INTEGRATED CIRCUITS

DATA SHEET

SZA1015
Brushless Motor Controller (BMC12)

Preliminary specification
File under Integrated Circuits, IC01

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FEATURES

- Direct full bridge driving system
- No external series resistor required in motor supply line
- Adjustable output current up to 2.1 A (over 20X DVD and over 50X CD)
- D-MOSFET output with a total on-resistance of 0.7 Ω (typical)
- PWM controlled commutation
- Internal compensation for EMF of motor (EMF regenerator)
- Start/stop function with built-in power saving circuit
- Hall amplifiers with a minimum input level of 25 mV
- Built-in frequency generator (FG output)
- Adjustable motor current limiter
- Built-in thermal shutdown
- Reverse torque brake function (full bridge)
- Built-in reverse rotation protection circuit
- 32 mA Hall bias circuit
- Few external components
- Interfaces to 3 V and 5 V logic
- Package with very low thermal resistance from junction to heatsink (reflowable die pad).

GENERAL DESCRIPTION

The BMC12 is a 3-phase Brushless Motor Controller (BMC) for Hall commutated spindle motors in CD and DVD drives suitable for DVD speeds over 20X and CD speeds over 50X.

It uses a 5 V supply for the internal control circuit and a 5 to 12 V supply for the motor driver.

The switching PWM output is highly efficient resulting in a low power dissipation for forward torque acceleration as well as for reverse torque brake (PWM controlled reverse torque).

Sensitive Hall sensor amplifiers with a very low offset are integrated which can operate on very small Hall signals.

The current limiter circuit requires no external series resistor in the power ground which increases efficiency. The limiting current can be adjusted by means of an external resistor at pin RLIM (not in series with motor supply line). The current limiter is active during accelerating as well as during braking.

The EMF voltage of the motor is internally measured and is used to compensate for the PWM commutation. A scaling factor can be set by means of an external resistor at pin REMF.

The tacho-generator can be used to measure the rotational speed of the disk. It shows the triple frequency of the Hall signals.

A thermal shutdown circuit with a small hysteresis protects the IC from overheating.

A heatsink at the bottom of the chip with a very low thermal resistance enables effective cooling.

The start/stop function reduces current consumption of the IC to a minimum when the motor is stopped (stop mode) and also turns off the Hall sensor bias in the stop mode.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
SZA1015TT	HTSSOP32	plastic, heatsink thin shrink small outline package; 32 leads; body width 6.1 mm; lead pitch 0.65 mm	SOT549-1

QUICK REFERENCE DATA

SYMBOL	PARAMETER	MIN.	TYP.	MAX.	UNIT
V_{DD}	supply voltage	4.5	5.0	5.5	V
V_{DDM}	motor supply voltage	4.5	12.0	14.5	V
I_{DDM}	motor current	–	–	2.1	A
$R_{ds(on)}$	D-MOSFET on-resistance (high or low)	–	0.35	–	Ω
P_{tot}	total power dissipation	–	–	3.0	W
T_{amb}	ambient temperature	0	–	85	°C

