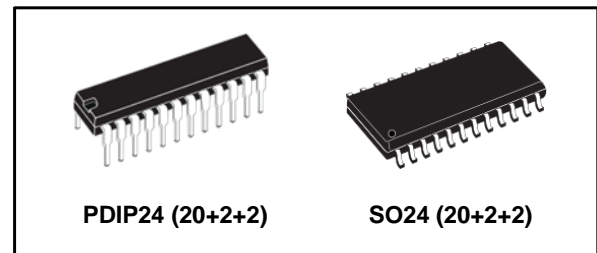# Stepper Motor Driver

## Feature

- Able to drive both windings of bipolar stepper motor
- Output current up to 750 mA each winding
- Wide voltage range: 10 V to 46 V
- Half-step, full-step and micro-stepping mode
- Built-in protection diodes
- Internal PWM current control
- Low output saturation voltage
- Designed for unstabilized motor supply voltage
- Internal thermal shutdown

**PDIP24 (20+2+2)**     **SO24 (20+2+2)**

## Description

The TB6219 is a bipolar monolithic integrated circuits intended to control and drive both winding of a bipolar stepper motor or bidirectionally control two DC motors.

The TB6219 with a few external components form a complete control and drive circuit for LS-TTL or microprocessor controlled stepper motor system. The power stage is a dual full bridge capable of sustaining 46V and including four diodes for current recirculation.

A cross conduction protection is provided to avoid simultaneous cross conduction during switching current direction.
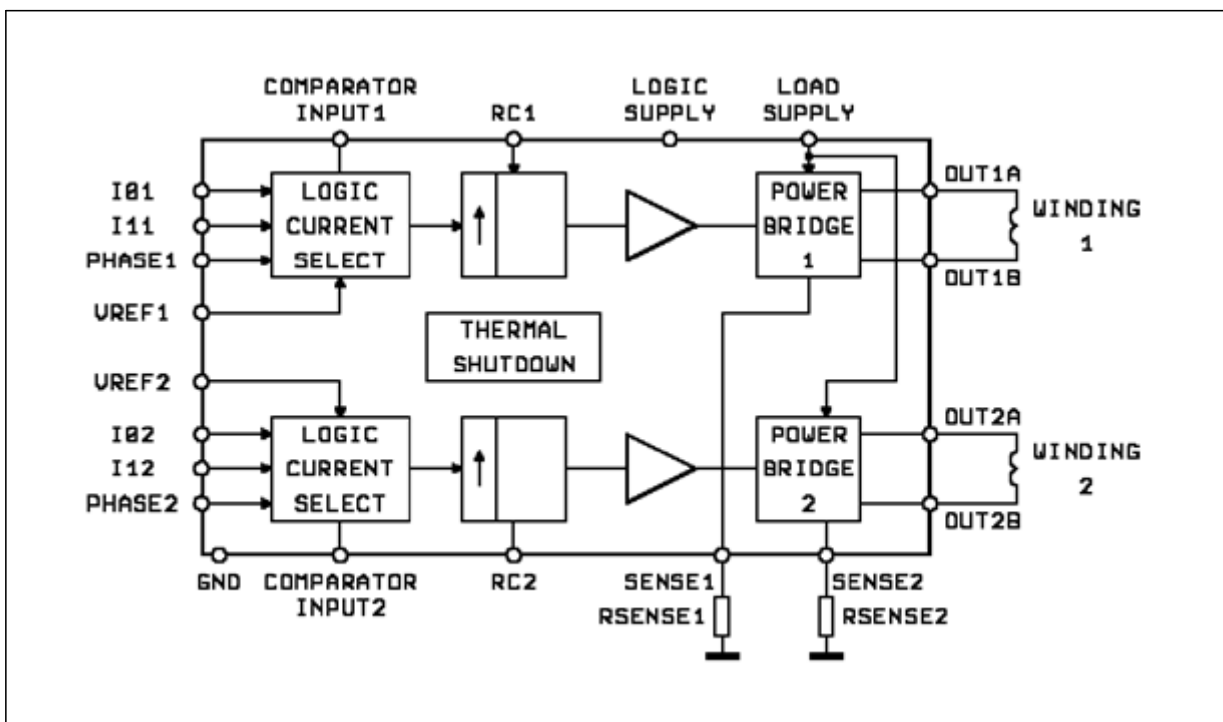
An internal pulse-width-modulation (PWM) controls the output current to 750 mA with peak startup current up to 1 A. Wide range of current control from 750 mA (each bridge) is permitted by means of two logic inputs and an external voltage reference. A phase input to each bridge determines the load current direction. A thermal protection circuitry disables the outputs if the chip temperature exceeds safe operating limits.

