# SA56203S

## One-chip motor driver

Rev. 01 — 31 January 2005 Preliminary data sheet

## 1. General description

The SA56203S is a one-chip motor driver IC that is capable of driving all motors of CD or DVD systems e.g. spindle, sled and loading motors and actuators on the optical pick-up unit. The driver intended for the 3-phase, brushless, Hall-commutated spindle motor uses True-Silent PWM. This proprietary technology ensures that all 3-phase motor currents are sinusoidal resulting in an optimally silent driver. Internal regeneration of the back EMF of the spindle motor 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 SA56203S is available in an exposed die pad HTSSOP56 package.

## 2. Features

- True-Silent PWM spindle motor driver
- Low heat generation due to power-efficient direct full-bridge switching of spindle motor driver
- Controlled spindle motor current during acceleration and brake
- Reverse torque brake function (full bridge)
- Adjustable spindle motor current limiter
- Internal regeneration for EMF of spindle motor
- Current-steering PWM controlled stepper motor driver for sled
- Four class-AB linear channels for loading motor and 3D actuators (focus, tracking and tilt)
- Tracking actuator driver with back EMF amplifier
- Loading motor driver with transresistance amplifier for loading current
- Low on-resistance D-MOSFET output power stages
- Built-in thermal shutdown and thermal warning
- Interfaces to 3 V and 5 V logic
- Package with low thermal resistance to heatsink (reflowable die pad)
- Lead free package.

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## 3. Applications

- DVD+RW, DVD-RW and DVD-RAM
- Combi
- CD-RW
- Other compact disc media.

## 4. Ordering information

**Table 1: Ordering information**

| Type number | Package | | |
|---|---|---|---|
| | Name | Description | Version |
| SA56203STW | HTSSOP56 | plastic thermal enhanced thin shrink small outline package; 56 leads; body width 6.1 mm; exposed die pad | SOT793-1 |

# 5. Block diagram

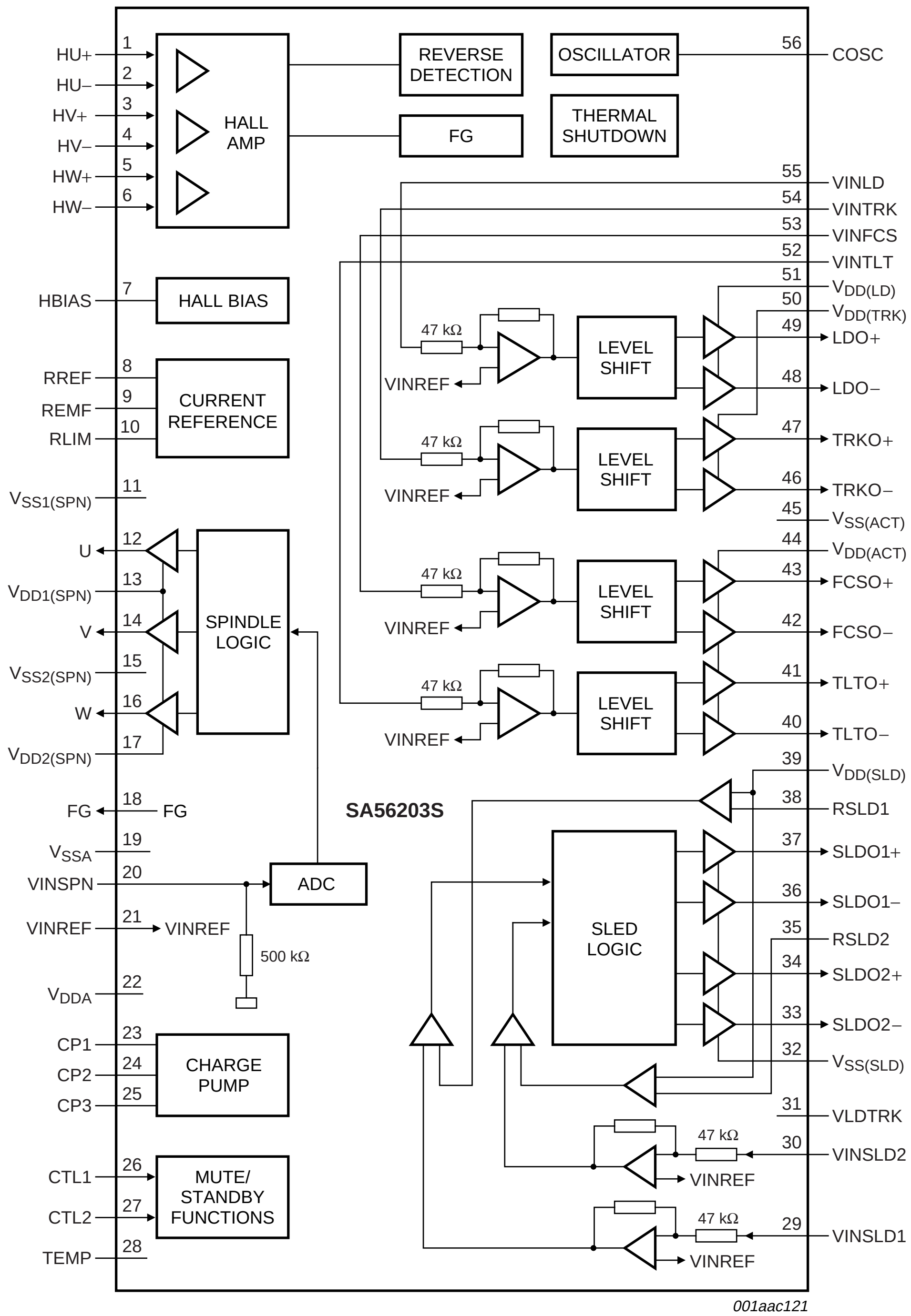



Fig 1. Block diagram

# 6. Pinning information

## 6.1 Pinning

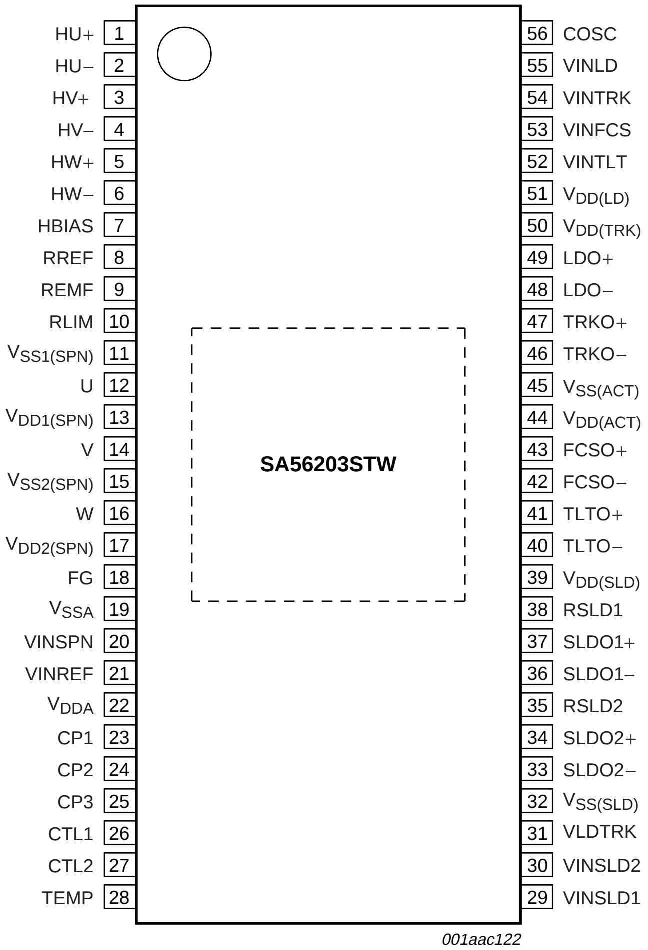



**Fig 2. Pin configuration**

## 6.2 Pin description

**Table 2: Pin description**

| Symbol | Pin | Description |
|---|---|---|
| HU+ | 1 | Hall input U positive |
| HU– | 2 | Hall input U negative |
| HV+ | 3 | Hall input V positive |
| HV– | 4 | Hall input V negative |
| HW+ | 5 | Hall input W positive |
| HW– | 6 | Hall input W negative |
| HBIAS | 7 | Hall element bias |
| RREF | 8 | external resistor for current reference |

