Integrated Circuits

DATA SHEET

SA56203

OneChip MotorDriver

Objective Specification
Rev 0.06

March 23, 2004

PHILIPS

GENERAL DESCRIPTION

The SA56203 is a OneChip Motordriver IC that is capable to drive all motors of CD or DVD systems: spindle, sled and loading motors and actuators on the optical pick-up unit. The driver for the 3-phase, brushless, Hall-commutated spindle motor uses full-bridge switching. Internal compensation of the spindle motor's back-EMF enables the driver to operate in current-steering mode without using external power-dissipating sense resistors. The driver for the 2-phase sled stepper motor operates in current-steering PWM mode. In addition the IC contains four full-bridge linear channels that can be used to drive a loading motor and 3D actuators (focus, tracking and tilt).

The SA56203 is available in an exposed-pad TSSOP-56 package.

FEATURES

- power-efficient direct full-bridge switching for spindle motor driver
- internal compensation for EMF of spindle motor
- reverse torque brake function (full bridge)
- adjustable spindle motor current limiter
- controlled spindle motor current during acceleration and brake
- current-steering stepper motor driver for sled
- PWM controlled stepper motor driver
- 4 linear channels for loading motor and 3D actuators (focus, tracking and tilt)
- low on-resistance D-MOSFET output power stages

- built-in thermal shutdown and thermal warning
- interfaces to 3V and 5V logic
- package with low thermal resistance to heatsink (reflowable die pad)

APPLICATIONS

- CD-ROM, CD-RW
- DVD-ROM, DVD-RAM, DVD-RW, DVD+RW
- Combi
- other compact disk media

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
SA56203	exposed-pad TSSOP56	plastic, exposed-pad thin shrink small outline package, 56 leads, 6.1mm * 14.0mm body size, lead pitch 0.5mm	SOT793-1

ABSOLUTE MAXIMUM RATINGS

PARAMETER	SYMBOL	MIN	MAX	UNIT
spindle driver power supply	VDDSPN	-0.5	16	V
sled driver power supply	VDDSLD	-0.5	16	V
loading driver power supply	VDDLD	-0.5	16	V
tracking actuator driver power supply	VDDTRK	-0.5	16	V
focus/tilt actuator drivers power supply	VDDACT	-0.5	6.5	V
system supply	VDDANA	-0.5	6.5	V
power dissipation	PD	-	3.9	W
storage temperature	T_S	-55	150	ºC
operating temperature range	T_A	-40	85	ºC
spindle output current NOTE1	IMAXSPN	-	2.1	A
sled output current	IMAXSLD	-	1.2	A
loading/actuator drivers output current	IMAXACT	-	1.5	A

NOTE1 Programmable through RLIM.

THERMAL CHARACTERISTICS

PARAMETER	SYMBOL	VALUE	UNIT
thermal resistance, junction to ambient	θ_{JA}	33.5	ºC/W

TSSOP56, multilayer PCB, no airflow, details: TBD:

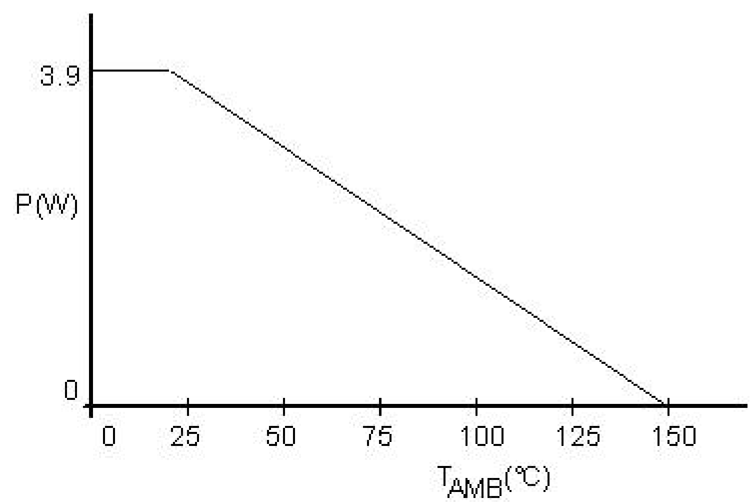


Fig.1 Maximum dissipation as a function of ambient temperature.

