakage current vs. supply voltage. 0V ≤ V_{in} ≤ 0.8V. Output = V_{cc}.

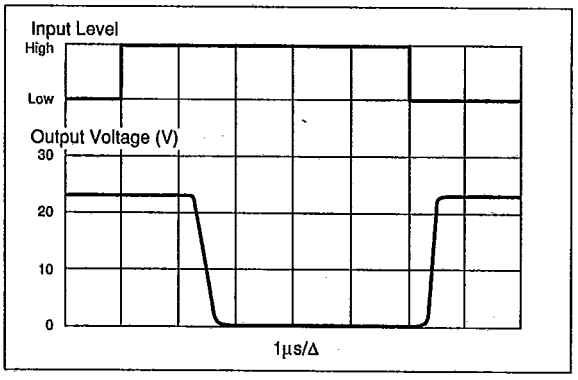

Figure 8. Timing diagram, typical timing input vs. output. V_{cc} = 24V.

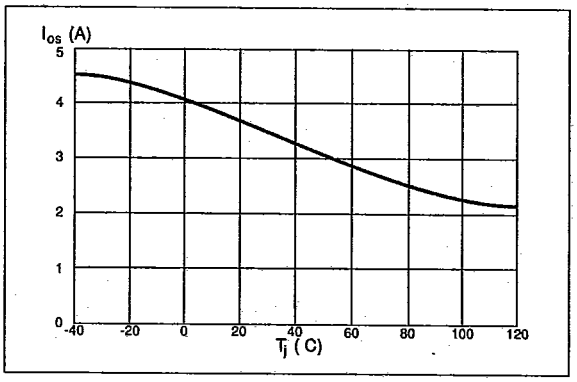

Figure 9. Typical output current sut-down vs. chip temperature. 5V ≤ V_{cc} ≤ 40V.

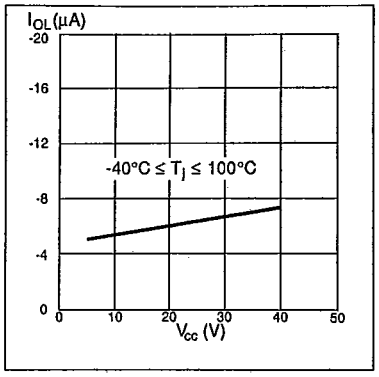

Figure 10. Typical output leakage current vs. supply voltage. 0V ≤ Vin ≤ 0.8V. Output = 0V.

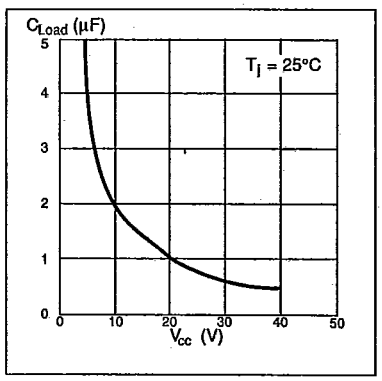

Figure 11. Maximum load capacitance vs. supply voltage.

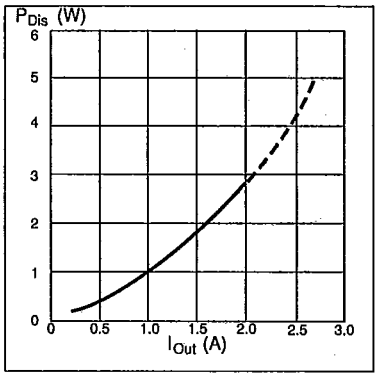

Figure 12. Typical power dissipation vs. output current.

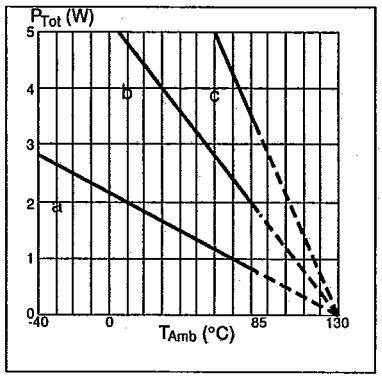

Figure 13. Alowable power dissipation vs. ambient temperature:
a. No heatsink
b. Heatsink $R_{th\,j\text{-}case}$ = 15°C/W @ 4W
c. Heatsink $R_{th\,j\text{-}amb}$ 3.2°C/W @ 25W

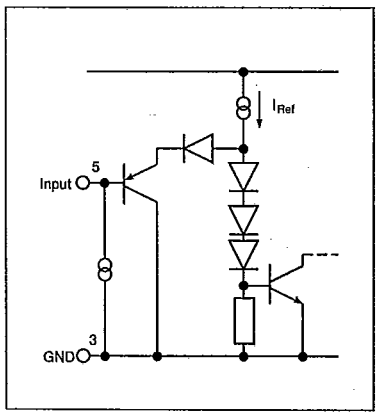

Figure 14. Input stage.