BLOCK DIAGRAM

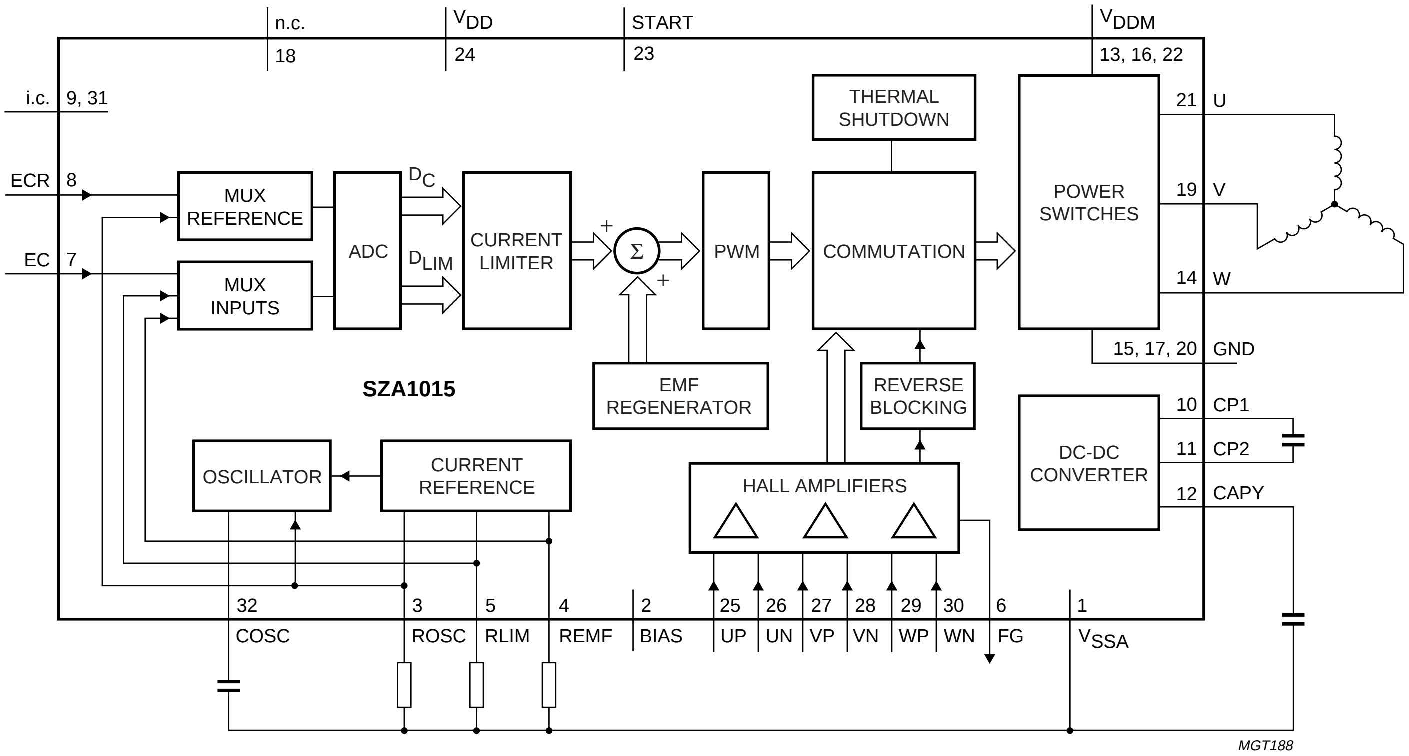


Fig.1 Block diagram.

PINNING

SYMBOL	PIN	DESCRIPTION
V_{SSA}	1	motor control ground supply
BIAS	2	Hall element bias
ROSC	3	external resistor for internal oscillator
REMF	4	external resistor for EMF regeneration
RLIM	5	external resistor for current limiting
FG	6	frequency generator output
EC	7	output current control pin
ECR	8	output current control reference voltage pin
i.c.	9	internally connected (leave open-circuit)
CP1	10	booster capacitor connection 1
CP2	11	booster capacitor connection 2
CAPY	12	booster output
V_{DDM}	13	motor supply voltage
W	14	motor terminal W
GND	15	ground supply
V_{DDM}	16	motor supply voltage
GND	17	ground supply
n.c.	18	not connected
V	19	motor terminal V
GND	20	ground supply
U	21	motor terminal U
V_{DDM}	22	motor supply voltage
START	23	start/stop control pin
V_{DD}	24	system supply voltage
UP	25	positive Hall input U
UN	26	negative Hall input U
VP	27	positive Hall input V
VN	28	negative Hall input V
WP	29	positive Hall input W
WN	30	negative Hall input W
i.c.	31	internally connected (leave open-circuit)
COSC	32	external capacitor for internal oscillator

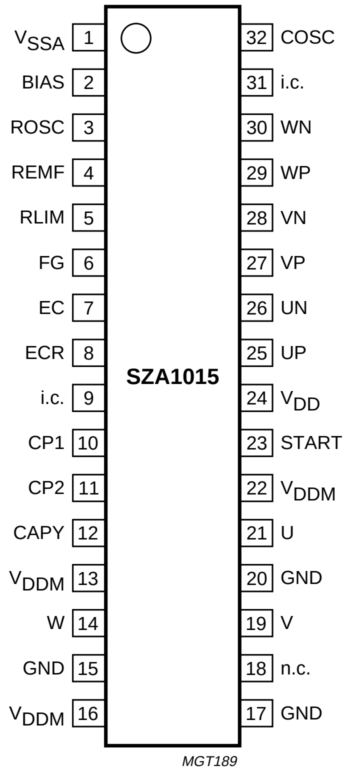


Fig.2 Pin configuration.

FUNCTIONAL DESCRIPTION

Motor control

The control input voltage E_C is converted into a digital value (D_C) by the ADC where voltage E_{CR} is the midpoint reference for E_C (see Fig.3).

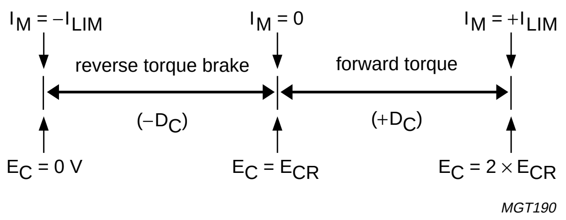


Fig.3 Motor control.