## Block diagram

## Absolute maximum rating

| Parameter | Description | Value | Unit |
|---|---|---|---|
| $V_S$ | Supply voltage | 50 | V |
| $I_O$ | Output current (peak) | ±1 | A |
| $I_O$ | Output current (continuous) | ±0.75 | A |
| $V_{SS}$ | Logic supply voltage | 7 | V |
| $V_{in}$ | Logic input voltage range | -0.3 to +7 | V |
| $V_{sense}$ | Sense output voltage | 1.5 | V |
| $T_j$ | Junction temperature | +150 | °C |
| $T_{op}$ | Operating temperature range | -20 to +85 | °C |
| $T_{stg}$ | Storage temperature range | -55 to +150 | °C |

## Pin connection (top view)
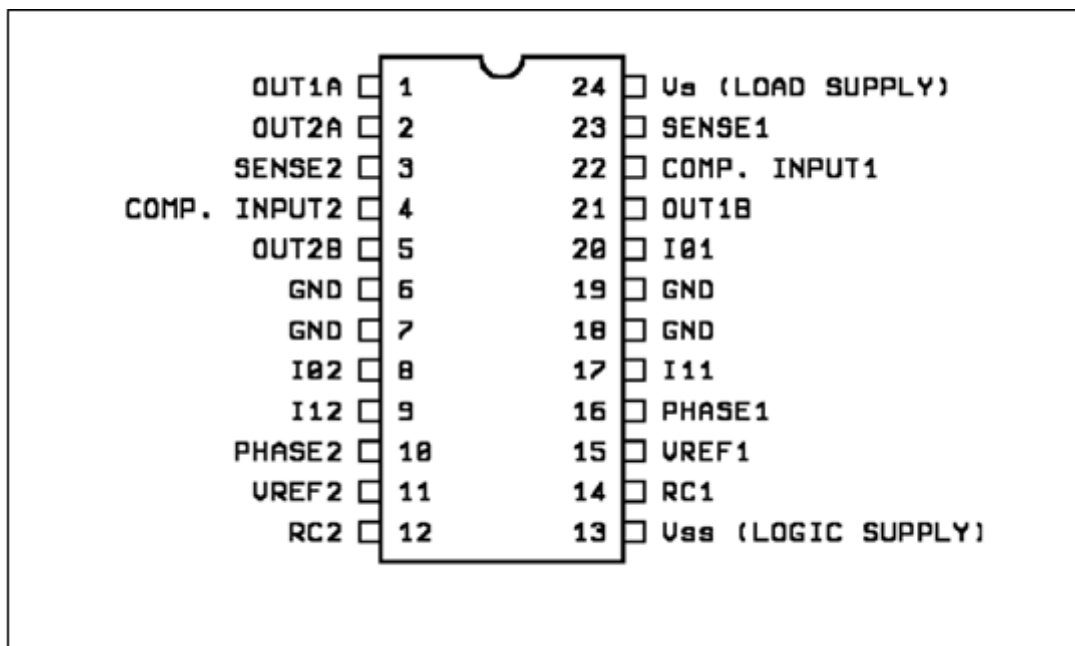


## Thermal data

| Parameter | Description | | PDIP | SO | Unit |
|---|---|---|---|---|---|
| $R_{thj-case}$ | Thermal resistance junction-case | Max. | 14 | 18 | °C/W |
| $R_{thj-amb}$ | Thermal resistance junction-ambient | Max. | 60[1] | 75[1] | °C/W |

1. With minimized copper area.

## Pin functions

| Pin # | Name | Description |
|-------|------|-------------|
| 1, 2 | Output A | See pins 5, 21 |
| 3, 23 | Sense resistor | Connection to lower emitters of output stage for insertion of current sense resistor |
| 4, 22 | Comparator input | Input connected to the comparators. The voltage across the sense resistor is feedback to this input throught the low pass filter RC CC. The higher power transistors are disabled when the sense voltage exceeds the reference voltage of the selected comparator. When this occurs the current decays for a time set by RT CT ($t_{off}$ = 1.1 RT CT). See Figure 1 |
| 5, 21 | Output B | Output connection. The output stage is a H bridge formed by four transistors and four diodes suitable for switching applications |
| 6, 19 | Ground | See pins 7, 18 |
| 7, 18 | Ground | Ground connection With pins 6 and 19 also conducts heat from die to printed circuit copper |
| 8, 20 | Input 0 | See Input 1 (pins 9, 17) |
| 9, 17 | Input 1 | These pins and pins 8, 20 (input 0) are logic inputs which select the outputs of the comparators to set the current level. Current also depends on the sensing resistor and reference voltage. See functional description |
| 10, 16 | Phase | This TTL-compatible logic inputs sets the direction of current flow through the load. A high level causes current to flow from output A (source) to output B (sink). A schmitt trigger on this input provides good noise immunity and a delay circuit prevents output stage short circuits during switching |
| 11, 15 | Reference voltage | A voltage applied to this pin sets the reference voltage of the comparators, this determining the output current (also thus depending on Rs and the two inputs input 0 and input 1) |
| 12, 14 | RC | A parallel RC network connected to this pin sets the OFF time of the higher power transistors. The pulse generator is a monostable triggered by the output of the comparators ($t_{off}$ = 1.1 RT CT) |