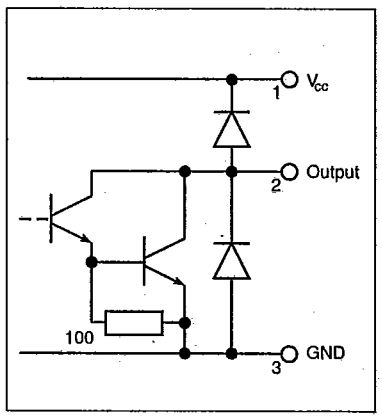

Figure 15. Output stage.

Functional Description

The circuit PBD 3545/1 is an active high sink driver (low side switch) capable of driving resistive or inductive loads not exceeding 2 amps.

The driver has an error function which generates an ERROR signal when a fault condition has occurred.

The circuits PBD 3545/1 and PBD 3548/1 are complementary drivers with equivalent functions and similar data. PBD 3548/1 is a source driver (high side switch).

Input

The output stage is switched on/off according to the status of the input. HIGH level activates the output. If the input is left open, the circuit will accept it as a LOW level. The input pin can be connected by a pull-up resistor to the appropriate logic supply voltage or to the V_{cc} supply voltage. See figure 17.

Output stage

The output stage contains a power transistor and two clamping diodes. The diodes are used for terminating line transients from inductive loads. See figure 15.

ERROR functions

The ERROR signal occurs on a separate pin. The following conditions generate an error signal:

1. When the driver is activated and:
   - thermal overload
   - short circuit to V_{cc}
   - short circuit to ground
   - open circuit

   Output currents less than 8mA might be detected as "open circuit." Output currents larger than 8mA and less than 2A will definitely not generate an error.
2. When driver is inactivated and:
   - short circuit to GND

   See Error Table and figures 18 & 19 for more details.

When the error-detection function is activated, the output is capable of sinking 5mA, supporting direct connection of an LED.

If the ERROR signal is used, it should be connected by a pull-up resistor to the appropriate logic supply voltage or the V_{cc} supply voltage. See figure 17.

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Overload and short circuit protection

The overload protection will typically be activated at I_{out} = 3.2A at T_j = +25°C, see figure 9.

The output will be turned off immediately and latched to high-impedance state after an overload (short circuit) has been detected.

A logic-level change at the input will reset the error, if no overload or short circuit is present.

Due to a slight delay in the circuit, a high current transient will occur when the output is shorted to V_{cc}. This current transient may reach 8A during 5µs. Consequently, switching at high frequencies with a shorted output may destroy the circuit. To prevent destruction of the device in such cases, input switching frequency should be lowered to a safe value, or inhibited completely. See figures 20 through 24 "Safe operating areas."

Thermal overload protection

The output of PDB 3545/1 is equipped with a thermal shut-down function, which will limit the junction temperature to typically +130°C. The output current will approach zero until the junction temperature decreases to approximately 120°C. Switching of the input is not possible if junction temperature is above 120°C. See Error table.

Applications Information

Important application areas are:

- Intelligent interfaces between microprocessors and loads,
- Vehicle control systems.,
- Robotics
- Dashboard information systems,
- Print head drivers,
- High-current stepper motor drivers with security aspects,
- PC systems
- Security systems
- Hydraulic valves

User hints

1. Connect INPUT and ERROR via pull-up resistors to the appropriate logic supply level or V_{CC} to obtain highest noise immunity.
2. Keep V_{CC} and GND leads as short as possible.