**Table 2: Pin description** *...continued*

| Symbol | Pin | Description |
|---|---|---|
| REMF | 9 | external resistor for EMF regeneration |
| RLIM | 10 | external resistor for current limit |
| $V_{SS1(SPN)}$ | 11 | spindle driver ground 1 |
| U | 12 | spindle driver output U |
| $V_{DD1(SPN)}$ | 13 | spindle driver supply voltage 1 |
| V | 14 | spindle driver output V |
| $V_{SS2(SPN)}$ | 15 | spindle driver ground 2 |
| W | 16 | spindle driver output W |
| $V_{DD2(SPN)}$ | 17 | spindle driver supply voltage 2 |
| FG | 18 | frequency generator output |
| $V_{SSA}$ | 19 | analog ground |
| VINSPN | 20 | spindle driver input voltage for spindle motor current |
| VINREF | 21 | reference input voltage for all motor drivers |
| $V_{DDA}$ | 22 | analog supply voltage |
| CP1 | 23 | charge pump capacitor connection 1 |
| CP2 | 24 | charge pump capacitor connection 2 |
| CP3 | 25 | charge pump capacitor connection 3 |
| CTL1 | 26 | driver logic control input 1 |
| CTL2 | 27 | driver logic control input 2 |
| TEMP | 28 | thermal warning |
| VINSLD1 | 29 | sled driver 1 input for sled motor current |
| VINSLD2 | 30 | sled driver 2 input for sled motor current |
| VLDTRK | 31 | voltage output loader/track |
| $V_{SS(SLD)}$ | 32 | sled driver ground |
| SLDO2– | 33 | sled driver output 2 negative |
| SLDO2+ | 34 | sled driver output 2 positive |
| RSLD2 | 35 | sled driver 2 current sense |
| SLDO1– | 36 | sled driver output 1 negative |
| SLDO1+ | 37 | sled driver output 1 positive |
| RSLD1 | 38 | sled driver 1 current sense |
| $V_{DD(SLD)}$ | 39 | sled driver sense supply voltage |
| TLTO– | 40 | tilting driver output negative |
| TLTO+ | 41 | tilting driver output positive |
| FCSO– | 42 | focus driver output negative |
| FCSO+ | 43 | focus driver output positive |
| $V_{DD(ACT)}$ | 44 | focus/tilt drivers supply voltage |
| $V_{SS(ACT)}$ | 45 | actuator drivers ground |
| TRKO– | 46 | tracking driver output negative |
| TRKO+ | 47 | tracking driver output positive |
| LDO– | 48 | loading driver output negative |
| LDO+ | 49 | loading driver output positive |

**Table 2: Pin description** *...continued*

| Symbol | Pin | Description |
|---|---|---|
| $V_{DD(TRK)}$ | 50 | tracking driver supply voltage |
| $V_{DD(LD)}$ | 51 | loading driver supply voltage |
| VINTLT | 52 | tilting driver input for tilt actuator driver |
| VINFCS | 53 | focus driver input for focus actuator voltage |
| VINTRK | 54 | tracking driver input for tracking actuator voltage |
| VINLD | 55 | loading driver input for loading motor voltage |
| COSC | 56 | external capacitor for internal oscillator |

# 7. Functional description

## 7.1 Spindle motor control

The control input voltage on pin VINSPN is converted into a digital value by the ADC where the voltage on pin VINREF is the midpoint reference. The transconductance gain from input voltage $V_{VINSPN}$ to output motor current $I_{MOT}$ is:

$$g_{m(SPN)} = \frac{I_{MOT}}{(V_{VINSPN} - V_{VINREF})} = \frac{I_{LIM}}{V_{VINREF}}$$

where $I_{LIM}$ can be programmed by means of external resistor $R_{LIM}$. The motor current is described by Figure 3.

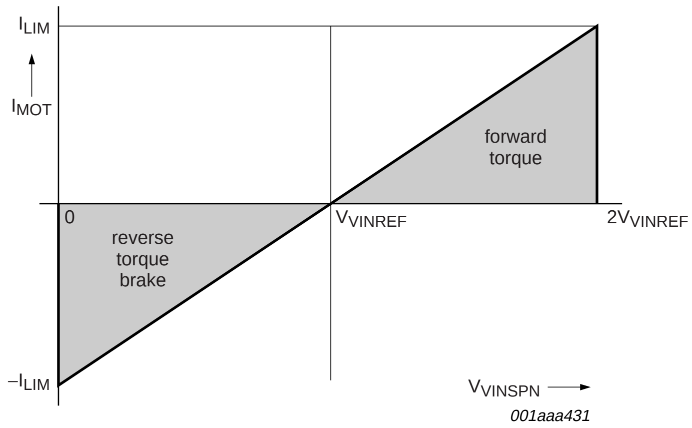



**Fig 3. Spindle motor current as a function of control input voltage VINSPN**

For VINSPN voltages larger than $V_{VINREF}$ the motor will accelerate with forward torque control. For VINSPN voltages smaller than $V_{VINREF}$ the motor will brake with reverse torque control.

## 7.2 Spindle brake

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. It should be noted that because of this active brake mechanism energy of the motor can be recuperated back to the supply. Especially at large speeds, this can result in currents delivered back to the supply.

If the supply and / or other circuits than the motor driver do not use this recuperated current, then the supply voltage can rise to unacceptable values. In this event it is recommended to lower the spindle current during brake by means of the VINSPN setting. The SA56203S has a clamp incorporated on the spindle driver supply voltage for protecting the IC against this overvoltage.

Upon detection of reverse rotation all U, V and W driver outputs are connected to $V_{DD(SPN)}$. This short brake prevents the motor from spinning backwards.

## 7.3 Internal regeneration 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 4).

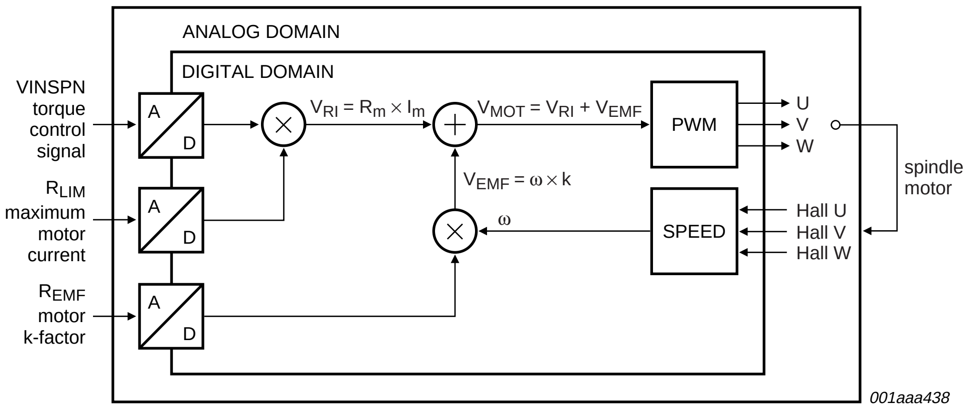



**Fig 4. Regeneration of back EMF voltage spindle motor**

Rotational speed $\omega$ is derived from the Hall event frequency. Multiplying $\omega$ with the k-factor of the motor gives the back EMF voltage $V_{EMF}$. This $V_{EMF}$ is added to the current-limited scaled spindle input voltage $V_{VINSPN}$. This sum $V_{MOT}$ steers the PWM outputs U, V and W. The result is that the input voltage $V_{VINSPN}$ represents the current through the motor. This explains how the SA56203S spindle motor driver exhibits a current control transfer function without using external sense resistors.

The simplified motor schematic in Figure 5 shows the series resistance and back EMF voltage of the motor.

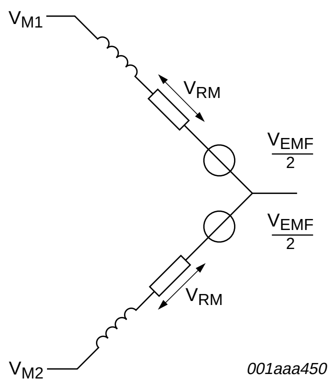



**Fig 5. Simplified spindle motor schematic**

Figure 6 shows the motor voltages $V_{M1}$ and $V_{M2}$ during accelerating and braking. The back EMF voltage is part of these motor voltages.

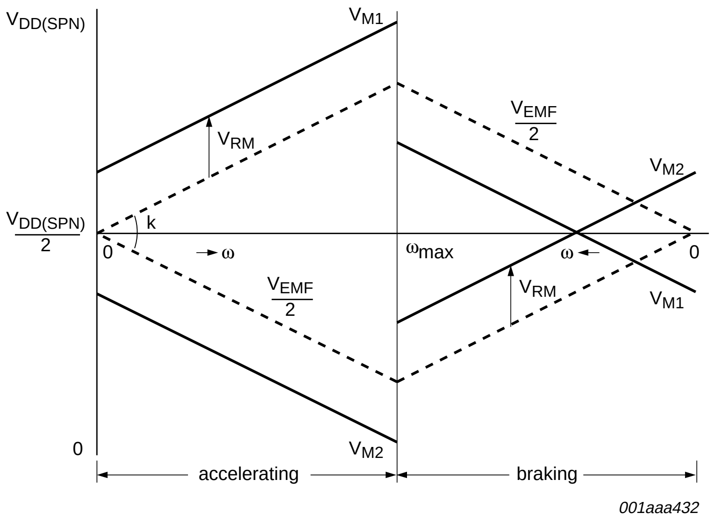



**Fig 6. Motor voltages when accelerating and braking with constant motor current**

## 7.4 Sine generation using True-Silent signals

For the phase relation between the Hall inputs and the spindle outputs in forward rotation, see Figure 7. These are the signal shapes in sine mode using our True-Silent PWM technology. The particular shape of the 120° symmetrical U, V and W steering voltages are because of improved drive strength and improved power efficiency. The drive strength is improved because with this signal shape a 15 % larger sine can be fit within the supply rails compared to direct-written sine signals. Also the power efficiency is improved because this signal shape has 33 % less switching losses compared to a direct-written sine.