The gain from input voltage (E_C) to motor current (I_M) is I_{LIM}/E_{CR} (A/V). The motor current can be determined with the following formula: $I_M = \frac{I_{LIM}}{E_{CR}} \times (E_C - E_{CR})$

The maximum motor current I_{LIM} is set by the motor current limiter. When the rotational speed of the motor has become zero the motor current is switched off and all driver outputs (pins U, V and W) are connected to ground. This prevents the motor of spinning backwards.

Internal motor voltage generation

The simplified motor schematic in Fig.4 shows the series resistance and back-EMF voltage of the motor.

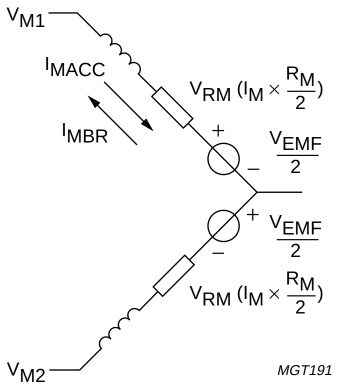


Fig.4 Simplified motor schematic.

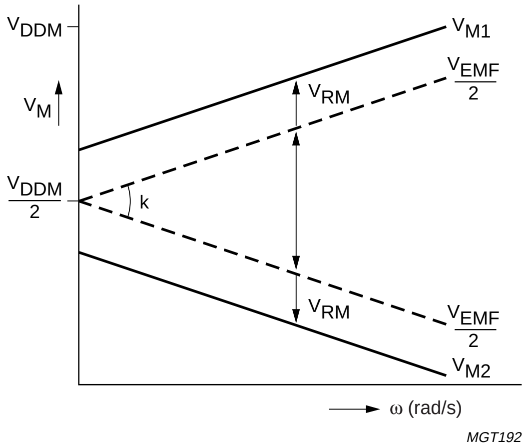


Fig.5 Motor voltage when accelerating.

If we assume that I_{MACC} is used to accelerate and I_{MBR} is used to brake we can draw two pictures shown in Figs 5 (accelerate) and 6 (brake).

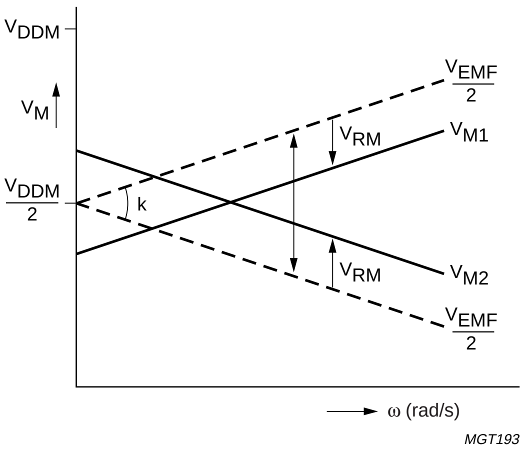


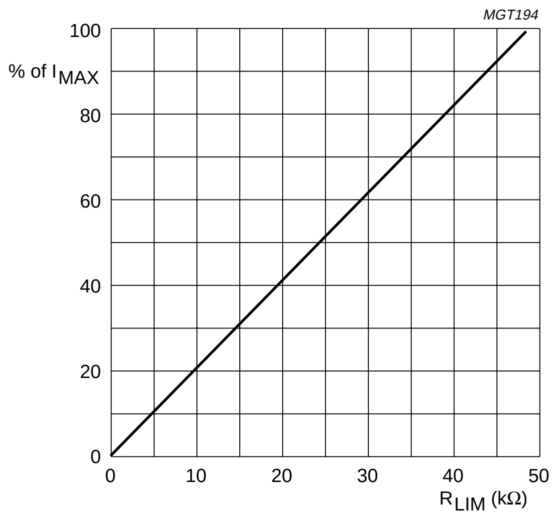
Fig.6 Motor voltage when actively braking.

The BMC12 regenerates V_{EMF} and superimposes V_M ($0 \leq I_M \leq I_{LIM}$) which depends on the E_C (gain) input voltage. V_{RM} (I_M) can be positive (accelerate) or negative (brake).

Motor current limiting function

The maximum motor current is determined with the following formula: $I_{MAX} = \frac{V_{DDM}}{R_{motor} + R_{switches(min)}}$

I_{LIM} is a fraction of the maximum motor current I_{MAX}. During accelerating and braking the motor current will not exceed the limiting current set by R_{LIM}.



R_{OSC} = 47 kΩ.

Fig.7 Maximum output current as a function of R_{LIM}.