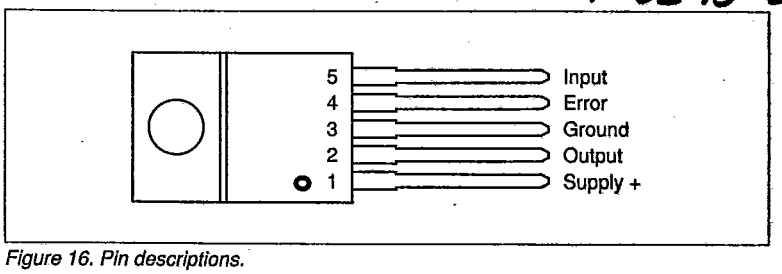
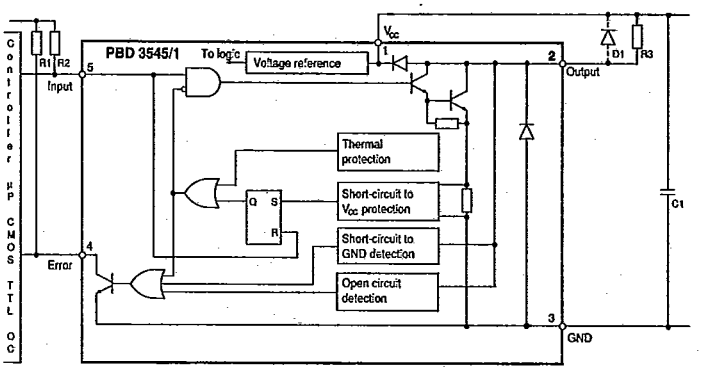


Figure 16. Pin descriptions.



Comp.	Purpose	Value	Larger than value	Smaller than value
R1	Pull-up resistor for ERROR	$\frac{V_{cc}}{5mA} \leq R1 \leq \frac{V_{cc}}{1mA}$	Lower external drive capability. Risk of pick up of noise to external device.	Higher external drive capability. Risk of failure in ERROR output transistor.
R2	Pull-up resistor for INPUT	$R2 \approx \frac{V_{cc}}{\text{External device sink capability}}$	Less current consumption. Lower stress on external sinking devices. Higher noise sensitivity.	Higher current consumption. Stress on external sinking divice. Lower noise sensitivity.
R3	Output load device	$\frac{V_{cc}}{2A} \leq R3 \leq \frac{V_{cc}}{8mA}$	Open-circuit ERROR. Short-circuit to ground ERROR.	Operation outside SOA. Overload error.
C1	Filtering of short-circuit spikes	C1 ≥ 6.8µF, tantalum	Better filtering of noise. Increases price. Less sensitive to load variations. Proper short circuit protection.	Increases noise sensitivity. Normal functions inoperable.
D1	Termination of inductive load currents at freqencies higher than 2kHz	$t_{rr} \leq 100ns$ $I_f \geq I_{out}$ max		

Figure 17. Typical application and table of component values.

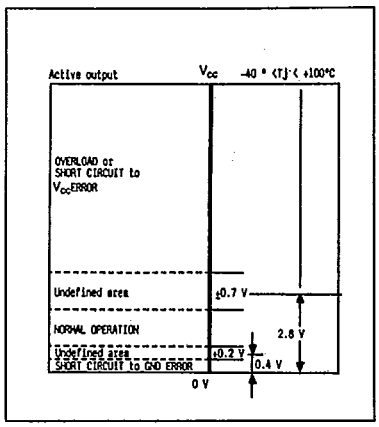


Figure 18. Output voltage vs. error state, Active output ($2.0 \le V_{in} \le V_{CC}$), $5V < V_{CC} < 40V$.

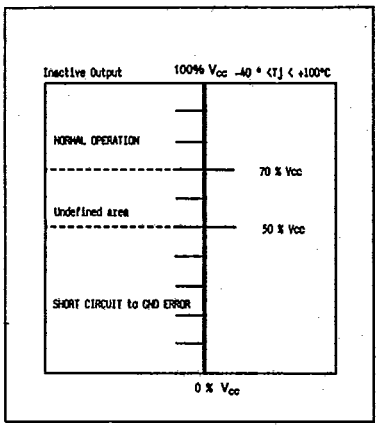


Figure 19. Output voltage in % of V_{CC} vs. error state, inactive output ($0V \le V_{in} \le 0.8V$), $5V \le V_{CC} \le 40V$.

Error Table

Also see "Signal diagrams," figures 25 through 29.

Input	OUTPUT condition	OUTPUT state	How to reset
HIGH	Short circuit to ground	Output on, but no current flow from IC	Automatic when fault disappears
(ON)	Short circuit to V_{CC}	Output current from IC goes toward zero.	Change input to LOW
	Open circuit	Output on, but no current flow from IC.	Automatic when fault disappears, or change input to LOW
	Over temperature	Output current from IC goes toward zero.	Automatic when T_j decreases about 10°C, or change input to LOW. (Temp hysterises remains active until T_j has decreased about 10°C)
LOW	Short circuit to ground	Output off, but current flow through load	Automatic when fault disappears
(OFF)	Short circuit to V_{CC}	No change	No detection, no error
	Open circuit*	No change	No detection, no error
	Over temperature*	No change	No detection, no error

Note: These conditions are not vital for detection of drive function.