The result is that the motor currents (and motor torques) are pure sine waves generated in such a way that the motor is driven optimally silent, optimally power efficient and with maximum driving strength.

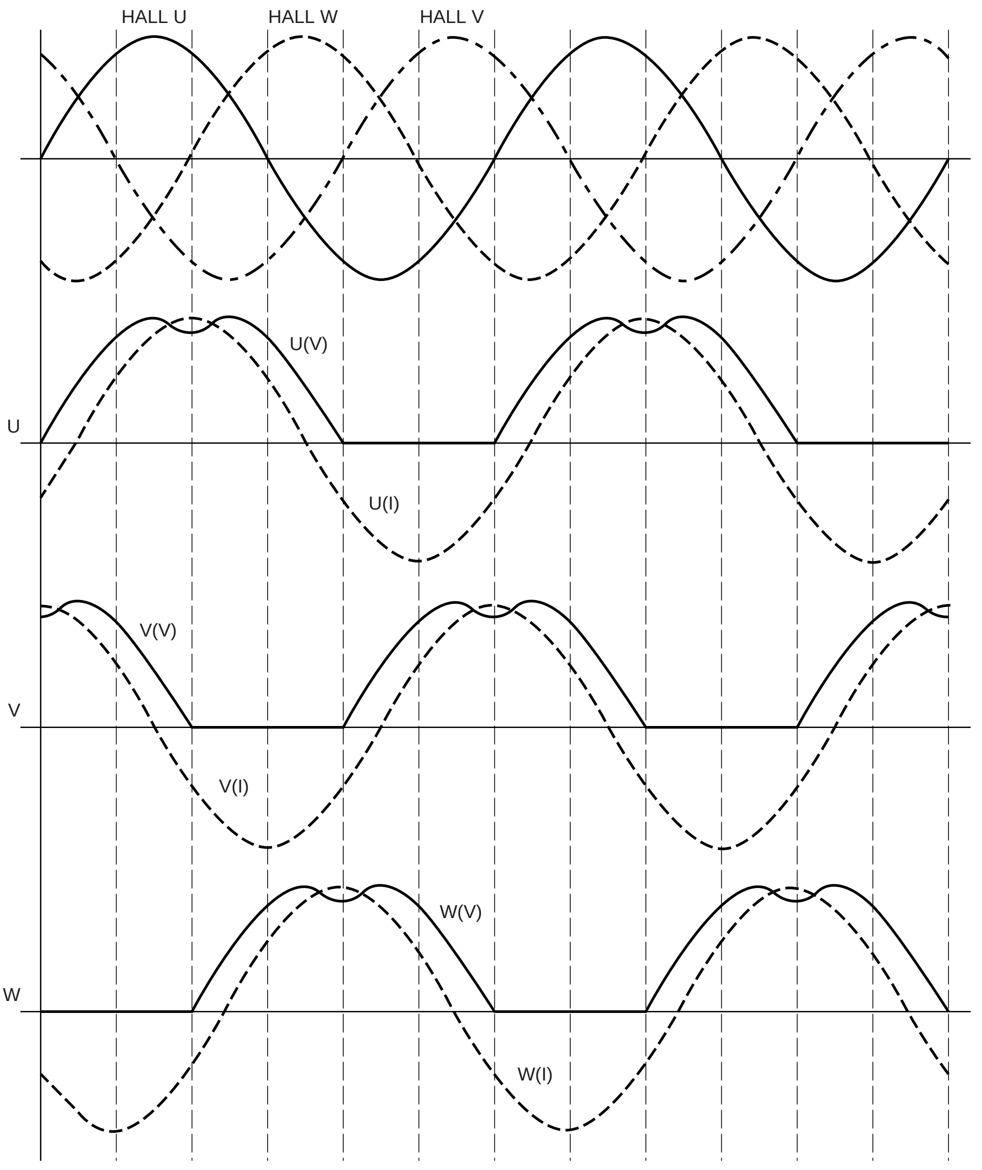



**Fig 7. Phase relation between Hall input signals and spindle motor driver output voltages U(V), V(V), W(V) and motor currents U(I), V(I), W(I) in forward rotation mode**

## 7.5 Programming $R_{LIM}$

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 $R_{LIM}$. In order to calculate the required $R_{LIM}$ first a typical maximum motor current $I_{MAX}$ needs to be determined:

$$I_{MAX} = \frac{V_{DD(SPN)}}{R_{motor} + R_{switches} + R_{wiring}}$$

$I_{LIM}$ can be chosen to be a fraction of this maximum current $I_{MAX}$. By making the ratio between $R_{LIM}$ and $R_{REF}$ this same fraction, $I_{LIM}$ is programmed as expressed in the following formula: $I_{LIM} = \frac{R_{LIM}}{R_{REF}} \times I_{MAX}$

Figure 8 shows the limit current as a function of $R_{LIM}$ with $R_{REF}$ = 47 kΩ.

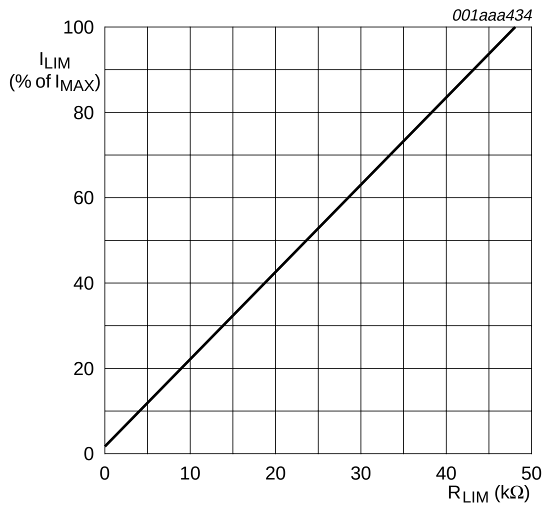



**Fig 8. Limit current $I_{LIM}$ as a function of external resistor $R_{LIM}$**

During accelerating and braking the motor current will not exceed $I_{LIM}$. $I_{LIM}$ also sets the transconductance gain, $g_m = \frac{I_{LIM}}{V_{VINREF}}$ of the spindle driver.

## 7.6 Programming $R_{EMF}$

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

$$R_{EMF} = \frac{k \times 2.6 \times 10^3 \times R_{REF}}{N_{PP} \times V_{DD(SPN)}}$$ with k in units Nm/A.

## 7.7 Frequency generator

The raw zero-crossings of the Hall sensors are first filtered and debounced before being passed to the Frequency generator (FG). The FG 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. The FG has an open-drain output for easy interfacing to 3 V and 5 V logic.

## 7.8 Sled 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 $V_{DD(SLD)}$. A peak-current control loop is implemented that modulates the duty cycle of the PWM signal (see Figure 9).

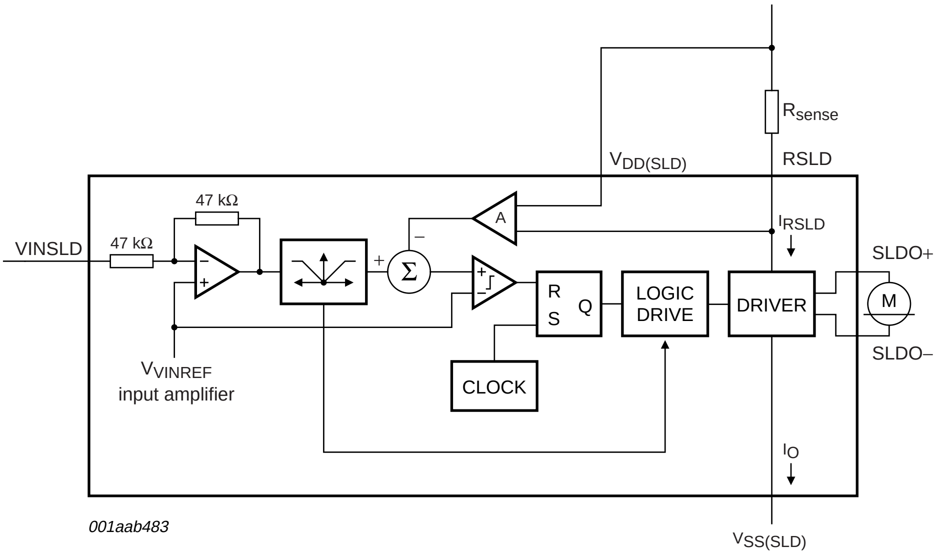



**Fig 9. Peak-current control architecture of sled motor driver**

The clock generator has a nominal frequency of $\frac{f_{osc}}{256} = 70$ kHz. See Figure 10, transfer function from input voltage $V_{VINSLD}$ to output current at a typical $R_{sense}$ of 0.5 Ω. Input-to-output transconductance gain can be scaled down by connecting external resistor $R_{ext}$ in series with the input VINSLD.