The formula to determine the limiting current is as follows:

$$I_{LIM} = \frac{R_{LIM}}{R_{OSC}} \times I_{MAX}$$

Back-EMF regeneration

The back-EMF voltage is internally regenerated. The ratio between R_{EMF} and R_{OSC} can be used to scale the internal EMF regeneration. The value of resistor R_{EMF} depends on the type of motor (k-factor, number of pole pairs) and the motor supply voltage used. This is shown in the following formula: $R_{EMF} = \frac{k \times 2.6 \times 10^3 \times R_{OSC}}{N_{PP} \times V_{DDM}}$

For noise reduction the Hall signals are internally filtered.

FG generator

The FG generator output shows a frequency which depends on the number of Hall signals (three) and the number of pole pairs (N_{PP}). The formula to determine the motor frequency is as follows: $f_{motor} = \frac{FG}{3 \times N_{PP}}$

The FG has an open-drain output for easy interfacing to 3 V and 5 V logic.

Thermal shutdown

The thermal shutdown block sets all outputs to 3-state mode if the junction temperature of the BMC12 exceeds 155 °C (typical). There is a hysteresis of 15 °C (typical) between the temperatures at which the thermal shutdown activates and deactivates. As soon as the thermal shutdown deactivates, the commutation control continues its operation.

Oscillator

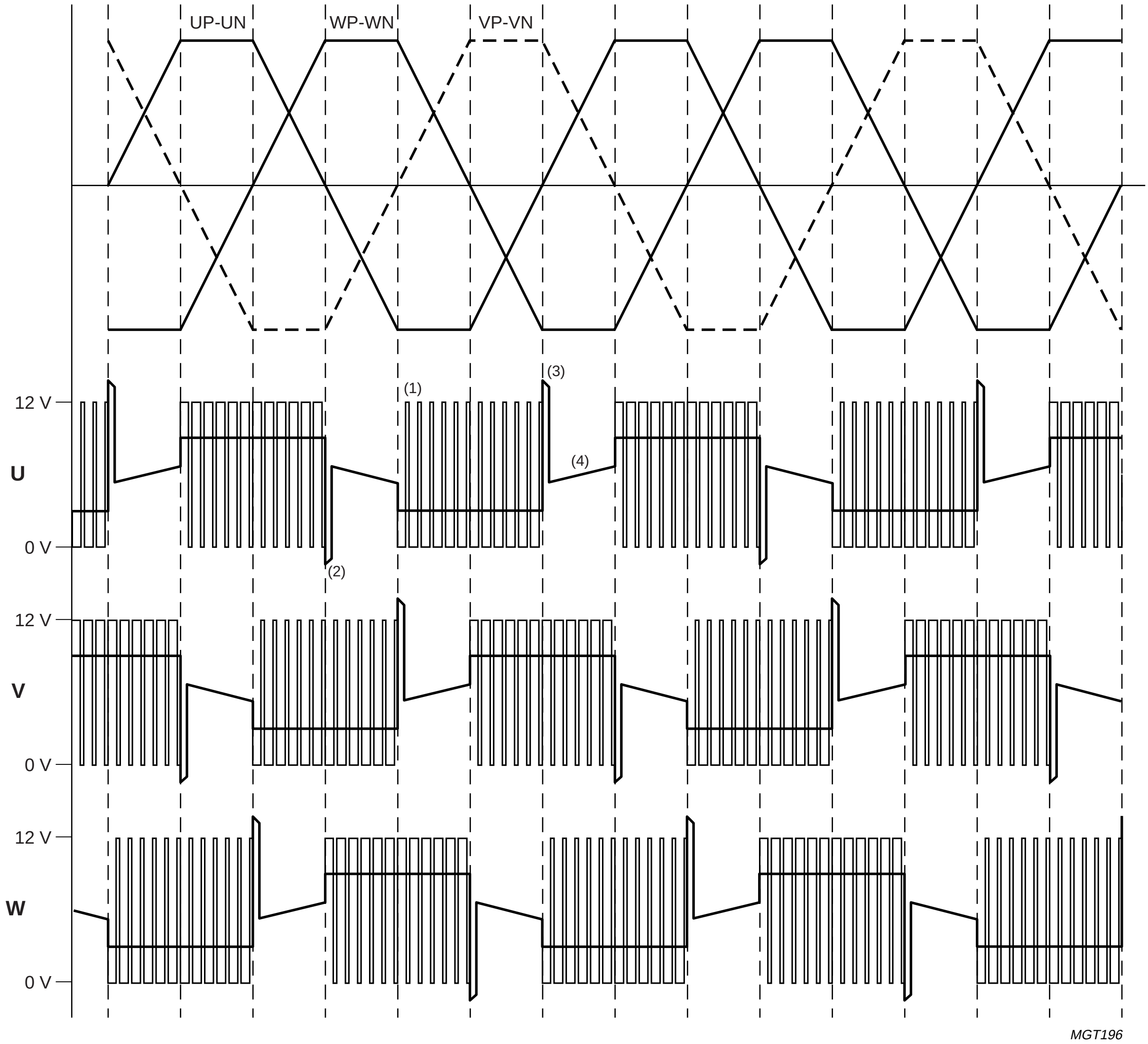
The RC oscillator uses two external components (R_{OSC} and C_{OSC}) to fix its frequency. To ensure a stable oscillator frequency the oscillator and R_{OSC} both use a reference current made by the current reference block. The nominal frequency is 3 MHz with R_{OSC} = 47 kΩ (2% tolerance) and C_{OSC} = 100 pF (5% tolerance). The values of the external components for the oscillator are fixed. The oscillator can be overruled by applying a 3 MHz clock to pin COSC (R_{OSC} is used to determine I_{LIM} and R_{EMF} and should always be connected).