PIN CONFIGURATION

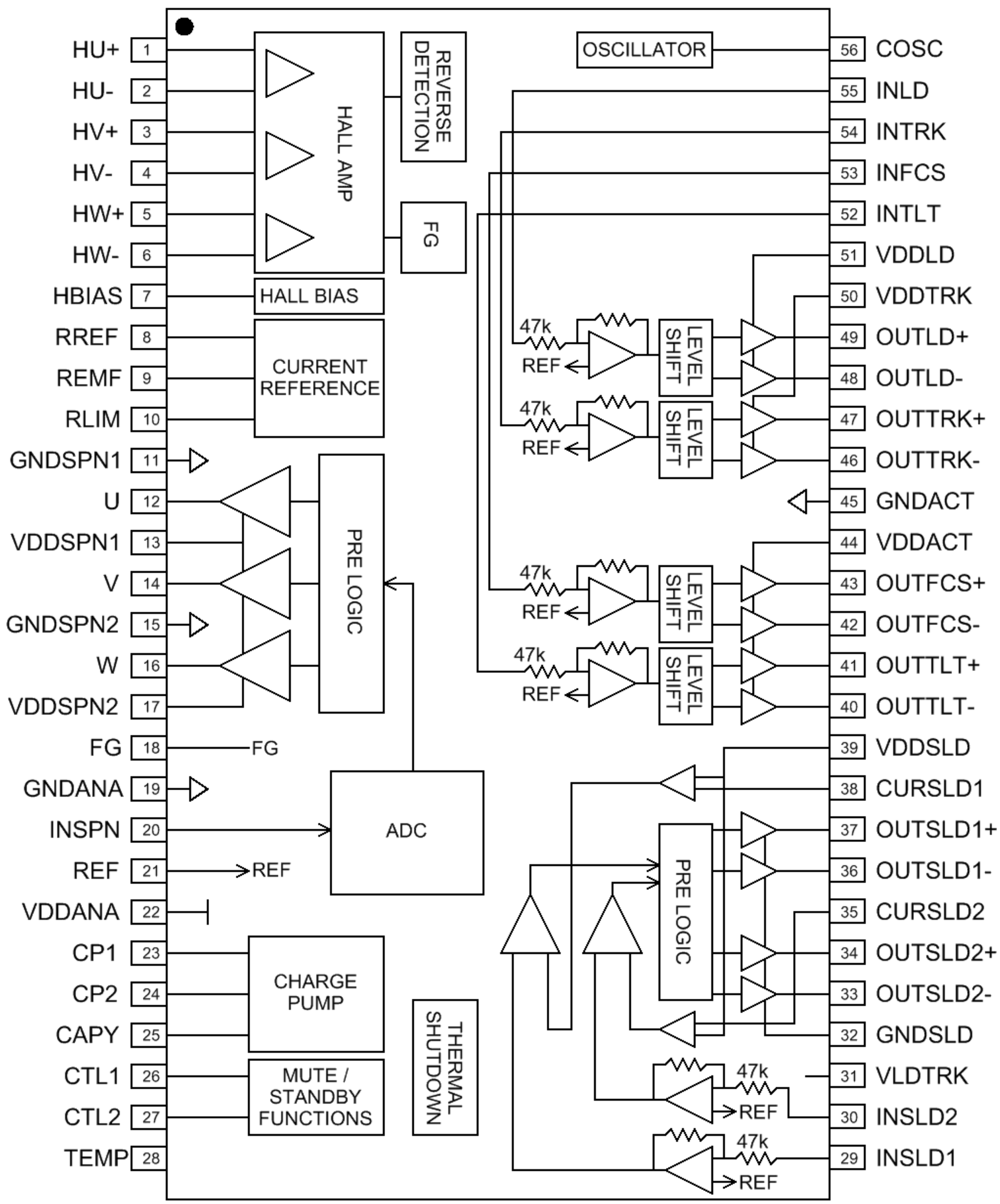


Fig.2 Block diagram.

