

DATA SHEET

TDA5145TS Brushless DC motor drive circuit

Product specification
File under Integrated Circuits, IC11

1998 Oct 27

Brushless DC motor drive circuit

TDA5145TS

FEATURES

- Full-wave commutation (using push-pull drivers at the output stages) without position sensors
- Built-in start-up circuitry
- Three push-pull outputs:
 - Output current 2.0 A (typ.)
 - Built-in current limiter
 - Soft-switching outputs for low Electromagnetic Interference (EMI).
- Thermal protection
- Flyback diodes
- Motor brake facility
- Direction control input
- Reset function.

APPLICATIONS

- General purpose spindle driver e.g.:
 - Hard disk drive
 - Tape drive
 - Optical disk drive.

GENERAL DESCRIPTION

The TDA5145TS is a bipolar integrated circuit used to drive 3-phase brushless DC motors in full-wave mode. The device is sensorless (saving of 3 hall-sensors) using the back EMF sensing technique to sense the rotor position. It includes bidirectional control, brake function and has a special circuit built-in to reduce the EMI (soft-switching output stages).

QUICK REFERENCE DATA

Measured over full voltage and temperature range.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
V_P	supply voltage	note 1	4	–	18	V
$V_{i(VMOT)}$	input voltage to the output driver stages	note 2	1.7	–	16	V
V_{DO}	drop-out output voltage	$I_o = 100 \text{ mA}$	–	0.90	1.05	V
I_{LIM}	current limiting	$V_{VMOT} = 10 \text{ V}; R_o = 1.2 \Omega$	1.8	2.0	2.5	A

Notes

1. An unstabilized supply can be used.
2. $V_{VMOT} = V_P$; all outputs $I_o = 0 \text{ mA}$.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
TDA5145TS	SSOP24	plastic shrink small outline package; 24 leads; body width 5.3 mm	SOT340-1