Start/stop function

At pin START = LOW, the BMC12 can be set to a power saving mode, reducing the current consumption. In the power saving mode the outputs will be in 3-state.

DC-DC converter

The on-board DC-DC converter generates a voltage of approximately $2 \times V_{DDM} - 1.2$ V with a maximum voltage of 19.3 V typical (internal clamp circuit). This voltage is used internal to switch the upper drivers of the U, V and W outputs.



(1) In this example, a PWM output signal with a 25% duty cycle is drawn as a thin line. The average motor voltage (drawn with a thicker line width) is 25% × V_{DDM}, i.e. 3.0 V. At the opposite side of the coil (in this drawing pin W) the duty cycle is 75%, so the average voltage on pin W is 9.0 V. The differential voltage over the motor pins then is: 9 − 3 = 6 V.

(2) There is still a current flowing from pin U into the motor. The lower flyback diode starts conducting, and causes a flyback voltage of around 0.7 V below GND, until the current is zero.

(3) There is still a current flowing from the motor into pin U. The upper flyback diode starts conducting, and causes a flyback voltage of around 0.7 V above V_{DDM}, until the current is zero.

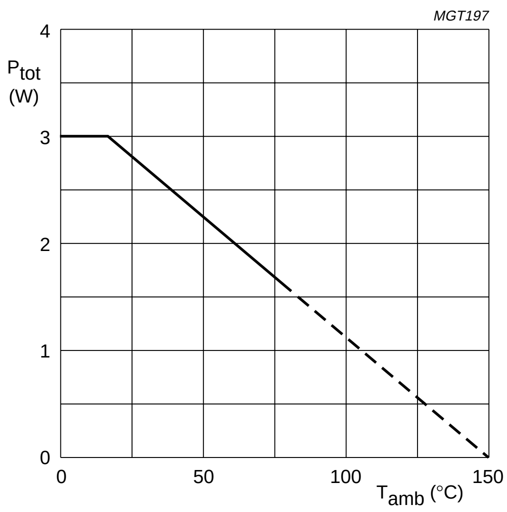
(4) During this phase, the driver output is 3-state. Because there is no current flowing through pin U, the back-EMF of the motor is seen.

Fig.8 Phase condition of Hall input and output voltage (motor running with $E_C > E_{CR}$).

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134).

SYMBOL	PARAMETER	MIN.	MAX.	UNIT
V_{DD}	supply voltage	–0.5	+6.5	V
V_{DDM}	motor supply voltage	–0.5	+15	V
I_{DDM}	motor current	–	2.1	A
P_{tot}	total power dissipation	–	3.0	W
T_{stg}	storage temperature	–55	+150	°C
T_{amb}	ambient temperature	0	85	°C



The IC is thermally connected with its heatsink to an external heatsink at ambient temperature, with a total thermal resistance of 35 K/W (10 K/W junction to case plus 25 K/W case to surrounding).

Fig.9 Maximum dissipation as a function of the ambient temperature.

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	VALUE	UNIT
$R_{th(j-c)}$	thermal resistance from junction to case	10	K/W

CHARACTERISTICS

V_{DD} = 5 V; V_{DDM} = 12 V; GND = 0 V; T_{amb} = 25 °C; R_{OSC} = 47 kΩ, C_{OSC} = 100 pF; unless otherwise specified.