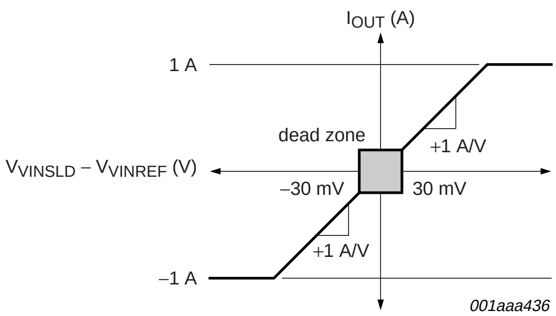



**Fig 10. Transfer function of sled motor driver**

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

Transconductance gain: $$g_m = \frac{I_o}{V_{in}} = \frac{1}{2 \times R_{sense}}$$

Limiting current: $I_{LIM} = \frac{1}{2 \times R_{sense}}$

## 7.9 Loading motor driver

One of the linear channels is available to drive a DC loading motor. Pin $V_{DD(LD)}$ is used to set the supply voltage for the loading motor driver. The following voltage-steering bridge topology is implemented in the SA56203S.

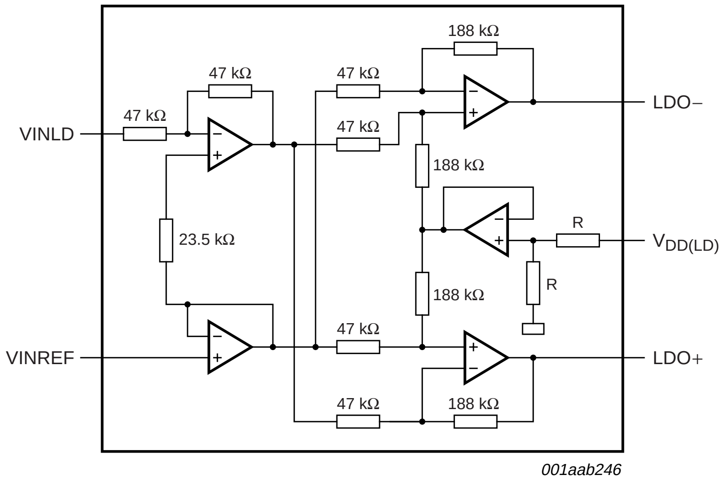



**Fig 11. Voltage steering bridge topology of linear driver**

## 7.10 Actuator motor drivers

Three linear channels are available to drive 3D actuators: focus, tracking and tilt. Pin $V_{DD(ACT)}$ is used to set the supply voltage for the focus and tilt actuators (maximum 5.5 V). A separate pin $V_{DD(TRK)}$ sets the supply voltage for the tracking actuator (maximum 14 V). The voltage-steering bridge topology is the same as depicted in Figure 11.

## 7.11 Charge pump

The on-board charge pump generates a voltage of typically 18.2 V by using the $V_{DD(SPN)}$ 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. Recommended values for the pump and hold capacitor are 10 nF and 22 nF respectively (see default settings). The charge pump should not be loaded with other components or circuitry other than these capacitors.

## 7.12 Thermal protection

If the junction temperature of the SA56203S exceeds 150 °C, then a thermal warning signal is given at pin TEMP. Pin TEMP has an active-LOW open-drain output for easy interfacing to the 3 V and 5 V 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 3-state. The temperature hysteresis for the thermal shutdown is 30 °C. As soon as the thermal shutdown deactivates at 130 °C, all motor drivers continue normal operation. At the same time the thermal warning signal is deactivated.

### 7.13 Oscillator

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

### 7.14 Muting Functions

Pins CTL1 and CTL2 are used to mute certain parts of the IC; see Table 3.

**Table 3: Muting functions [1]**

| CTL1 | CTL2 | Loading motor | Sled motor | Focus tilt | Tracking | Spindle motor | Special |
|---|---|---|---|---|---|---|---|
| L | L | off | off | off | off | off | standby |
| L | H | on | off | off | off | off | FG and Hall bias on; pin VLDTRK for loader motor |
| H | L | off | on | off | off | on | all actuators off; pin VLDTRK for tracking actuator |
| H | H | off | on | on | on | on | spindle, sled and all actuators on |

[1] Off equals 3-state.

## 8. Internal circuitry

**Table 4: Internal circuitry**

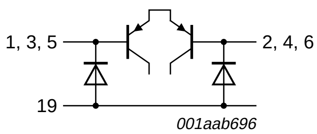
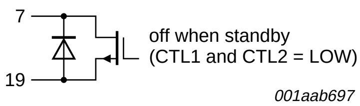
| Symbol | Pin | Equivalent circuit |
|---|---|---|
| **Hall amplifiers** | | |
| HU+ | 1 |  |
| HU– | 2 | |
| HV+ | 3 | |
| HV– | 4 | |
| HW+ | 5 | |
| HW– | 6 | |
| $V_{SSA}$ | 19 | |
| **Hall bias** | | |
| HBIAS | 7 |  |
| $V_{SSA}$ | 19 | |

**Table 4: Internal circuitry** *…continued*

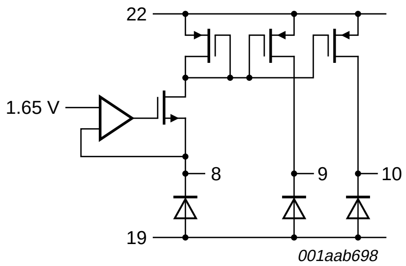
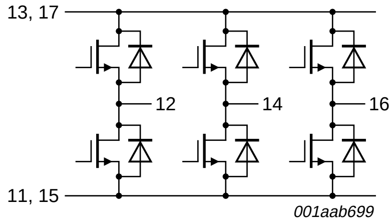
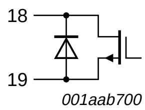
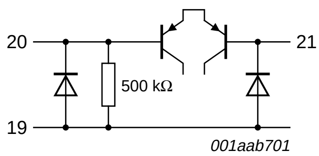
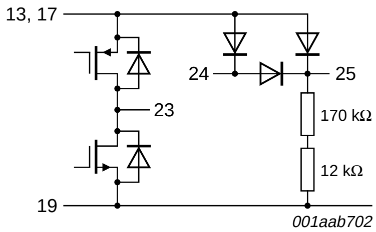
| Symbol | Pin | Equivalent circuit |
|---|---|---|
| **Current reference** | | |
| RREF | 8 |  |
| REMF | 9 | |
| RLIM | 10 | |
| $V_{SSA}$ | 19 | |
| $V_{DDA}$ | 22 | |
| **Spindle motor driver** | | |
| $V_{SS1(SPN)}$ | 11 |  |
| U | 12 | |
| $V_{DD1(SPN)}$ | 13 | |
| V | 14 | |
| $V_{SS2(SPN)}$ | 15 | |
| W | 16 | |
| $V_{DD2(SPN)}$ | 17 | |
| **Frequency generator** | | |
| FG | 18 |  |
| $V_{SSA}$ | 19 | |
| **Spindle input** | | |
| $V_{SSA}$ | 19 |  |
| VINSPN | 20 | |
| VINREF | 21 | |
| **Charge pump** | | |
| $V_{DD1(SPN)}$ | 13 |  |
| $V_{DD2(SPN)}$ | 17 | |
| $V_{SSA}$ | 19 | |
| CP1 | 23 | |
| CP2 | 24 | |
| CP3 | 25 | |