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BLOCK DIAGRAM

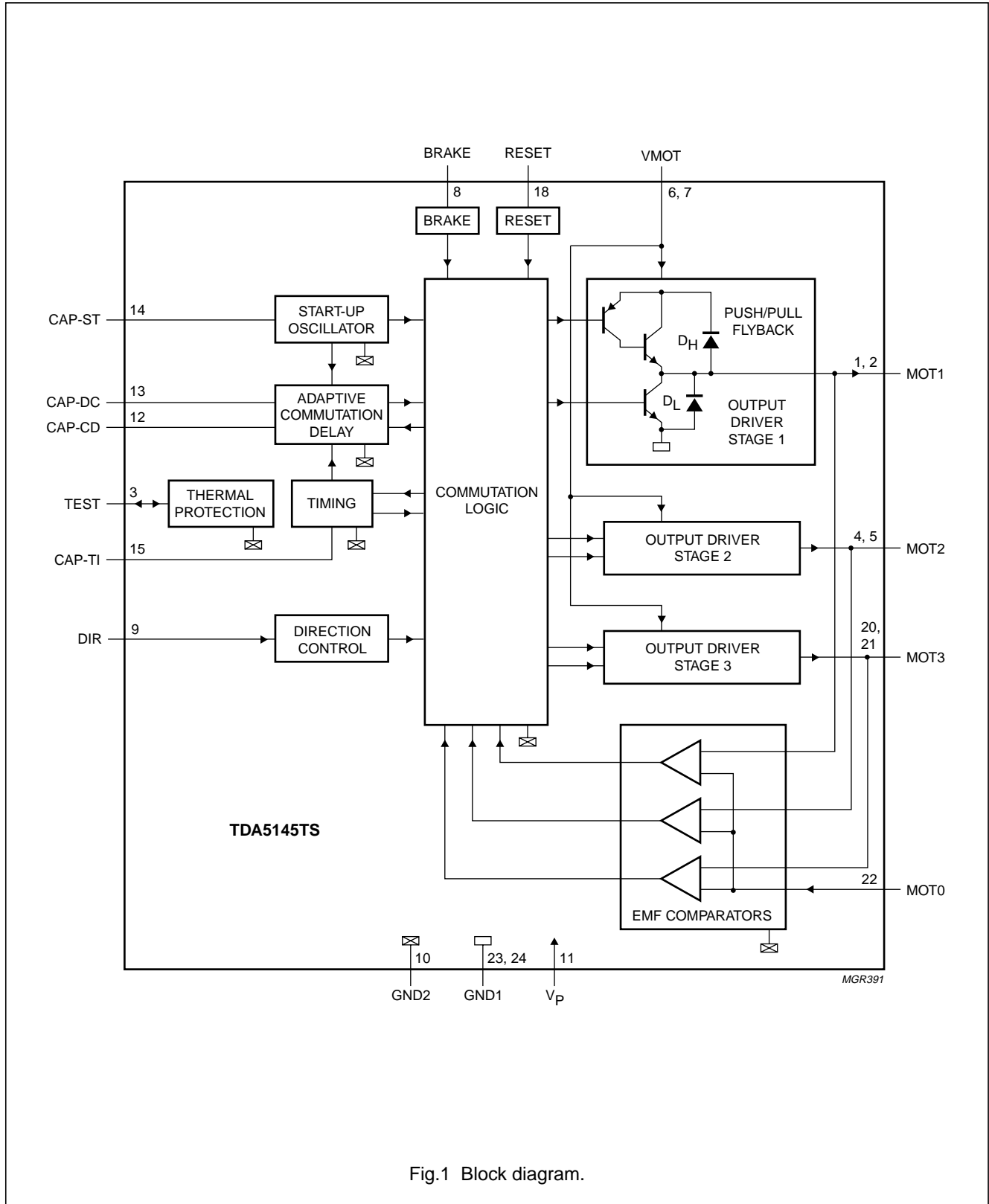


Fig.1 Block diagram.

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PINNING

SYMBOL	PIN	DESCRIPTION
MOT1	1	driver output 1
MOT1	2	driver output 1
TEST	3	test input/output
MOT2	4	driver output 2
MOT2	5	driver output 2
VMOT	6	input voltage for the output driver stages
VMOT	7	input voltage for the output driver stages
BRAKE	8	brake input; this pin may not be left floating, a LOW-level voltage must be applied to disable this function
DIR	9	direction control input; this pin may not be left floating
GND2	10	ground supply return for control circuits
V _P	11	supply voltage
CAP-CD	12	external capacitor connection for adaptive communication delay timing
CAP-DC	13	external capacitor connection for adaptive communication delay timing copy
CAP-ST	14	external capacitor connection for start-up oscillator
CAP-TI	15	external capacitor connection for timing
n.c.	16	not connected
n.c.	17	not connected
RESET	18	reset input; this pin may not be left floating, a LOW-level voltage must be applied to disable this function
n.c.	19	not connected
MOT3	20	driver output 3
MOT3	21	driver output 3
MOT0	22	input from the star point of the motor coils
GND1	23	ground (0 V) motor supply return for output stages
GND1	24	ground (0 V) motor supply return for output stages

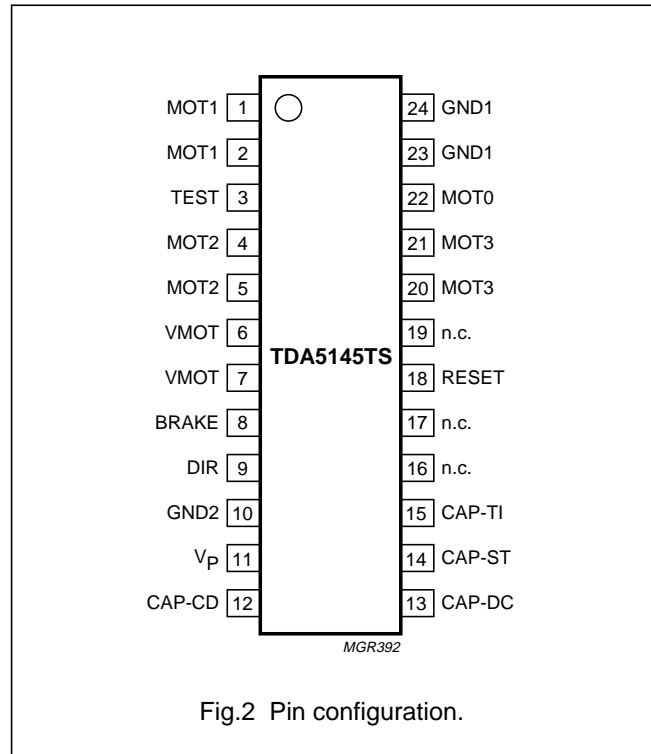


Fig.2 Pin configuration.

FUNCTIONAL DESCRIPTION

The TDA5145TS offers a sensorless 3-phase motor drive function. It is unique in its combination of sensorless motor drive and full-wave drive. The TDA5145TS offers protected outputs capable of handling high currents and can be used with star or delta connected motors. It can easily be adapted for different motors and applications. The TDA5145TS offers the following features:

- Sensorless commutation by using the motor EMF
- Built-in start-up circuit
- Optimum commutation, independent of motor type or motor loading
- Built-in flyback diodes
- Three phase full-wave drive
- High output current (2.0 A)
- Outputs protected by current limiting and thermal protection of each output transistor
- Low current consumption by adaptive base-drive
- Soft-switching pulse output for low radiation
- Direction of rotation controlled by one pin
- Brake function.