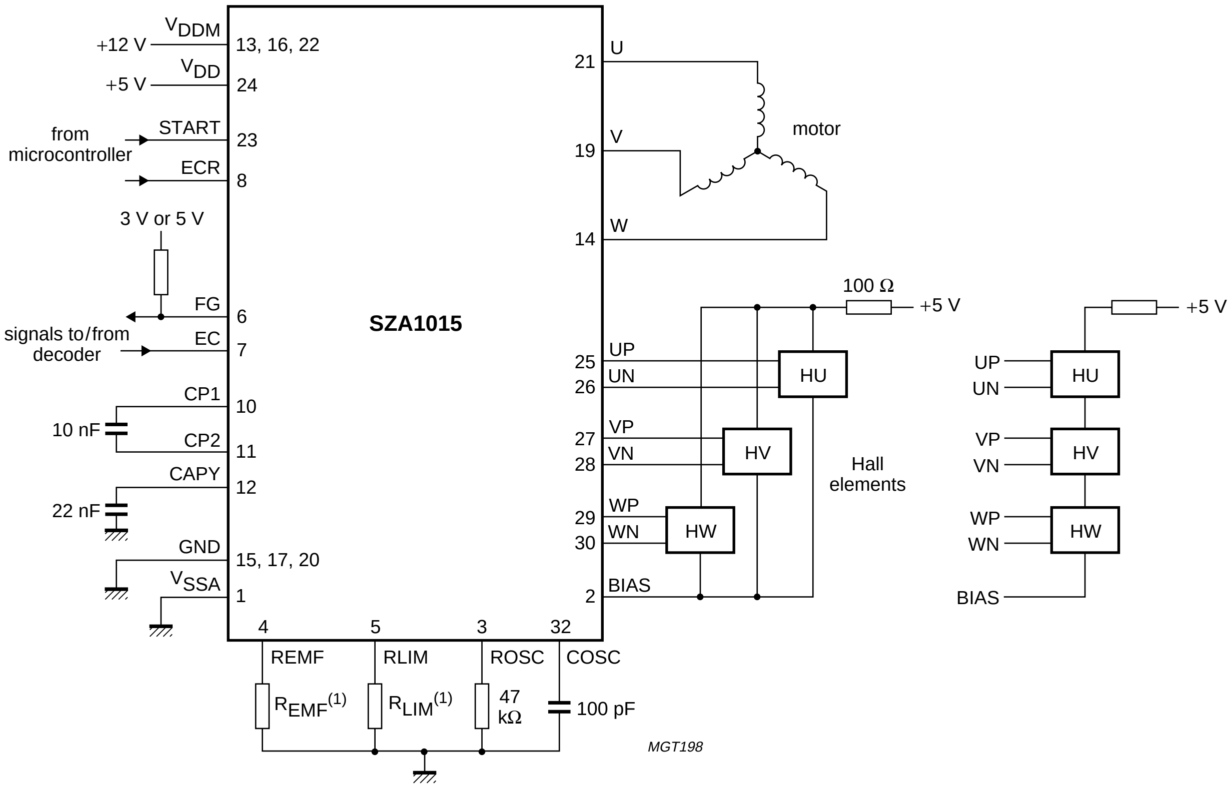
SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supplies						
V_{DD}	supply voltage		4.5	5.0	5.5	V
V_{DDM}	motor supply voltage		4.5	12.0	14.5	V
I_{DDM}	motor current		–	–	2.1	A

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{DD}	supply current	START = HIGH	–	15	–	mA
$I_{DD(q)}$	quiescent current in power saving mode	START = LOW	–	–	1	mA
P_{tot}	total power dissipation		–	–	3.0	W
T_{amb}	ambient temperature		0	–	85	°C
Hall amplifier inputs (pins UN, UP, VN, VP, WN and WP)						
V_{IO}	input offset voltage		–3	–	+3	mV
V_i	input voltage range		0	–	4.0	V
$V_{i(dif)(p-p)}$	Hall amplifier input voltage (peak-to-peak value)		25	–	–	mV
Hall elements bias (pin BIAS)						
I_{bias}	bias current		–	–	32	mA
V_{bias}	bias voltage	I_{bias} = 32 mA	0.3	0.4	0.5	V
Oscillator						
f_{osc}	oscillator frequency	note 1	–	3.0	–	MHz
Thermal shutdown circuit						
T_{SD}	thermal shutdown operating temperature		140	155	170	°C
Power switches						
$R_{ds(on)}$	D-MOSFET on-resistance (high or low)	V_{DDM} = 12 V	0.25	0.35	0.50	Ω
		V_{DDM} = 5 V	0.35	0.50	0.71	Ω
Booster						
V_{CAPY}	booster output voltage		19	19.3	19.6	V
Torque control (pins EC and ECR)						
V_{ECR}	reference voltage on pin ECR		1.2	1.8	2.5	V
V_{EC}	torque control voltage on pin EC	note 2	0	–	V_{DD}	V
Digital input (pin START)						
V_{IH}	HIGH-level input voltage		2.0	–	–	V
V_{IL}	LOW-level input voltage		–	–	0.8	V
Open-drain output (pin FG)						
V_{OL}	LOW-level output voltage	I_O = 2 mA	–	–	0.5	V

Notes

1. The PWM frequency is: $f_{PWM} = \frac{f_{osc}}{33}$
2. The maximum useful range of the control input voltage E_C is 0 to 2 × E_{CR} (midpoint reference voltage). When $E_C = E_{CR}$, then no torque is applied to the motor. The conversion characteristic does not have a ‘dead zone’.