**Table 4: Internal circuitry** *...continued*

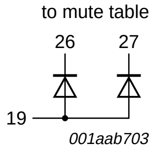
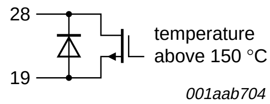
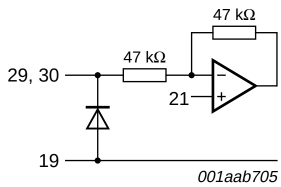
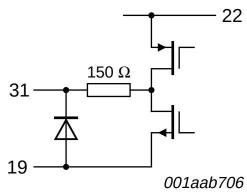
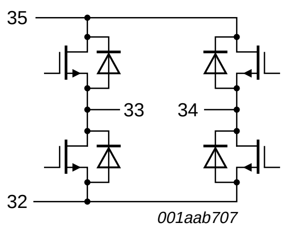
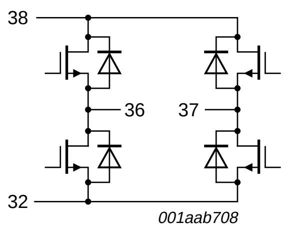
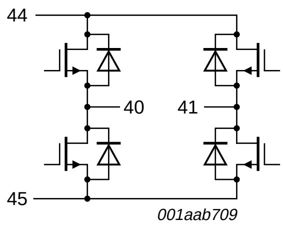
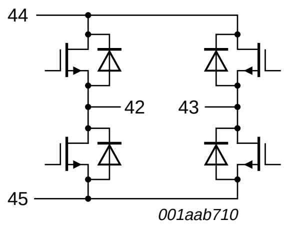
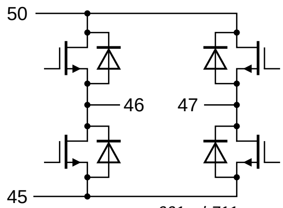
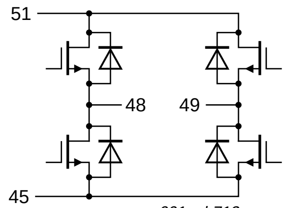
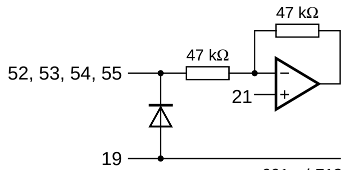
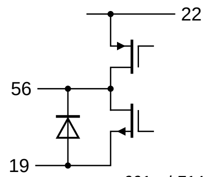
| Symbol | Pin | Equivalent circuit |
|---|---|---|
| **Control** | | |
| $V_{SSA}$ | 19 |  |
| CTL1 | 26 | |
| CTL2 | 27 | |
| **Temperature warning** | | |
| $V_{SSA}$ | 19 |  |
| TEMP | 28 | |
| **Sled inputs** | | |
| $V_{SSA}$ | 19 |  |
| VINREF | 21 | |
| VINSLD1 | 29 | |
| VINSLD2 | 30 | |
| **VLDTRK output** | | |
| $V_{SSA}$ | 19 |  |
| $V_{DDA}$ | 22 | |
| VLDTRK | 31 | |
| **Sled motor driver** | | |
| $V_{SS(SLD)}$ | 32 |   |
| SLDO2– | 33 | |
| SLDO2+ | 34 | |
| RSLD2 | 35 | |
| SLDO1– | 36 | |
| SLDO1+ | 37 | |
| RSLD1 | 38 | |
| **Linear motor drivers** | | |
| TLTO– | 40 |   |
| TLTO+ | 41 | |
| FCSO– | 42 | |
| FCSO+ | 43 | |
| $V_{DD(ACT)}$ | 44 | |
| $V_{SS(ACT)}$ | 45 | |

**Table 4: Internal circuitry** *...continued*

| Symbol | Pin | Equivalent circuit |
|---|---|---|
| $V_{SS(ACT)}$ | 45 |  001aab711  001aab712 |
| TRKO– | 46 | |
| TRKO+ | 47 | |
| LDO– | 48 | |
| LDO+ | 49 | |
| $V_{DD(TRK)}$ | 50 | |
| $V_{DD(LD)}$ | 51 | |
| **Linear inputs** | | |
| $V_{SSA}$ | 19 |  001aab713 |
| VINREF | 21 | |
| VINTLT | 52 | |
| VINFCS | 53 | |
| VINTRK | 54 | |
| VINLD | 55 | |
| **Oscillator** | | |
| $V_{SSA}$ | 19 |  001aab714 |
| $V_{DDA}$ | 22 | |
| COSC | 56 | |

## 9. Limiting values

**Table 5: Limiting values**

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

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_{DD1(SPN)}$, $V_{DD2(SPN)}$ | spindle driver supply voltage | | –0.5 | +16 | V |
| $V_{DD(SLD)}$ | sled driver sense supply | | –0.5 | +16 | V |
| $V_{DD(LD)}$ | loading driver supply voltage | | –0.5 | +16 | V |
| $V_{DD(TRK)}$ | tracking driver supply voltage | | –0.5 | +16 | V |
| $V_{DD(ACT)}$ | focus/tilt drivers supply voltage | | –0.5 | +6.5 | V |
| $V_{DDA}$ | analog supply voltage | | –0.5 | +6.5 | V |
| $T_{stg}$ | storage temperature | | –55 | +150 | °C |
| $T_{amb}$ | operating temperature range | | –40 | +85 | °C |
| $T_j$ | junction temperature | | –40 | +160 | °C |
| $I_{O(SPN)}$ | spindle output current, pins 12, 14 and 16 | | - | 2.1 | A |

**Table 5: Limiting values** *…continued*

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

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $I_{O(SLD)}$ | sled output current, pins 33, 34, 35, 36, 37 and 38 | | - | 1.2 | A |
| $I_{O(ACT)}$ | loading/actuator drivers output current, pins 40, 41, 42, 43, 46, 47, 48 and 49 | | - | 2.0 | A |
| $I_{Hall}$ | Hall current on pins 1, 2, 3, 4, 5 and 6 | | –1 | +1 | mA |
| $I_{HBIAS}$ | Hall bias current on pin HBIAS | | –1 | +100 | mA |
| $I_{RPROG}$ | current on external resistor pins 8, 9 and 10 | | –1 | +1 | mA |
| $I_{O(n)}$ | current on pins 18, 28 and 31 | | –1 | +10 | mA |
| $I_{DIG}$ | driver logic control current on pins 26 and 27 | | –1 | +1 | mA |
| $I_{CPUMP}$ | charge pump current on pins 23, 24 and 25 | | –20 | +20 | mA |
| $I_{STEER}$ | steering current on pins 20, 21, 29, 30, 52, 53, 54 and 55 | | –1 | +1 | mA |
| $I_{COSC}$ | current on pin COSC | | –20 | +20 | mA |
| $V_{esd}$ | electrostatic discharge voltage | | | | |
| | pins 23, 40 to 44 and 51 | human body model | - | 1000 | V |
| | | machine model | - | 100 | V |
| | all other pins | human body model | - | 2000 | V |
| | | machine model | - | 200 | V |

## 10. Recommended operating conditions

**Table 6: Recommended operating conditions**

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD1(SPN)}$, $V_{DD2(SPN)}$ | spindle driver supply voltage | $V_{DD1(SPN)} = V_{DD2(SPN)}$ | 4.5 | 12 | 14 | V |
| $V_{DDA}$ | analog supply voltage | | 4.5 | 5.0 | 5.5 | V |
| $V_{DD(SLD)}$ | sled driver sense supply | | 4.5 | 12 | 14 | V |
| $V_{DD(ACT)}$ | focus/tilt drivers supply voltage | | 4.5 | 5 | 5.5 | V |
| $V_{DD(TRK)}$ | tracking driver supply voltage | | 4.5 | 12 | 14 | V |
| $V_{DD(LD)}$ | loading driver supply voltage | | 4.5 | 12 | 14 | V |

# 11. Thermal characteristics

**Table 7: Thermal characteristics**

| Symbol | Parameter | Conditions | Typ | Unit |
|---|---|---|---|---|
| $R_{th(j-a)}$ | thermal resistance from junction to ambient | in free air; multilayer printed-circuit board | 33 | K/W |

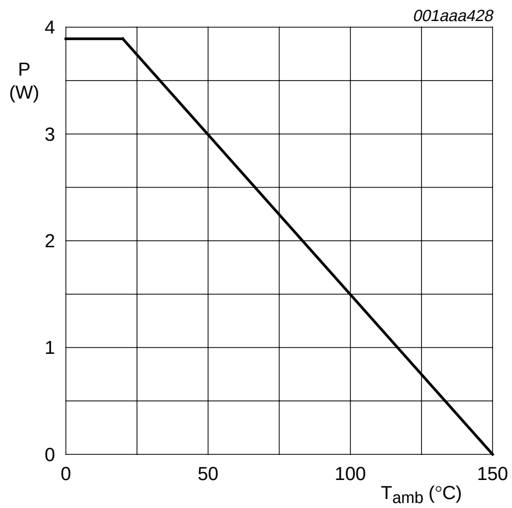



**Fig 12. Maximum power dissipation as a function of ambient temperature**

# 12. Characteristics

**Table 8: Characteristics**

*$V_{DDA}$ = 5 V; $V_{DD1(SPN)}$ = $V_{DD2(SPN)}$ = 12 V; $V_{DD(SLD)}$ = 12 V; $V_{DD(TRK)}$ = 12 V; $V_{DD(ACT)}$ = 5 V; $V_{DD(LD)}$ = 12 V; $T_{amb}$ = 25 °C; all characteristics are specified for the default settings (see Table 9); all voltages are referenced to $V_{SS}$; positive currents flow into the device; unless otherwise specified.*