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LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_P	supply voltage		–	18	V
$V_{I(n)}$	input voltage; all pins except VMOT	$V_I < 18\text{ V}$	–0.3	$V_P + 0.5$	V
$V_{I(VMOT)}$	VMOT input voltage		–0.5	+17	V
V_O	output voltage MOT0, MOT1, MOT2 and MOT3		–1	$V_{VMOT} + V_{dFD}$	V
$V_{I(n1)}$	input voltage CAP-ST, CAP-TI, CAP-CD and CAP-DC		–	2.5	V
T_{stg}	storage temperature		–55	+150	°C
T_{amb}	operating ambient temperature		0	+70	°C
P_{tot}	total power dissipation	see Fig. 3	–	–	W
V_{es}	electrostatic handling	see Chapter “Handling”	–	2000	V

HANDLING

Every pin withstands the ESD test according to “MIL-STD-883C class 2”. Method 3015 (HBM 1500 Ω; 100 pF) 3 pulses positive and 3 pulses negative on each pin referenced to ground.

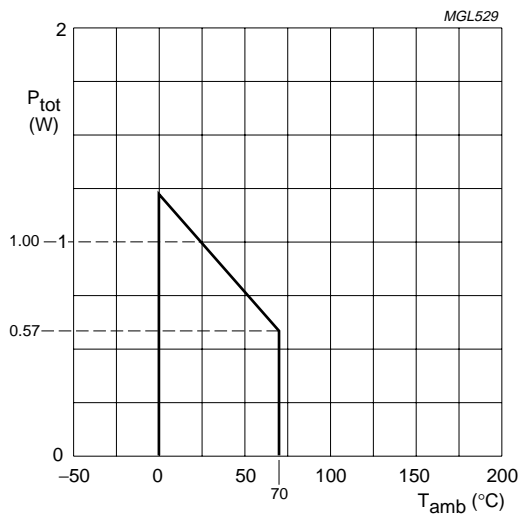


Fig.3 Power derating curve.

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CHARACTERISTICS

$V_P = 14.5\text{ V}$; $T_{\text{amb}} = 25\text{ }^\circ\text{C}$; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_P	supply voltage	note 1	4	–	18	V
I_P	supply current	note 2	–	6.8	7.8	mA
$V_{i(\text{VMOT})}$	input voltage to the output driver stages	see Fig.1	1.7	–	16	V
Thermal protection						
T_{SD}	local temperature at temperature sensor causing shut-down		130	140	150	$^\circ\text{C}$
ΔT	reduction in temperature before switch-on	after shut-down	–	$T_{\text{SD}} - 30$	–	K
MOT0; centre tap						
V_i	input voltage		–0.5	–	V_{VMOT}	V
I_{bias}	input bias current	$0.5\text{ V} < V_i < V_{\text{VMOT}} - 1.5\text{ V}$	–10	–	–	μA
V_{CSW}	comparator switching level	note 3	± 20	± 25	± 30	mV
ΔV_{CSW}	variation in comparator switching levels		–	–	3	mV
V_{hys}	comparator input hysteresis		–	75	–	μV
MOT1, MOT2 and MOT3; see Fig.4						
V_{DO}	drop-out output voltage	$I_o = 100\text{ mA}$	–	0.9	1.05	V
		$I_o = 1000\text{ mA}$	–	1.6	1.85	V
$\Delta V_{\text{sat}(\text{lt})}$	variation in saturation voltage between lower transistors	$I_o = 100\text{ mA}$	–	–	180	mV
$\Delta V_{\text{sat}(\text{ut})}$	variation in saturation voltage between upper transistors	$I_o = -100\text{ mA}$	–	–	180	mV
I_{LIM}	current limiting	$V_{\text{VMOT}} = 10\text{ V}$; $R_o = 1.2\ \Omega$	1.8	2.0	2.5	A
t_r	rise time switching output	$V_{\text{VMOT}} = 15\text{ V}$; see Fig.5	5	10	15	μs
t_f	fall time switching output	$V_{\text{VMOT}} = 15\text{ V}$; see Fig.5	10	15	20	μs
$V_{\text{dF}(\text{DH})}$	diode forward voltage (diode D_H)	$I_o = -500\text{ mA}$; notes 4 and 5; see Fig.1	–	–	1.5	V
$V_{\text{dF}(\text{DL})}$	diode forward voltage (diode D_L)	$I_o = 500\text{ mA}$; notes 4 and 5; see Fig.1	–1.5	–	–	V
I_{dM}	peak diode current	note 5	–	–	2.5	A
DIR						
V_{IH}	HIGH-level input voltage	$4\text{ V} < V_P < 18\text{ V}$	2.0	–	–	V
V_{IL}	LOW-level input voltage	$4\text{ V} < V_P < 18\text{ V}$	–	–	0.8	V
I_{IL}	LOW-level input current		–	–20	–	μA
I_{IH}	HIGH-level input current		–	20	–	μA