APPLICATION INFORMATION



(1) For selection of the resistors R_{EMF} and R_{LIM} see Chapter “Functional description”.

Fig.10 Typical application diagram.

INTERNAL PIN CONFIGURATION

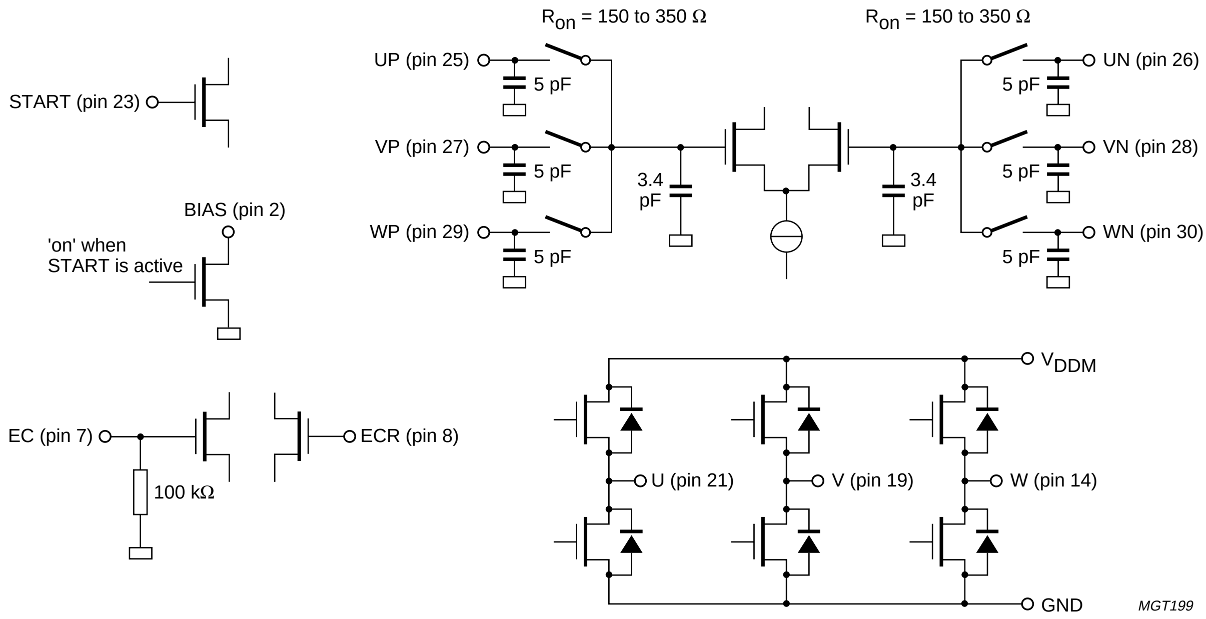
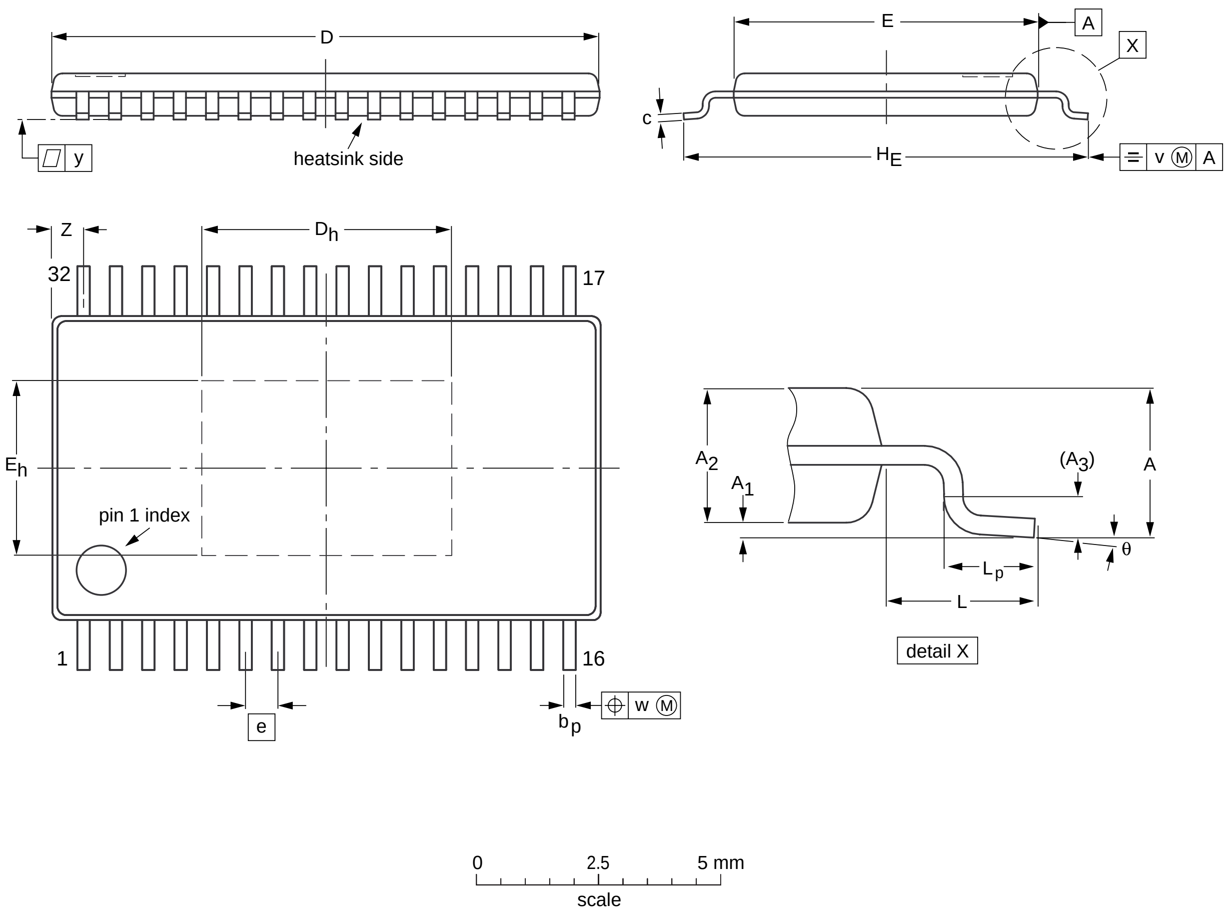