OneChip MotorDriver SA56203

PIN DESCRIPTION

PIN	SYMBOL	DESCRIPTION	PIN	SYMBOL	DESCRIPTION
1	HU+	positive Hall input U	56	COSC	ext. capacitor for int. oscillator
2	HU-	negative Hall input U	55	INLD	loading driver input
3	HV+	positive Hall input V	54	INTRK	tracking driver input
4	HV-	negative Hall input V	53	INFCS	focus driver input
5	HW+	positive Hall input W	52	INTLT	tilting driver input
6	HW-	negative Hall input W	51	VDDLD	loading driver power supply
7	HBIAS	Hall element bias	50	VDDTRK	tracking driver power supply
8	RREF	ext. res. for current reference	49	OUTLD+	loading driver positive output
9	REMF	ext. res. for EMF regeneration	48	OUTLD-	loading driver negative output
10	RLIM	ext. res. for current limit	47	OUTTRK+	focus driver positive output
11	GNDSPN1	spindle driver power ground 1	46	OUTTRK-	focus driver negative output
12	U	spindle driver output U	45	GNDACT	actuator drivers power ground
13	VDDSPN1	spindle driver power supply 1	44	VDDACT	focus/tilt drivers power supply
14	V	spindle driver output V	43	OUTFCS+	tracking driver pos. output
15	GNDSPN2	spindle driver power ground 2	42	OUTFCS-	tracking driver neg. output
16	W	spindle driver output W	41	OUTTLT+	tilting driver pos. output
17	VDDSPN2	spindle driver power supply 2	40	OUTTLT-	tilting driver neg. output
18	FG	frequency generator output	39	VDDSLD	sled driver sense supply
19	GNDANA	ground supply	38	CURSLD1	sled driver 1 current sense
20	INSPN	spindle driver input	37	OUTSLD1+	sled driver 1 positive output
21	REF	reference input voltage	36	OUTSLD1-	sled driver 1 negative output
22	VDDANA	system supply voltage	35	CURSLD2	sled driver 2 current sense
23	CP1	charge pump cap. conn. 1	34	OUTSLD2+	sled driver 2 positive output
24	CP2	charge pump cap. conn. 2	33	OUTSLD2-	sled driver 2 negative output
25	CAPY	charge pump output voltage	32	GNDSLD	sled driver power ground
26	CTL1	driver logic control input 1	31	VLDTRK	voltage output loader/track
27	CTL2	driver logic control input 2	30	INSLD2	sled driver 2 input
28	TEMP	thermal warning	29	INSLD1	sled driver 1 input

OPERATING SPECIFICATIONS

T_A = 25°C, V_{DDANA}=5V, V_{DDSPN}=12V, V_{DDSLD}=12V, V_{DDTRK}=5V, V_{DDACT}=5V, V_{DDLD}=12V, unless otherwise noted.

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Spindle Motor Driver						
supply voltage	V_{DDANA}		4.5	5.0	5.5	V
motor supply voltage	V_{DDSPN}		4.5	12	14	V
input offset voltage Hall amps			-3.5		3.5	mV
input voltage range Hall amps			0		V_{DDANA}	V
Hall amp input voltage (peak-to-peak)			25			mV
voltage Hall Bias pin		$I_{hallbias}$ = 32mA	0.1		0.5	V
oscillator frequency	f_{osc}	COSC = 70pF		18		MHz
PWM frequency				f_{osc}/ 256		
D-MOSFET on-resistance (high or low)				0.35	0.50	Ω
reference voltage pin REF	REF		1.2	1.65	2.5	V
torque control voltage pin INSPN			0		V_{DDANA}	V
Stepper Motor Driver						
supply voltage	V_{DDANA}		4.5	5.0	5.5	V
motor supply voltage	V_{DDSLD}		4.5	12	14	V
motor current limit		R_{sense} = 0.5Ω	0.85	1.0	1.15	A
PWM frequency				f_{osc}/ 256		
input dead-zone trip level			15	30	45	mV
transconductance gain		R_{sense} = 0.5Ω	0.85	1.0	1.15	A/V
D-MOSFET on-resistance (high or low)				1.0	1.4	Ω
Loading Motor Driver						
supply voltage	V_{DDLD}		4.5	12	14	V
current limit (high or low)			1.0	1.5	2.0	A
output offset voltage			-100	0	100	mV
voltage gain			17.2	18	18.8	dB
D-MOSFET on-resistance (high or low)				0.6	0.9	Ω
Actuator Drivers tracking, focus, tilt						
supply voltage tracking driver	V_{DDTRK}		4.5	5	14	V
supply voltage focus/tilt drivers	V_{DDACT}		4.5	5	5.5	V
current limit			1.0	1.5	2.0	A
output offset voltage			-55	0	55	mV
voltage gain tracking driver			17.2	18	18.8	dB
voltage gain focus/tilt drivers			11.2	12	12.8	dB
D-MOSFET on-resistance (high or low)				0.6	0.9	Ω