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SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
RESET						
V_{IH}	HIGH-level input voltage	reset mode; $4\text{ V} < V_P < 18\text{ V}$	2.0	–	–	V
V_{IL}	LOW-level input voltage	normal mode; $4\text{ V} < V_P < 18\text{ V}$	–	–	0.8	V
I_{IL}	LOW-level input current	$V_i = 2.0\text{ V}$	–	–20	–	μA
I_{IH}	HIGH-level input current	$V_i = 0.8\text{ V}$	–	20	–	μA
BRAKE						
V_{IH}	HIGH-level input voltage	brake mode; $4\text{ V} < V_P < 18\text{ V}$	2.0	–	–	V
V_{IL}	LOW-level input voltage	normal mode; $4\text{ V} < V_P < 18\text{ V}$	–	–	0.8	V
I_{IL}	LOW-level input current	$V_i = 2.0\text{ V}$	–	–20	–	μA
I_{IH}	HIGH-level input current	$V_i = 0.8\text{ V}$	–	20	–	μA
CAP-ST						
$I_{o(\text{sink})}$	output sink current		1.5	2.0	2.5	μA
$I_{o(\text{source})}$	output source current		–2.5	–2.0	–1.5	μA
V_{swL}	LOW-level switching voltage		–	0.20	–	V
V_{swH}	HIGH-level switching voltage		–	2.20	–	V
CAP-TI						
$I_{o(\text{sink})}$	output sink current		–	28	–	μA
$I_{o(\text{source})}$	output source current	$0.2\text{ V} < V_{\text{CAP-TI}} < 0.3\text{ V}$	–	–57	–	μA
		$0.3\text{ V} < V_{\text{CAP-TI}} < 2.2\text{ V}$	–	–5	–	μA
V_{swL}	LOW-level switching voltage		–	50	–	mV
V_{swM}	MIDDLE-level switching voltage		–	0.30	–	V
V_{swH}	HIGH-level switching voltage		–	2.20	–	V
CAP-CD						
$I_{o(\text{sink})}$	output sink current		10.6	16.2	22	μA
$I_{o(\text{source})}$	output source current		–5.3	–8.1	–11	μA
$I_{\text{sink}}/I_{\text{source}}$	ratio of sink to source current		1.85	2.05	2.25	
V_{IL}	LOW-level input voltage		850	875	900	mV
V_{IH}	HIGH-level input voltage		2.3	2.4	2.55	V
CAP-DC						
$I_{o(\text{sink})}$	output sink current		10.1	15.5	20.9	μA
$I_{o(\text{source})}$	output source current		–20.9	–15.5	–10.1	μA
$I_{\text{sink}}/I_{\text{source}}$	ratio of sink to source current		0.9	1.025	1.15	
V_{IL}	LOW-level input voltage		850	875	900	mV
V_{IH}	HIGH-level input voltage		2.3	2.4	2.55	V

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Notes

1. An unstabilized supply can be used.
2. $V_{VMOT} = V_P$, all other inputs at 0 V; all outputs at V_P ; $I_o = 0$ mA.
3. Switching levels with respect to MOT1, MOT2 and MOT3.
4. Drivers are in the high-impedance OFF-state.
5. The outputs are short-circuit protected by limiting the current and the IC temperature.

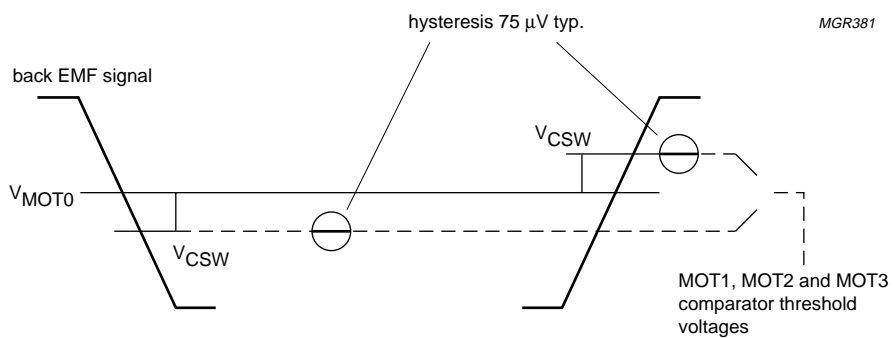


Fig.4 Switching levels with respect to MOT1, MOT2 and MOT3.



Fig.5 Output transition time measurement.

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The TDA5145TS is designed for systems with low current consumption: use of I²L logic, adaptive base drive for the output transistors (patented).