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Supplies: pins $V_{DD1(SPN)}$, $V_{DD2(SPN)}$, $V_{DDA}$, $V_{DD(ACT)}$, $V_{DD(SLD)}$, $V_{DD(LD)}$, $V_{DD(TRK)}$** | | | | | | |
| $I_{DD(SPN)}$ | spindle driver supply current | $I_{DD1(SPN)} + I_{DD2(SPN)}$ | 2 | 3 | 5 | mA |
| $I_{DDA}$ | analog supply current | | 14 | 16 | 18 | mA |
| $I_{DD(SLD)}$ | sled driver supply current | | - | 1 | 1.5 | mA |
| $I_{DD(ACT)}$ | focus/tilt drivers supply current | | - | 19 | 26 | mA |
| $I_{DD(TRK)}$ | tracking driver supply current | | 2 | 4 | 6 | mA |
| $I_{DD(LD)}$ | loading driver supply current | CTL2 = H | 2 | 4 | 6 | mA |
| $I_{stb(tot)}$ | total standby current | CTL1 = CTL2 = L | - | 6 | 9 | mA |
| $V_{DDA(POR)}$ | power-on reset voltage on $V_{DDA}$ | | - | 3.5 | - | V |

**Table 8: Characteristics** *...continued*

*$V_{DDA}$ = 5 V; $V_{DD1(SPN)}$ = $V_{DD2(SPN)}$ = 12 V; $V_{DD(SLD)}$ = 12 V; $V_{DD(TRK)}$ = 12 V; $V_{DD(ACT)}$ = 5 V; $V_{DD(LD)}$ = 12 V; $T_{amb}$ = 25 °C; all characteristics are specified for the default settings (see Table 9); all voltages are referenced to $V_{SS}$; positive currents flow into the device; unless otherwise specified.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **Charge pump: pin CP3** | | | | | | | |
| $V_O$ | output voltage | | | - | 18.7 | - | V |
| **Spindle motor driver: pins HU+, HV+, HW+ HU–, HV–, HW–, HBIAS, RREF, REMF, RLIM, U, V, W FG, VINSPN, VINREF and COSC** | | | | | | | |
| $V_{IO}$ | input offset voltage Hall amplifier | $V_{HU-}$ = $V_{HV-}$ = $V_{HW-}$ = 1.65 V | [1] | –3.5 | - | +3.5 | mV |
| $V_i$ | input voltage range Hall amplifier | | | 0 | - | $V_{DDA}$ | V |
| $V_{HBIAS}$ | voltage on pin HBIAS | $I_{HBIAS}$ = 32 mA | | - | 0.6 | - | V |
| $f_{osc}$ | oscillator frequency on pin COSC | | | - | 18 | - | MHz |
| $f_{PWM}$ | PWM frequency on pins U, V and W | | | - | 70 | - | kHz |
| $R_{ds(on)}$ | D-MOSFET on-resistance (high or low) | I = 100 mA | | - | 0.35 | - | Ω |
| $V_{VINREF}$ | input voltage range on reference pin VINREF | | | 1.2 | 1.65 | 2.5 | V |
| $V_{VINSPN}$ | input voltage range on torque control pin VINSPN | | | 0 | - | $V_{DDA}$ | V |
| $I_U$, $I_V$, $I_W$ | spindle motor current limit | see Figure 3; $R_{switches}$ + $R_{motor}$ + $R_{wiring}$ = 2.5 Ω; $V_{VINSPN}$ = 0 V and 3.3 V | [2] | - | 2.0 | - | A |
| $g_{m(SPN)}$ | transconductance gain spindle | see Figure 3; $R_{switches}$ + $R_{motor}$ + $R_{wiring}$= 2.5 Ω; $V_{VINSPN}$ = 0 V and 3.3 V | [3] | - | 1.24 | - | A/V |
| **Sled motor driver: pins RSLD1, SLDO1+, SLDO1–, RSLD2, SLDO2+, SLDO2–, VINSLD2 and VINSLD1** | | | | | | | |
| $I_{SLDO}$ | motor current limit | $R_{sense}$ = 0.5 Ω; $V_{VINSLD}$ = 0 V and 3.3 V | | - | 1.0 | - | A |
| $f_{PWM}$ | PWM frequency on pins SLDO1+, SLDO1–, SLDO2+ and SLDO2– | | | - | 70 | - | kHz |
| $V_{i(trip)}$ | input dead zone trip level | | [4] | 15 | 30 | 45 | mV |
| $g_m$ | transconductance gain | | [4] [5] | 0.60 | 0.75 | 0.90 | A/V |
| $R_{ds(on)}$ | D-MOSFET on-resistance (high or low) | I = 100 mA; $V_{VINSLD}$ = 0 V and 3.3 V | | - | 1.0 | - | Ω |
| **Loading motor driver: pins VINLD, LDO+ and LDO–** | | | | | | | |
| $I_{LDO}$ | current limit (high or low) | CTL1 = L; $R_L$ = 4 Ω; $V_{VINLD}$ = 0 V and 3.3 V | | 0.85 | 1.0 | 1.5 | A |
| $V_{OO}$ | output offset voltage | CTL1 = L; no load | | –100 | 0 | +100 | mV |
| $G_V$ | voltage gain | CTL1 = L; no load | [6] | 17.2 | 18.0 | 18.8 | dB |
| $R_{ds(on)}$ | D-MOSFET on-resistance (high or low) | CTL1 = L; I = 100 mA; $V_{VINLD}$ = 0 V and 3.3 V | | - | 0.7 | 1.0 | Ω |

**Table 8: Characteristics** *...continued*

*$V_{DDA}$ = 5 V; $V_{DD1(SPN)}$ = $V_{DD2(SPN)}$ = 12 V; $V_{DD(SLD)}$ = 12 V; $V_{DD(TRK)}$ = 12 V; $V_{DD(ACT)}$ = 5 V; $V_{DD(LD)}$ = 12 V; $T_{amb}$ = 25 °C; all characteristics are specified for the default settings (see Table 9); all voltages are referenced to $V_{SS}$; positive currents flow into the device; unless otherwise specified.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **Tracking actuator driver: pins VINTRK, TRKO+ and TRKO–** | | | | | | | |
| $I_{TRKO}$ | current limit | $R_L$ = 4 Ω; $V_{VINTRK}$ = 0 V and 3.3 V | | 1.0 | 1.5 | 2.0 | A |
| $V_{OO}$ | output offset voltage | no load | | –70 | 0 | +70 | mV |
| $G_V$ | voltage gain tracking driver | | [7] | 17.2 | 18.0 | 18.8 | dB |
| $R_{ds(on)}$ | D-MOSFET on-resistance (high or low) | I = 100 mA; $V_{VINTRK}$ = 0 V or 3.3 V | | - | 0.7 | 1.0 | Ω |
| **Focus and tilt actuator drivers: pins VINFCS, VINTLT, FCSO+, FCSO–, TLTO+ and TLTO–** | | | | | | | |
| $I_{FCSO}$, $I_{TLTO}$ | current limit | $R_L$ = 4 Ω; $V_{VINFCS}$ = 0 V or 3.3 V; $V_{VINTLT}$ = 0 V or 3.3 V | | 1.0 | 1.5 | 2.0 | A |
| $V_{OO}$ | output offset voltage | no load | | –55 | 0 | +55 | mV |
| $G_V$ | voltage gain focus/tilt drivers | | [7] | 11.2 | 12 | 12.8 | dB |
| $G_{v(m)}$ | gain mismatch between focus and tilt drivers | | [8] | 0 | - | 5 | % |
| $R_{ds(on)}$ | MOSFET on-resistance (high or low) | I = 100 mA; $V_{VINFCS}$ = 0 V or 3.3 V; $V_{VINTLT}$ = 0 V or 3.3 V | | - | 0.6 | 0.9 | Ω |
| **Voltage output loader/tracking actuator: pin VLDTRK** | | | | | | | |
| $G_R$ | transresistance gain of current loading motor | CTL1 = L; $I_{LDO}$ = 250 mA; $R_L$ = 4 Ω | | 1.3 | 1.5 | 1.7 | V/A |
| $V_{OO}$ | output offset transresistance amplifier | CTL1 = L; no load | | –100 | 0 | +100 | mV |
| $G_V$ | voltage gain of back EMF voltage tracking actuator | CTL2 = L | [9] | 29.2 | 30.0 | 30.8 | dB |
| $V_{OO}$ | output offset back EMF amplifier | CTL2 = L; $R_L$ = 4 Ω | | –250 | 0 | +250 | mV |
| $V_{O(CM)}$ | common mode output voltage | | | - | $V_{VINREF}$ | - | V |
| $R_O$ | output resistance | I = 0.1 mA | | - | 150 | - | Ω |
| $I_{O(source/sink)}$ | source and sink current drive capability | | | - | - | 0.3 | mA |
| **Digital inputs and outputs** | | | | | | | |
| Inputs: pins CTL1 and CTL2 | | | | | | | |
| $V_{IH}$ | HIGH-level input voltage | | | 2.0 | - | - | V |
| $V_{IL}$ | LOW-level input voltage | | | - | - | 0.8 | V |
| Outputs: pins FG and TEMP | | | | | | | |
| $V_{OL}$ | LOW-level output voltage | I = 2 mA | | - | - | 0.5 | V |

**Table 8: Characteristics** *...continued*

*$V_{DDA}$ = 5 V; $V_{DD1(SPN)}$ = $V_{DD2(SPN)}$ = 12 V; $V_{DD(SLD)}$ = 12 V; $V_{DD(TRK)}$ = 12 V; $V_{DD(ACT)}$ = 5 V; $V_{DD(LD)}$ = 12 V; $T_{amb}$ = 25 °C; all characteristics are specified for the default settings (see Table 9); all voltages are referenced to $V_{SS}$; positive currents flow into the device; unless otherwise specified.*

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Temperature protection: pin TEMP** | | | | | | |
| $T_{TEMP}$ | thermal warning temperature | | - | 150 | - | °C |
| $T_{hys(TEMP)}$ | thermal warning hysteresis | | - | 20 | - | °C |
| $T_{SD}$ | thermal shutdown temperature | | - | 160 | - | °C |
| $T_{hys(SD)}$ | thermal shutdown hysteresis | | - | 30 | - | °C |

[1] The recommended minimum Hall amplifier differential input voltage is 25 mV (p-p).