PARAMETER	SYMBOL	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Voltage Output Loader / Tracking Actuator (pin 31)						
voltage gain of back-EMF voltage tracking actuator			29.2	30.0	30.8	dB
output offset back-EMF amplifier			-200	0	200	mV
transresistance gain of current loading motor		I_{LD} = 250mA	1.4	1.65	1.9	V/A
output offset transresistance amplifier			-100	0	100	mV
common mode output voltage				REF		
output resistance				150		Ω
current drive capability			0.3	0.5		mA
General						
charge pump output voltage				18.2		V
HIGH-level input voltage Digital			2.0			V
LOW-level input voltage Digital					0.8	V
LOW-level output voltage Digital		I = 2mA			0.5	V
quiescent current				TBD	TBD	mA
standby current, mute-all				TBD	30	μA
thermal warning temperature				150		°C
thermal warning hysteresis				20		°C
thermal shutdown temperature				160		°C
thermal shutdown hysteresis				30		°C

TECHNICAL DISCUSSION

Spindle Motor Control

The control input voltage INSPN is converted into a digital value by the ADC where voltage REF is the midpoint reference. The transconductance gain from input voltage INSPN to output motor current I_{MOT} is I_{LIM}/REF where I_{LIM} can be programmed by means of external resistor RLIM. The motor current is described by the following figure.

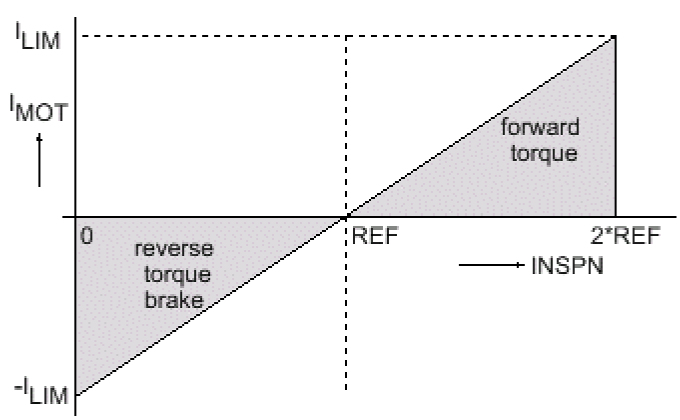


Fig.4 Spindle motor current as a function of control input voltage INSPN.

For INSPN voltages larges than REF the motor will accelerate with forward torque control. For INSPN voltages smaller than REF the motor will brake with reverse torque control. Because the U, V and W half-bridges of the spindle motor driver use a direct PWM full-bridge switching scheme, the motor current can also be controlled and limited during brake. Upon detection of reverse rotation all U, V and W driver outputs are connected to VDDSPN. This short brake prevents the motor of spinning backwards.

Internal Compensation of back–EMF Spindle Motor

The spindle motor driver uses the information from the Hall sensors to internally regenerate the back-EMF of the motor. See figure below.

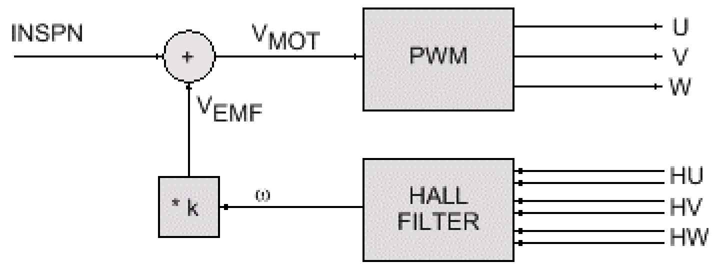


Fig.5 Regeneration of back-EMF voltage spindle motor.

Rotational speed ω is derived from the Hall event frequency. Multiplying ω with the k-factor of the motor gives the back-EMF voltage V_{EMF}. This V_{EMF} is added to the spindle input voltage INSPN. This sum V_{MOT} steers the PWM outputs U, V and W. The result is that the input voltage INSPN represents the current through the motor. This explains how the SA56203 spindle motor driver exhibits a current control transfer function without using external sense resistors.

The simplified motor schematic in left Figure below shows the series resistance and back-EMF voltage of the motor.