Adjustments

The system has been designed in such a way that the tolerances of the application components are not critical. However, the approximate values of the following components must still be determined:

- The start capacitor; this determines the frequency of the start oscillator.
- The two capacitors in the adaptive commutation delay circuit; these are important in determining the optimum moment for commutation, depending on the type and loading of the motor.
- The timing capacitor; this provides the system with its timing signals.

THE START CAPACITOR (CAP-ST)

This capacitor determines the frequency of the start oscillator. It is charged and discharged, with a current of 2 µA, from 0.05 to 2.2 V and back to 0.05 V. The time taken to complete one cycle is given by:

$$t_{\text{start}} = (2.15 \times C) \text{ s (with C in } \mu\text{F)}$$

The start oscillator is reset by a commutation pulse and so is only active when the system is in the start-up mode. A pulse from the start oscillator will cause the outputs to change to the next state (torque in the motor). If the movement of the motor generates enough EMF the TDA5145TS will run the motor. If the amount of EMF generated is insufficient, then the motor will move one step only and will oscillate in its new position. The amplitude of the oscillation must decrease sufficiently before the arrival of the next start pulse, to prevent the pulse arriving during the wrong phase of the oscillation. The oscillation of the motor is given by:

$$f_{\text{osc}} = \frac{1}{2\pi \sqrt{\frac{K_t \times I \times p}{J}}}$$

where:

K_t = torque constant (N.m/A)

I = current (A)

p = number of magnetic pole-pairs

J = inertia J (kg.m²)

Example: $J = 72 \times 10^{-6} \text{ kg.m}^2$, $K_t = 25 \times 10^{-3} \text{ N.m/A}$, $p = 6$ and $I = 0.5 \text{ A}$; this gives $f_{\text{osc}} = 5 \text{ Hz}$.

If the damping is high then a start frequency of 2 Hz can be chosen or $t = 500 \text{ ms}$, thus $C = 0.5/2 = 0.25 \mu\text{F}$ (choose 220 nF).

THE ADAPTIVE COMMUTATION DELAY (CAP-CD AND CAP-DC)

In this circuit, capacitor CAP-CD is charged during one commutation period, with an interruption of the charging current during the diode pulse. During the next commutation period this capacitor (CAP-CD) is discharged at twice the charging current. The charging current is 8.1 µA and the discharging current 16.2 µA; the voltage range is from 0.9 to 2.2 V. The voltage must stay within this range at the lowest commutation frequency of interest, f_{C1} :

$$C = \frac{8.1 \times 10^{-6}}{f \times 1.3} = \frac{6231}{f_{C1}} \text{ (C in nF)}$$

If the frequency is lower, then a constant commutation delay after the zero-crossing is generated by the discharge from 2.2 to 0.9 V at 16.2 µA; maximum delay = $(0.076 \times C) \text{ ms}$ (with C in nF)

Example: nominal commutation frequency = 900 Hz and the lowest usable frequency = 400 Hz; thus:

$$\text{CAP-CD} = \frac{6231}{400} = 15.6 \text{ (choose 18 nF)}$$

The other capacitor, CAP-DC, is used to repeat the same delay by charging and discharging with 15.5 µA. The same value can be chosen as for CAP-CD. Figure 8 illustrates typical voltage waveforms.