3. Connect a filter capacitor close to the circuit. Recommended filter capacitor between V_{CC} and GND is 6.8µF, of tantalum type.
4. When driving inductive loads at frequencies higher than 2 kHz, connect an external fast recovery clamping diode between output and V_{CC}. Recommended diodes are BYV27/100, BYV98/100, UF4001, or similar types with a $T_{rr} < 100ns$ and $I_f \ge 1A$.
5. When the circuit is switched on/off, a short pulse (t_{err}<10µs for resistive loads) is generated at the ERROR output. This is a correct detection of an incorrect level and consequently the ERROR output should not be detected at switch on/off. An alternative is to low-pass filter the ERROR output at around 100kHz.
6. Avoid V_{CC} power supplies with small output capacitors or power supplies with common ground with the logic supply. Use separate ground leads with only one common point, at the ground pin of the PBD 3545/1.
7. When switching and an error is detected, immediately decrease the switching frequency. If the error is a short circuit to V_{CC}, continued switching may result in an operating point outside the safe operating area, which will shorten the life expectancy of the device. See figures 20 through 24.
8. The leadframe is grounded, so it is not necessary to isolate the driver from the heatsink in most cases. This will improve thermal resistance.

Diagrams

How to use the diagrams:

1. Figure 8 shows the timing diagram for input-output delays with a resistive load.
2. Figure 9 shows the output current shutdown vs. junction temperature.
3. Figure 11 shows the max. load capacitance vs. supply voltage. Generallly a slow capacitive load (high ESR) will accept higher supply voltages than a fast capacitive load without going into short-circuit protection.

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4. What is the maximum drive current in the application?
   - The ambient temperature sets the maximum allowable power dissipation in the driver, which relates to the driver current. For PBD 3545/1, without any measures taken to reduce the chip temperature via heatsinks, the allowable power dissipation vs. temperature follows curve "a" in figure 13.
   - Figure 12 gives the relationship between drive current and the actual power dissipation.
5. How to find the maximum operating frequency:
   - For resistive loads, the maximum input frequency can be found in figures 20 through 24. The figures show safe operating areas (SOA) for different supply voltages. The left side of the SOA areas shows correctly working short-circuit protection without exceeding thermal limitations due to repetative high current transients. The right SOA area shows correctly working driver without exceeding the I_{Out} = 2A limit. The shaded area represents a non-safe area. The limit is set by the short-circuit transients, currents that form a high average level due to short-circuit detection delays. This results in temperatures exceeding the maximum ratings and consequently reducing the life expectancy. Note that, for switching frequencies below 0.1Hz, any load can be tolerated.

Ordering Information

Package	Temp. range	Part No.
TO-220	-40 to +85°C	PBD3545/1N

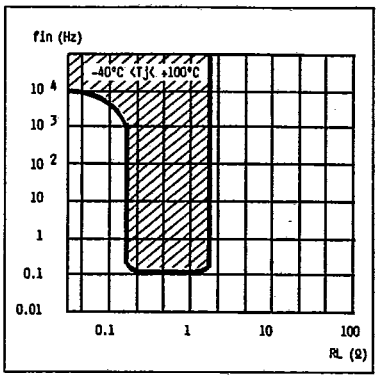

Figure 20. SOA for load resistance vs. input frequency. V_{CC} = +5V.

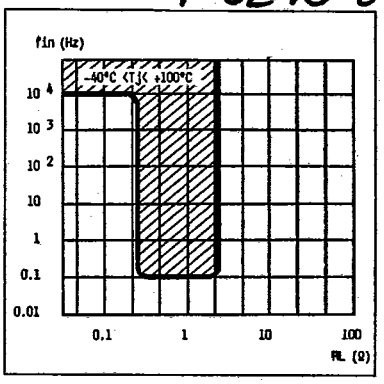

Figure 21. SOA for load resistance vs. input frequency. V_{CC} = +6V.

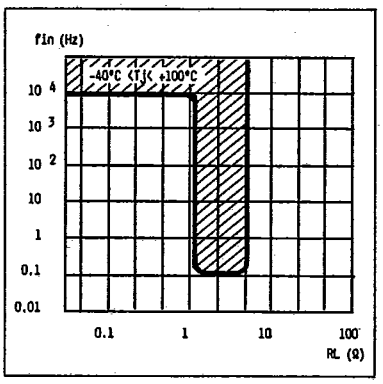

Figure 22. SOA for load resistance vs. input frequency. V_{CC} = +12V.