[2] The motor current limit of the spindle is tested by applying VINSPN = 0 V and 3.3 V, measuring the duty cycles on the U, V and W spindle driver outputs and calculating the corresponding motor currents with the applied 12 V supply voltage and the 2.5 Ω motor, switches and wiring resistance.

[3] The transconductance gain of the spindle is tested by applying VINSPN = 0 V and 3.3 V and calculating the corresponding motor currents (see Table note 2) and determining the slope (see Figure 3).

[4] The sled motor is tested loaded with $R_L$ = 4 Ω in series with $L_L$ = 1 mH.

[5] The transconductance gain of the sled motor driver is tested as:
$g_m = \{(I_{SLDO-} \text{ at } V_{VINSLD} = 1.85\text{ V}) - (I_{SLDO-} \text{ at } V_{VINSLD} = 1.45\text{ V})\}/0.4\text{ V}$.

[6] The voltage gain of the loading motor driver is tested as:
$G_V = \{(V_{LDO+} - V_{LDO-} \text{ at } V_{VINLD} = 2.4\text{ V}) - (V_{LDO+} - V_{LDO-} \text{ at } V_{VINLD} = 0.9\text{ V})\}/1.5\text{ V}$.

[7] The voltage gain of the actuator driver is tested as:
$G_V = \{(V_{ACTO+} - V_{ACTO-} \text{ at } V_{VINACT} = 2.4\text{ V}) - (V_{ACTO+} - V_{ACTO-} \text{ at } V_{VINACT} = 0.9\text{ V})\}/1.5\text{ V}$.

[8] The gain mismatch is related to the absolute gain; an absolute gain of 8 (18 dB) corresponds with a maximum mismatch of 0.4 (5 %) and an absolute gain of 4 (12 dB) corresponds with a maximum mismatch of 0.2 (5 %).

[9] The voltage gain of the back EMF voltage tracking actuator is tested as:
$G_V = \{(V_{VLDTRK} \text{ at } V_{TRKO+} = 1.03\text{ V and } V_{TRKO-} = 1.00\text{ V}) - (V_{VLDTRK} \text{ at } V_{TRKO+} = 1.00\text{ V and } V_{TRKO-} = 1.03\text{ V})\}/0.06\text{ V}$.

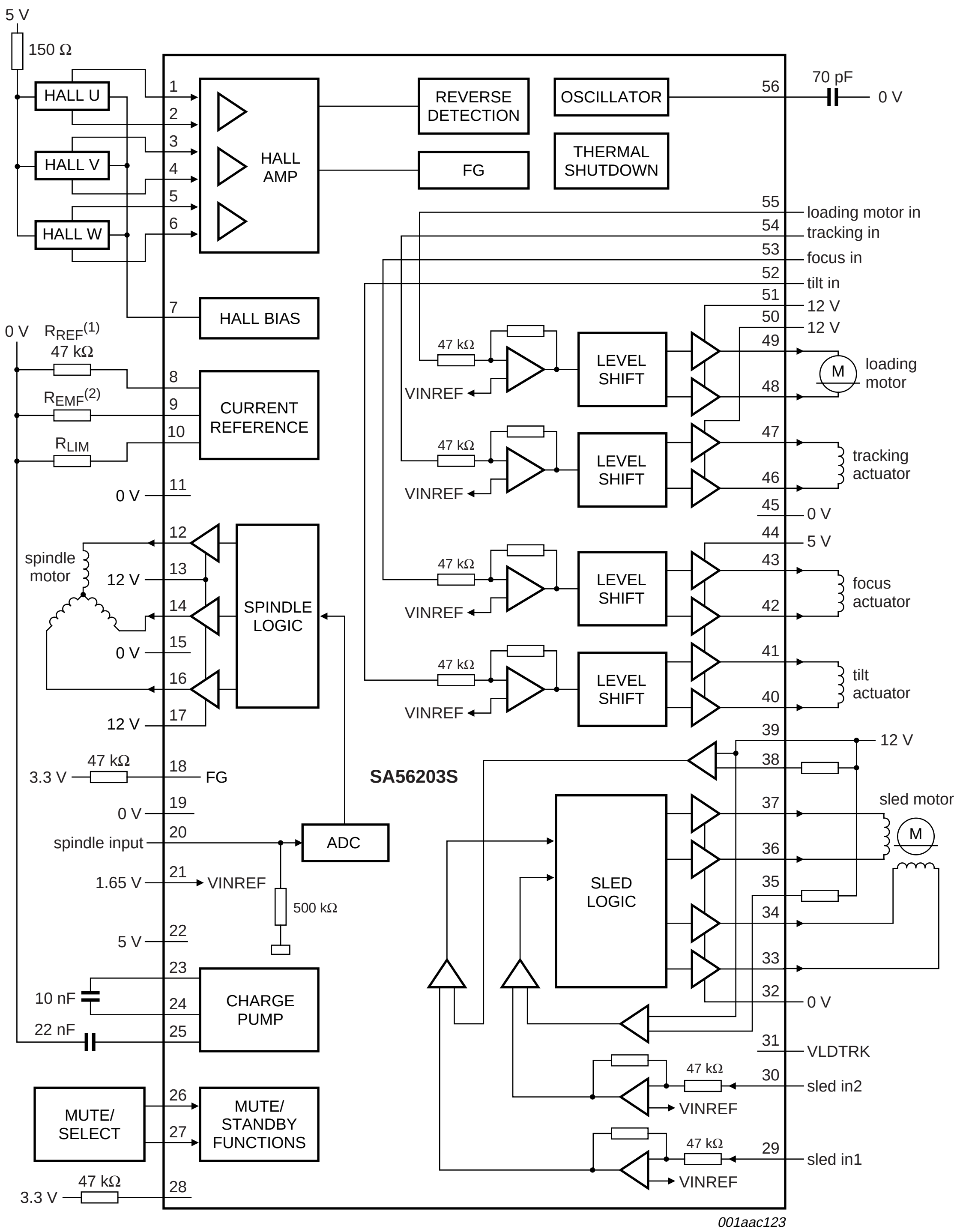
**Table 9: Default settings**

| Pin | Default setting |
|---|---|
| HU+, HV+ | 5 V |
| HW+ | ground |
| HU–, HV–, HW– | 1.650 V |
| HBIAS | open-circuit |
| RREF | 47 kΩ to $V_{SS}$, fixed value, should not be changed |
| REMF | 12 kΩ to $V_{SS}$ |
| RLIM | 20 kΩ to $V_{SS}$ |
| $V_{SS1(SPN)}$, $V_{SS2(SPN)}$ | ground |
| U, V, W | open-circuit |
| $V_{DD1(SPN)}$, $V_{DD2(SPN)}$ | 12 V supply |
| FG | open-circuit |
| $V_{SSA}$ | ground |
| VINSPN, VINREF | 1.65 V |
| $V_{DDA}$ | 5 V supply |

**Table 9: Default settings** *…continued*

| Pin | Default setting |
|---|---|
| CP1, CP2 | 10 nF between CP1 and CP2 |
| CP3 | 22 nF to ground |
| CTL1, CTL2 | 5 V |
| TEMP | open-circuit |
| COSC | 70 pF to ground, fixed value, should not be changed |
| VINLD, VINTRK, VINFCS, VINTLT | 1.65 V |
| $V_{DD(LD)}$, $V_{DD(TRK)}$ | 12 V supply |
| LDO+, LDO–, TRKO+, TRKO– | open-circuit |
| $V_{SS(ACT)}$ | ground |
| $V_{DD(ACT)}$ | 5 V supply |
| FCSO+, FCSO–, TLTO+, TLTO– | open-circuit |
| $V_{DD(SLD)}$ | 12 V supply |
| RSLD1 | 0.5 Ω sense resistor to $V_{DD(SLD)}$ |
| SLDO1+, SLDO1– | open-circuit |
| RSLD2 | 0.5 Ω sense resistor to $V_{DD(SLD)}$ |
| SLDO2+, SLDO2– | open-circuit |
| $V_{SS(SLD)}$ | ground |
| VLDTRK | open-circuit |
| VINSLD2, VINSLD1 | 1.65 V |

## 13. Application information




(1) For $R_{EMF}$ values see Section 7.6.