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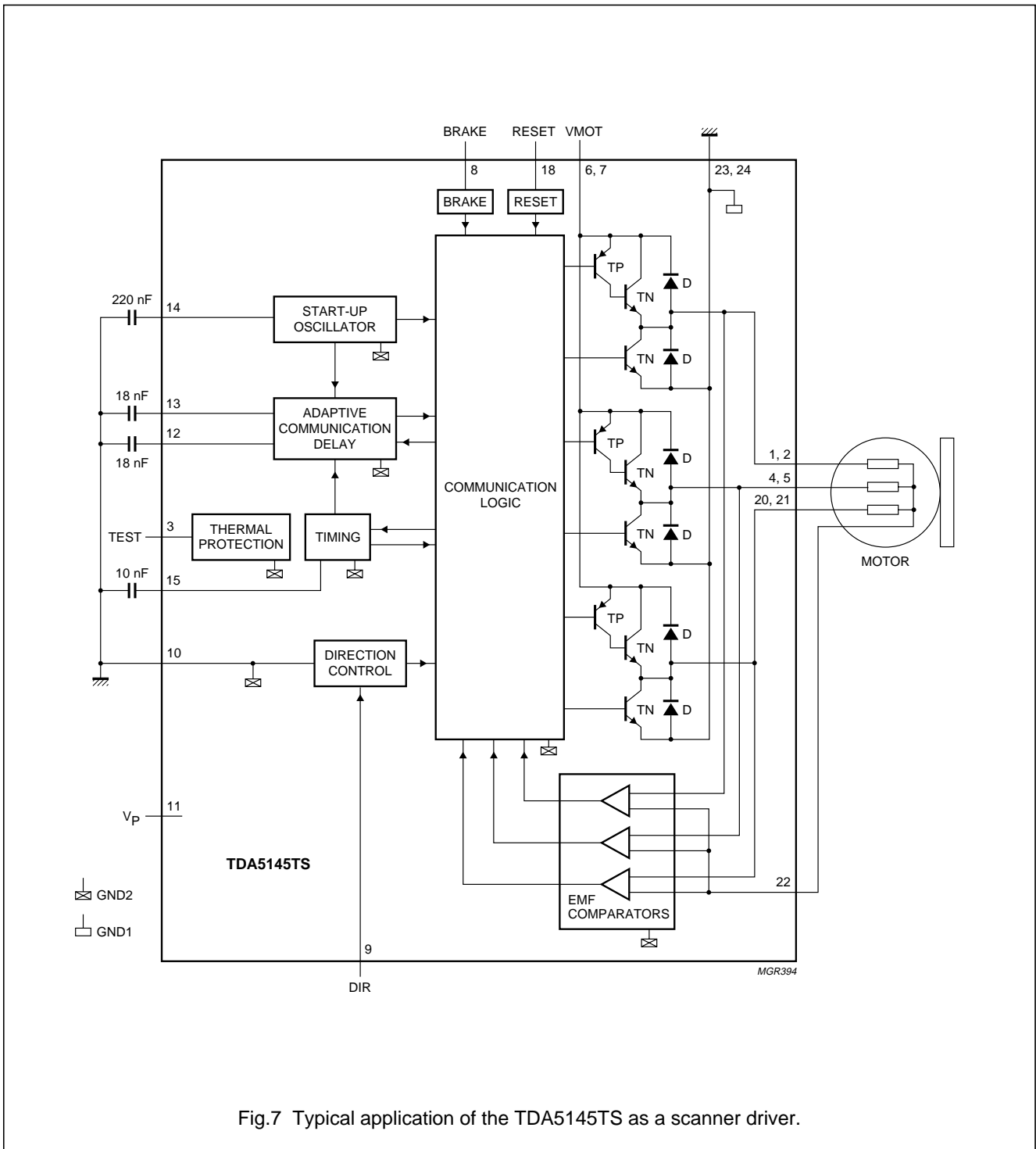


Fig.7 Typical application of the TDA5145TS as a scanner driver.

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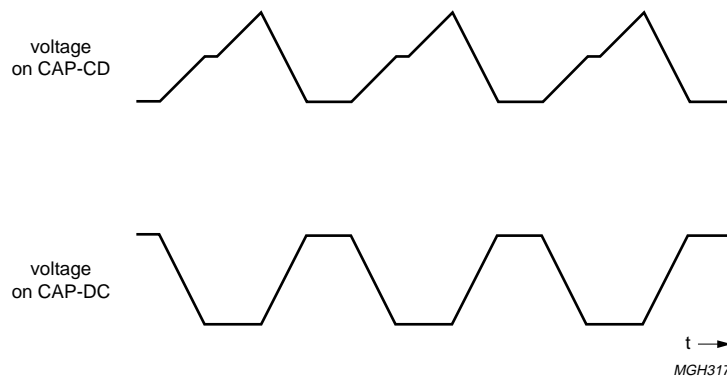


Fig.8 CAP-CD and CAP-DC typical voltage waveforms in normal running mode.

THE TIMING CAPACITOR (CAP-TI)

Capacitor CAP-TI is used for timing the successive steps within one commutation period; these steps include some internal delays.

The most important function is the watchdog time in which the motor EMF has to recover from a negative diode pulse back to a positive EMF voltage (or vice versa). A watchdog timer is a guarding function that only becomes active when the expected event does not occur within a predetermined time.

The EMF usually recovers within a short time if the motor is running normally (\ll ms). However, if the motor is motionless or rotating in the reverse direction, then the time can be longer (\gg ms).

A watchdog time must be chosen so that it is long enough for a motor without EMF (still) and eddy currents that may stretch the voltage in a motor winding; however, it must be short enough to detect reverse rotation. If the watchdog time is made too long, then the motor may run in the wrong direction (with little torque).

The capacitor is charged with a current of $57 \mu\text{A}$, from 0.2 to 0.3 V. Above this level it is charged with a current of $5 \mu\text{A}$, up to 2.2 V only if the selected motor EMF remains in the wrong polarity (watchdog function). At the end, or, if the motor voltage becomes positive, the capacitor is discharged with a current of $28 \mu\text{A}$. The watchdog time is the time taken to charge the capacitor with a current of $5 \mu\text{A}$, from 0.3 to 2.2 V.