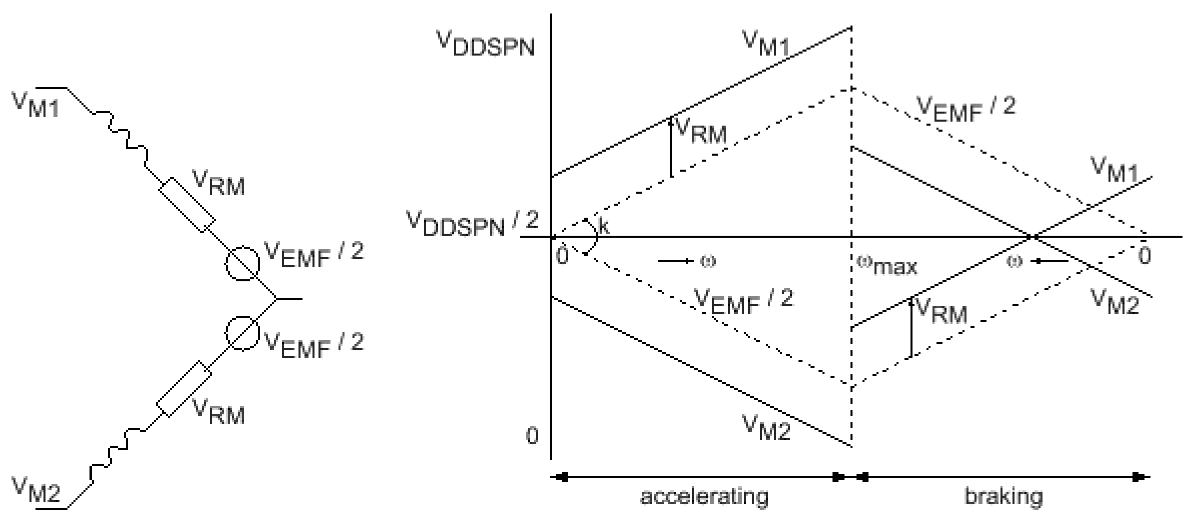


Fig.6 Simplified spindle motor schematic and motor voltages when accelerating and braking with constant motor current.

The right Figure above depicts the motor voltages V_{M1} and V_{M2} during accelerating and braking. The back-EMF voltage is part of these motor voltages.

Programming RLIM

If the supply is connected between the terminals of a non-running spindle motor, then usually a current will flow that is too large. The motor current can be limited to a value I_{LIM}. I_{LIM} can be programmed by means of RLIM. A typical maximum motor current I_{MAX} is determined by:

$$I_{MAX} = \frac{V_{DDSPN}}{R_{MOTOR} + R_{SWITCHES}}$$

I_{LIM} is a fraction of this maximum current I_{MAX}. By making the ratio between RLIM and RREF this same fraction, I_{LIM} is programmed as expressed in the following formula:

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

Figure below shows the limit current as a function of RLIM with RREF=47kΩ.

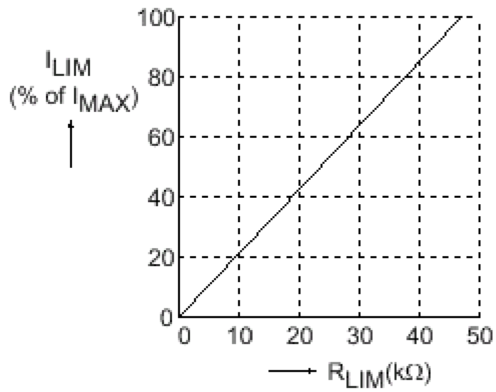


Fig.7 Limit current I_{LIM} as a function of external resistor R_{LIM}.

During accelerating and braking the motor current will not exceed I_{LIM}. Remember that I_{LIM} also sets the transconductance gain of the spindle driver.

Programming REMF

The back-EMF voltage is internally regenerated. The ratio between REMF and RREF is used to scale the internal EMF regeneration. The value of external resistor REMF depends on the type of motor (k-factor and number of pole pairs N_{PP}) and the motor supply voltage V_{DDSPN}. The following formula should be used to determine the REMF resistor:

$$R_{EMF} = \frac{k \times 2.6 \times 10^3 \times R_{REF}}{N_{PP} \times V_{DDSPN}}$$

FG Generator

The raw zero-crossings of the Hall sensors are first filtered and debounced before being passed to the FG generator. The FG generator toggles its output at every filtered Hall zero-crossing. For three Hall sensors this means that the motor frequency is linked to the FG frequency by:

$$f_{motor} = \frac{FG}{3 \times N_{PP}}$$

where N_{PP} indicates the number of pole pairs of the motor. FG has an open drain output for easy interfacing to 3V and 5V logic.