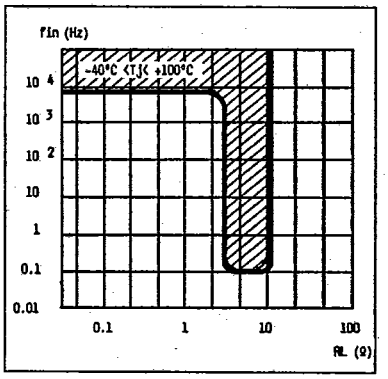

Figure 23. SOA for load resistance vs. input frequency. V_{CC} = +24V.

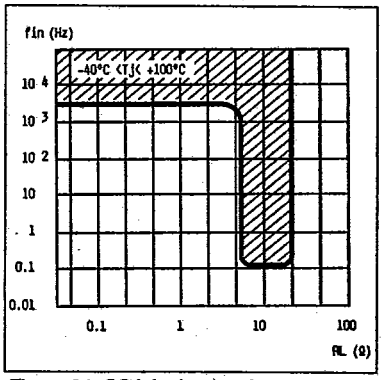

Figure 24. SOA for load resistance vs. input frequency. V_{CC} = +40V.

Signal Diagrams

The signal diagrams, figures 25 through 29, show the input signal and resulting output signals for each error mode. For details, see error table and user hints note 5.

V_{In} = input voltage. Active =High.
V_{Out} = output voltage.
I_{Out} = output current from driver.
V_{Err} = error output voltage. Error = Low.

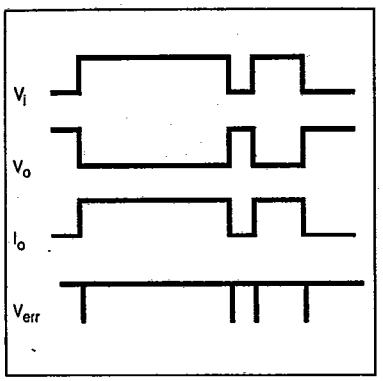

Figure 25. Normal operation.

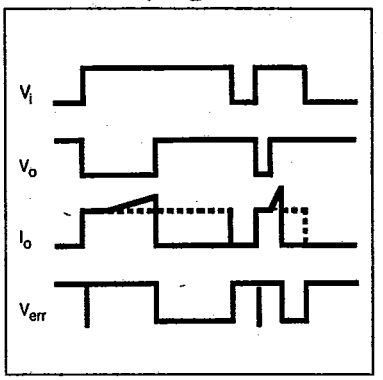

Figure 26. Overload or short circuit to V_{CC} error.

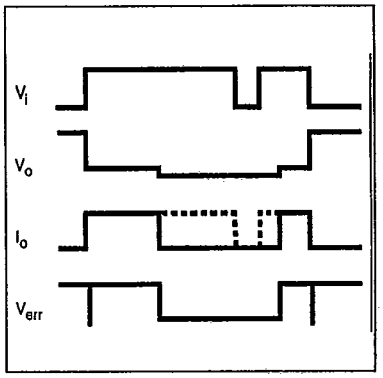

Figure 27. Short circuit to GND error. ON/OFF.

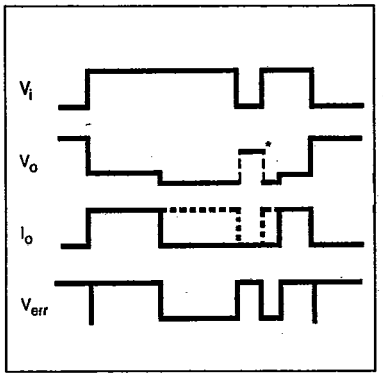

Figure 28. Open circuit error.
** = Undefined level.*

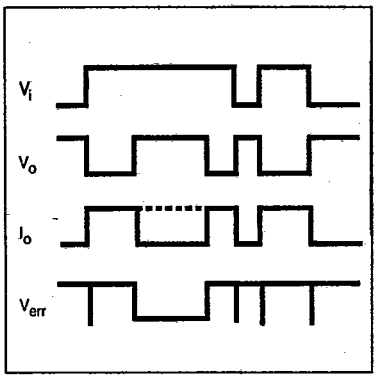

Figure 29. Overtemperature error.

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