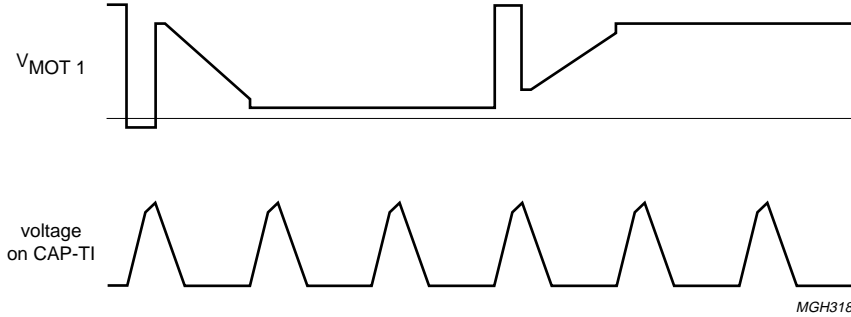
To ensure that the internal delays are covered CAP-TI must have a minimum value of 2 nF. For the watchdog function a value of 10 nF for CAP-TI is recommended.

To ensure a good start-up and commutation, care must be taken that no oscillations occur at the trailing edge of the flyback pulse. Snubber networks at the outputs should be critically damped.

Typical voltage waveforms are illustrated in Fig.9.

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If the chosen value of CAP-T1 is too small oscillations can occur in certain positions of a blocked rotor. If the chosen value is too large, then it is possible that the motor may run in the reverse direction (synchronously with little torque).

Fig.9 Typical CAP-T1 and V_{MOT1} voltage waveforms in normal running mode.

Other design aspects

There are other design aspects concerning the application of the TDA5145TS besides the commutation function. They are:

- Direction function
- Brake function
- Reliability.

DIRECTION FUNCTION

If the voltage at pin 9 is less than 0.8 V, the motor is running in one direction (depending on the motor connections). If the voltage at pin 9 is greater than 2.0 V, the motor is running in the opposite direction.

BRAKE FUNCTION

If the voltage at pin 8 is greater than 2.0 V, the motor brakes. In that condition, the 3 outputs MOT1, MOT2 and MOT3 are forced to a LOW voltage level and the current limitation is performed internally by the sink drivers.

RESET FUNCTION

If the voltage at pin 18 is greater than 2.0 V, the output states are shown in Table 2.

Table 2 Output states if $V_{RESET} > 2.0 V$

DRIVER OUTPUT	STATE ⁽¹⁾
MOT1	Z
MOT2	L
MOT3	H

Note

1. Z = high-impedance OFF-state; L = LOW state; H = HIGH state.

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Table 3 Switching sequence after a reset pulse; note 1

DIR	RESET	MOT1	MOT2	DIR	FUNCTION
H	H	Z	L	H	reset
H	L	Z	L	H	normal direction mode sequence
H	L	H	L	Z	
H	L	H	Z	L	
H	L	Z	H	L	
H	L	L	H	Z	
H	L	L	Z	H	
L	H	H	L	Z	reset
L	L	H	L	Z	reverse direction mode sequence
L	L	Z	L	H	
L	L	L	Z	H	
L	L	L	H	Z	
L	L	Z	H	L	
L	L	H	Z	L	

Note

1. Z = high-impedance OFF-state; L = LOW state; H = HIGH state.

Table 4 Priority of function; note 1

BRAKE	TEST	RESET	FUNCTION
L	L	L	normal
L	L	H	reset
L	H	L	test
L	H	H	test
H	L	L	brake
H	L	H	brake
H	H	L	brake
H	H	H	brake

Note

1. L = LOW state; H = HIGH state.

RELIABILITY

It is necessary to protect high current circuits and the output stages are protected in two ways:

- Current limiting of the 'lower' output transistors. The 'upper' output transistors use the same base current as the conducting 'lower' transistor (+15%). This means that the current to and from the output stages is limited.
- Thermal protection of the six output transistors is achieved by each transistor having a thermal sensor that is active when the transistor is switched on. The transistors are switched off when the ambient temperature becomes too high.