Fig.11 Input and output equivalent circuits.

PACKAGE OUTLINE

HTSSOP32: plastic, heatsink thin shrink small outline package; 32 leads; body width 6.1 mm; lead pitch 0.65 mm **SOT549-1**



DIMENSIONS (mm are the original dimensions).

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	D_h	$E^{(2)}$	E_h	e	H_E	L	L_p	v	w	y	Z	θ
mm	1.10	0.15 0.05	0.95 0.85	0.25	0.30 0.19	0.20 0.09	11.10 10.90	5.10 4.90	6.20 6.00	3.60 3.40	0.65	8.30 7.90	1.00	0.75 0.50	0.20	0.10	0.10	0.78 0.48	8° 0°

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic interlead protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES					EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ				
SOT549-1							99-03-04

SOLDERING

Introduction to soldering surface mount packages

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"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering is not always suitable for surface mount ICs, or for printed-circuit boards with high population densities. In these situations reflow soldering is often used.

Reflow soldering

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 methods exist for reflowing; for example, infrared/convection heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 250 °C. The top-surface temperature of the packages should preferable be kept below 230 °C.

Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.
- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

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.

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.

Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron 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.

Suitability of surface mount IC packages for wave and reflow soldering methods

PACKAGE	SOLDERING METHOD	
	WAVE	REFLOW(1)
BGA, LFBGA, SQFP, TFBGA	not suitable	suitable
HBCC, HLQFP, HSQFP, HSOP, HTQFP, HTSSOP, SMS	not suitable(2)	suitable
PLCC(3), SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended(3)(4)	suitable
SSOP, TSSOP, VSO	not recommended(5)	suitable

Notes

1. All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *“Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods”*.
2. These packages are not suitable for wave soldering as a solder joint between the printed-circuit board and heatsink (at bottom version) can not be achieved, and as solder may stick to the heatsink (on top version).
3. If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
4. Wave soldering is only suitable for LQFP, TQFP and QFP packages with a pitch (e) equal to or larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
5. Wave soldering is only suitable for SSOP and TSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

DATA SHEET STATUS

DATA SHEET STATUS	PRODUCT STATUS	DEFINITIONS [1]
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Preliminary specification	Qualification	This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
Product specification	Production	This data sheet contains final specifications. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

Note

1. Please consult the most recently issued data sheet before initiating or completing a design.

DEFINITIONS

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

Limiting values definition — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). 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.

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