Charge Pump

The on-board charge pump generates a voltage of typically 18.2V by using the V_{DDSPN} supply voltage. This boosted voltage is used to turn on the upper n-type DMOS transistors of the output stages of the spindle driver, sled driver, loading driver and actuator drivers.

Thermal Protection

If the junction temperature of the SA56203 exceeds 150°C, then a thermal warning signal is given at pin TEMP. TEMP has an active-low open drain output for easy interfacing to 3V and 5V logic. The temperature hysteresis for the thermal warning is 20°C. If the junction temperature of the IC rises to 160°C, then a thermal shutdown is activated that sets all power outputs in tri-state. The temperature hysteresis for the thermal shutdown is 30°C. As soon as the thermal shutdown deactivates, all motor drivers continue normal operation. At the same time the thermal warning signal is deactivated.

Oscillator

The RC oscillator uses two external components (RREF and COSC) to fix its frequency. RREF is used to generate a reference current. This reference current is used to charge and discharge COSC. The nominal oscillation frequency f_{osc} is 18MHz with RREF=47kΩ (2% tolerance) and COSC=70pF (5% tolerance). These values are fixed. The oscillator can be overruled by applying an 18MHz clock to pin COSC. The reference current derived from RREF is also used for RLIM and REMF. RREF should always be connected.

Stepper Motor Driver

Two current steering channels are available to drive a stepper motor. Per channel an external sense resistor R_{sense} is used that is connected to VDDSLD. A peak-current control loop is implemented that modulates the duty-cycle of the PWM signal. See Figure below.

Fig.8 Peak-current control architecture of stepper motor driver.

The clock generator has a nominal frequency of $f_{osc}/256$ = 70kHz. See below transfer function from input voltage INSLD to output current at a typical R_{sense} of 0.5Ω. Input-to-output transconductance gain can be scaled down by connecting external resistors (R_{ext1} and R_{ext2}) to the input INSLD.

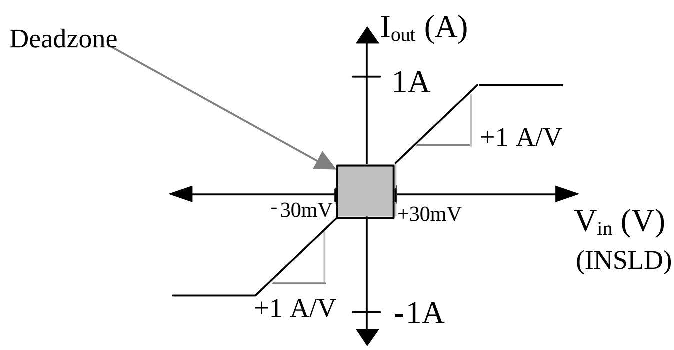


Fig.9 Transfer function of stepper motor driver.

Both limit current and transconductance gain are related to R_{sense} in the following way:

Transconductance Gain, $\frac{I_o}{V_{in}} = \frac{1}{2 * R_{sense}}$

Limit Current, $I_{LIMIT} = \frac{1}{2 * R_{sense}}$

Loading Motor Driver
One of the linear channels is available to drive a DC loading motor. A pin VDDLD is used to set the supply voltage for the loading motor driver. The following voltage-steering bridge topology is implemented in the SA56203:

Fig.10 Voltage steering bridge topology of linear driver.