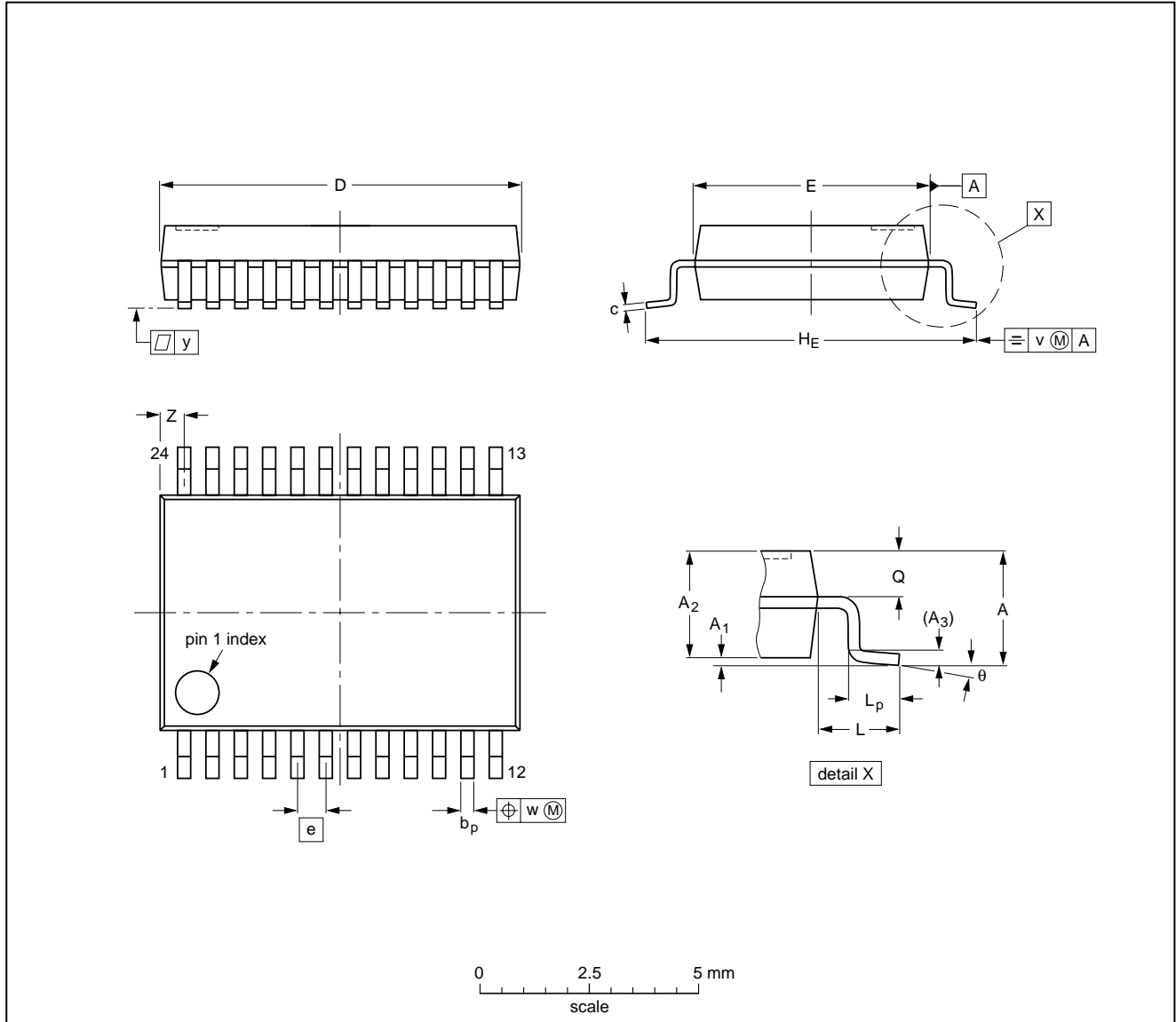
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PACKAGE OUTLINE

SSOP24: plastic shrink small outline package; 24 leads; body width 5.3 mm

SOT340-1



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A ₁	A ₂	A ₃	b _p	c	D ⁽¹⁾	E ⁽¹⁾	e	H _E	L	L _p	Q	v	w	y	Z ⁽¹⁾	θ
mm	2.0	0.21 0.05	1.80 1.65	0.25	0.38 0.25	0.20 0.09	8.4 8.0	5.4 5.2	0.65	7.9 7.6	1.25	1.03 0.63	0.9 0.7	0.2	0.13	0.1	0.8 0.4	8° 0°

Note

1. Plastic or metal protrusions of 0.20 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT340-1		MO-150AG				93-09-08 95-02-04

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SOLDERING

Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (order code 9398 652 90011).

Reflow soldering

Reflow soldering techniques are suitable for all SSOP packages.

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several techniques exist for reflowing; for example, thermal conduction by heated belt. Dwell times vary between 50 and 300 seconds depending on heating method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 minutes at 45 °C.

Wave soldering

Wave soldering is **not** recommended for SSOP packages. This is because of the likelihood of solder bridging due to closely-spaced leads and the possibility of incomplete solder penetration in multi-lead devices.

If wave soldering cannot be avoided, the following conditions must be observed:

- **A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.**
- **The longitudinal axis of the package footprint must be parallel to the solder flow and must incorporate solder thieves at the downstream end.**

Even with these conditions, only consider wave soldering SSOP packages that have a body width of 4.4 mm, that is SSOP16 (SOT369-1) or SSOP20 (SOT266-1).

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. Typical dwell time is 4 seconds at 250 °C.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

Repairing soldered joints

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C. When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

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DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

LIFE SUPPORT APPLICATIONS

These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

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NOTES

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NOTES

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