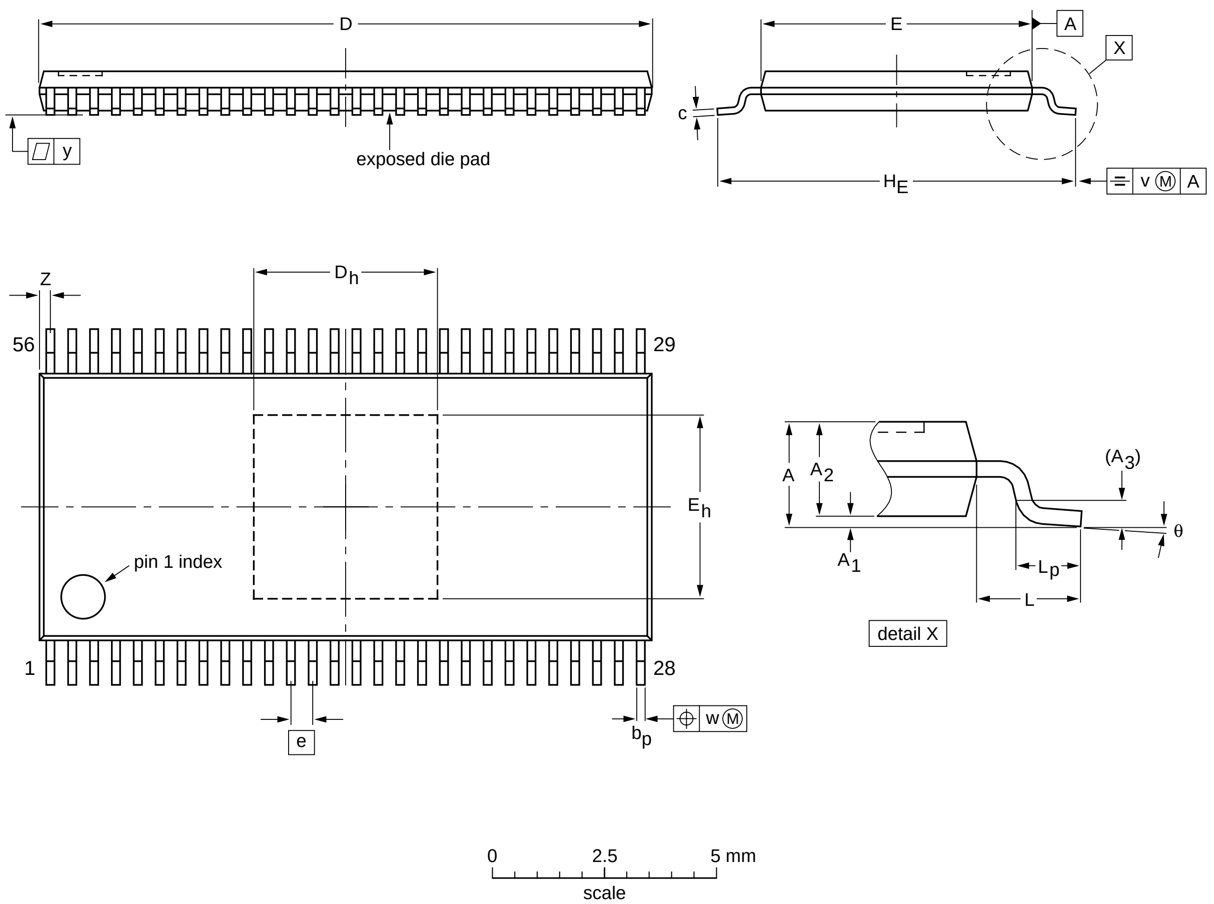
(2) For $R_{LIM}$ values see Section 7.5.

**Fig 13. Application diagram**

## 14. Package outline

**HTSSOP56: plastic thermal enhanced thin shrink small outline package; 56 leads; body width 6.1 mm; exposed die pad**

**SOT793-1**




**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(1) | θ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 1.2 | 0.15<br>0.05 | 1.05<br>0.80 | 0.25 | 0.27<br>0.17 | 0.20<br>0.09 | 14.1<br>13.9 | 4.3<br>4.1 | 6.2<br>6.0 | 4.3<br>4.1 | 0.5 | 8.3<br>7.9 | 1 | 0.8<br>0.4 | 0.2 | 0.08 | 0.1 | 0.4<br>0.1 | $8^o$<br>$0^o$ |

**Notes**

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 | | | | 03-03-04 |

**Fig 14. Package outline SOT793-1 (HTSSOP56)**

# 15. Soldering

## 15.1 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 can still be used for certain surface mount ICs, but it is not suitable for fine pitch SMDs. In these situations reflow soldering is recommended.

## 15.2 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. Driven by legislation and environmental forces the worldwide use of lead-free solder pastes is increasing.

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

Typical reflow peak temperatures range from 215 °C to 270 °C depending on solder paste material. The top-surface temperature of the packages should preferably be kept:

- below 225 °C (SnPb process) or below 245 °C (Pb-free process)
  - for all BGA, HTSSON..T and SSOP..T packages
  - for packages with a thickness ≥ 2.5 mm
  - for packages with a thickness < 2.5 mm and a volume ≥ 350 mm$^3$ so called thick/large packages.
- below 240 °C (SnPb process) or below 260 °C (Pb-free process) for packages with a thickness < 2.5 mm and a volume < 350 mm$^3$ so called small/thin packages.

Moisture sensitivity precautions, as indicated on packing, must be respected at all times.

## 15.3 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 of the leads in the wave ranges from 3 seconds to 4 seconds at 250 °C or 265 °C, depending on solder material applied, SnPb or Pb-free respectively.

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

## 15.4 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 seconds to 5 seconds between 270 °C and 320 °C.

## 15.5 Package related soldering information

**Table 10: Suitability of surface mount IC packages for wave and reflow soldering methods**

| Package [1] | Soldering method | |
|---|---|---|
| | Wave | Reflow [2] |
| BGA, HTSSON..T [3], LBGA, LFBGA, SQFP, SSOP..T [3], TFBGA, VFBGA, XSON | not suitable | suitable |
| DHVQFN, HBCC, HBGA, HLQFP, HSO, HSOP, HSQFP, HSSON, HTQFP, HTSSOP, HVQFN, HVSON, SMS | not suitable [4] | suitable |
| PLCC [5], SO, SOJ | suitable | suitable |
| LQFP, QFP, TQFP | not recommended [5] [6] | suitable |
| SSOP, TSSOP, VSO, VSSOP | not recommended [7] | suitable |
| CWQCCN..L [8], PMFP [9], WQCCN..L [8] | not suitable | not suitable |

[1] For more detailed information on the BGA packages refer to the *(LF)BGA Application Note* (AN01026); order a copy from your Philips Semiconductors sales office.

[2] 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*.

[3] These transparent plastic packages are extremely sensitive to reflow soldering conditions and must on no account be processed through more than one soldering cycle or subjected to infrared reflow soldering with peak temperature exceeding 217 °C ± 10 °C measured in the atmosphere of the reflow oven. The package body peak temperature must be kept as low as possible.

[4] These packages are not suitable for wave soldering. On versions with the heatsink on the bottom side, the solder cannot penetrate between the printed-circuit board and the heatsink. On versions with the heatsink on the top side, the solder might be deposited on the heatsink surface.

[5] 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.

[6] Wave soldering is suitable for LQFP, QFP and TQFP packages with a pitch (e) larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.

[7] Wave soldering is suitable for SSOP, TSSOP, VSO and VSSOP 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.

[8] Image sensor packages in principle should not be soldered. They are mounted in sockets or delivered pre-mounted on flex foil. However, the image sensor package can be mounted by the client on a flex foil by using a hot bar soldering process. The appropriate soldering profile can be provided on request.

[9] Hot bar soldering or manual soldering is suitable for PMFP packages.

## 16. Revision history

**Table 11: Revision history**

| Document ID | Release date | Data sheet status | Change notice | Doc. number | Supersedes |
|---|---|---|---|---|---|
| SA56203S_1 | 20050131 | Preliminary data sheet | - | 9397 750 14192 | - |

## 17. Data sheet status

| Level | Data sheet status [1] | Product status [2] [3] | Definition |
|---|---|---|---|
| I | Objective data | Development | This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice. |
| II | Preliminary data | Qualification | This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product. |
| III | Product data | Production | This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN). |

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

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL http://www.semiconductors.philips.com.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

## 18. 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.

**Application information —** Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

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## 20. Contact information

For additional information, please visit: **http://www.semiconductors.philips.com**

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## 21. Contents





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