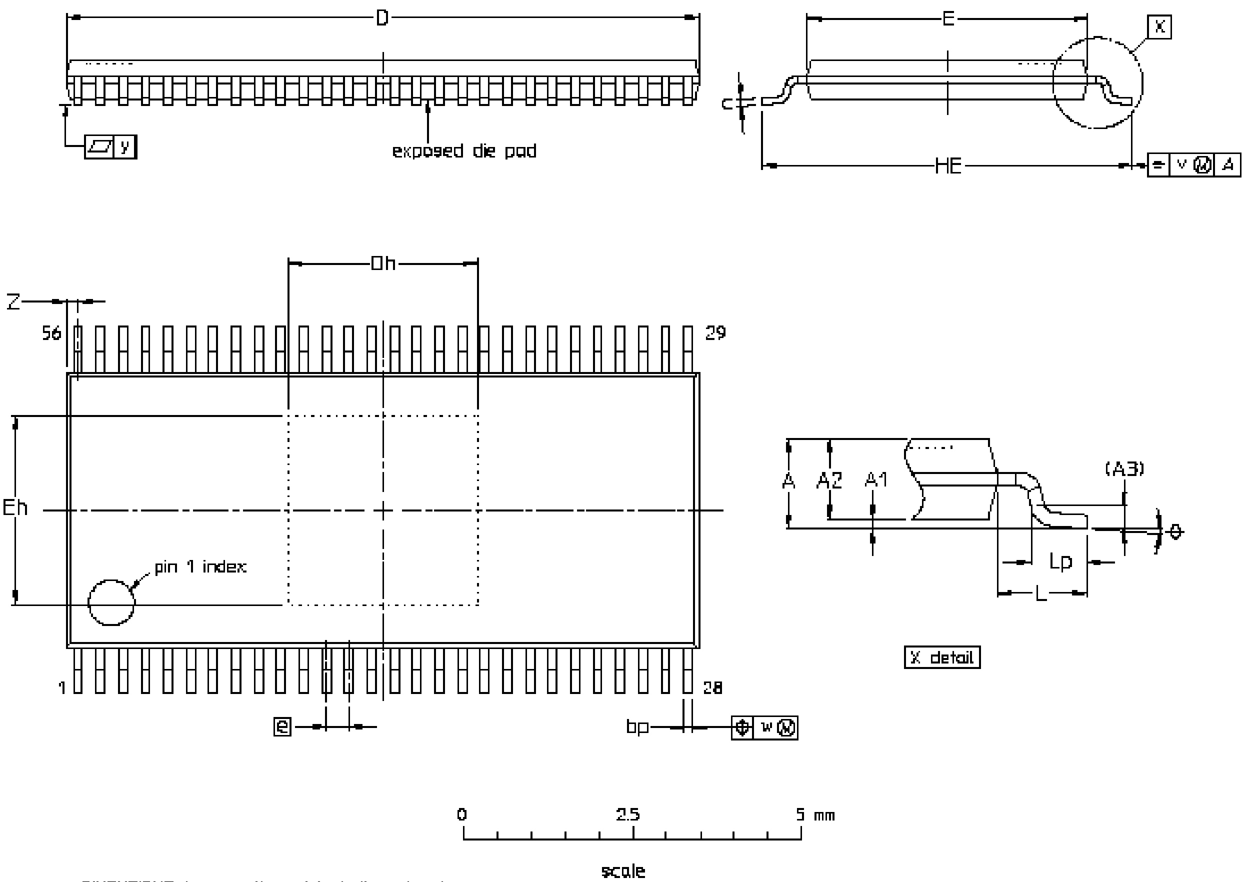
Actuator Motor Drivers
Three linear channels are available to drive 3D actuators: focus, tracking and tilt. A pin VDDACT is used to set the supply voltage for the focus and tilt actuators (max. 5.5V). A separate pin VDDTRK sets the supply voltage for the tracking actuator (max. 14V). The voltage-steering bridge topology is the same as depicted in Figure above.

Muting Functions
Pins CTL1 and CTL2 are used to mute certain parts of the IC. See table below.

CTL1	CTL2	Loading Motor	Sled Motor	Focus Tilt	Tracking	Spindle Motor	Special
0	0	off	off	off	off	off	
0	1	on	off	off	off	off	FG and Hallbias on; pin VLDTRK for loader motor
1	0	off	on	off	off	on	all actuators off; pin VLDTRK for tracking actuator
1	1	off	on	on	on	on	

PACKAGE OUTLINE

Exposed-pad TSSOP56, plastic thermal enhanced thin shrink small outline package, 56 leads, 6.1mm * 14.0mm body size, lead pitch 0.5mm.



DIMENSIONS (mm are the original dimensions).

UNIT	A max.	A1	A2	A3	bp	c	D(1)	Dh	E(2)	Eh	e	HE	L	Lp	v	w	y	Z(1)	θ
mm	1.2	0.15 0.05	1.05 0.80	0.25	0.27 0.17	0.20 0.09	14.1 13.9	4.3 4.1	6.2 6.0	4.3 4.1	0.5	8.3 7.9	1	0.8 0.4	0.2	0.08	0.1	0.4 0.1	8° 0

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

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT793-1	143E36T	MO-153				