## Pin functions (continued)

| Pin # | Name | Description |
|-------|------|-------------|
| 13 | $V_{SS}$ - Logic supply | Supply voltage input for logic circuitry |
| 24 | $V_S$ - Load supply | Supply voltage input for the output stages |

*Note:* *ESD on GND, V$_S$, V$_{SS}$, OUT 1A and OUT 2A is guaranteed up to 1.5 KV (human body model, 1500 W, 100 pF).*

## Figure 1. Timing diagram
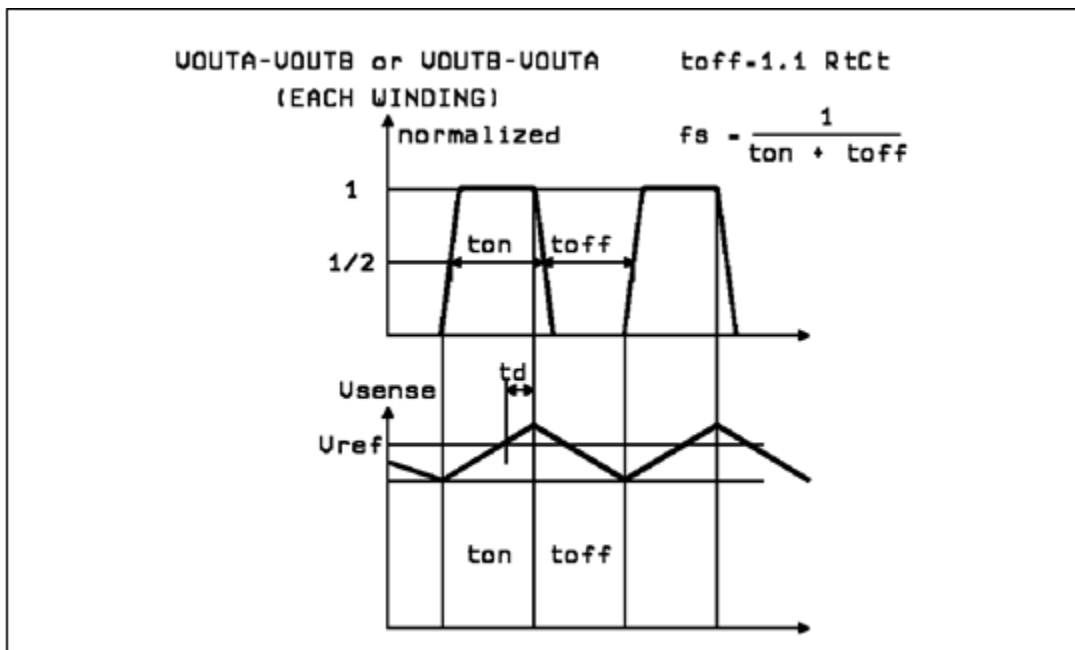
## Electrical characteristics

($T_j$ = 25 °C, $V_S$ = 46 V, $V_{SS}$ = 4.75 V to 5.25 V, $V_{REF}$ = 5 V, unless otherwise specified) See figure.3

| Parameter | Description | Test condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **Output drivers (OUT$_A$ or OUT$_B$)** | | | | | | |
| $V_S$ | Motor supply range | | 10 | | 46 | V |
| $I_{CEX}$ | Output leakage current | $V_{OUT}$ = Vs, | - | <1 | 50 | uA |
| | | $V_{OUT}$ = 0 | - | <-1 | -50 | uA |
| $V_{CE(sat)}$ | Output saturation voltage | Sink driver, $I_{OUT}$= +500 mA | - | 0.3 | 0.6 | V |
| | | Sink driver, $I_{OUT}$ = +750 mA | - | 0.7 | 1 | V |
| | | Source driver, $I_{OUT}$ = -500 mA | - | 1.1 | 1.4 | V |
| | | Source driver, $I_{OUT}$ = -750 mA | - | 1.3 | 1.6 | V |
| $I_R$ | Clamp diode leakage current | $V_R$ = 50 V | - | <1 | 50 | uA |
| $V_F$ | Clamp diode forward voltage | Sink diode | | 1 | 1.5 | V |
| | | Source diode $I_F$ = 750 mA | | 1 | 1.5 | V |
| $I_{S(on)}$ | Driver supply current | Both bridges ON, no load | - | 8 | 15 | mA |
| $I_{S(off)}$ | Driver supply current | Both bridges OFF | - | 6 | 10 | mA |
| **Control logic** | | | | | | |
| $V_{IN(H)}$ | Input voltage | All inputs | 2.4 | - | - | V |
| $V_{IN(L)}$ | Input voltage | All inputs | - | - | 0.8 | V |
| $I_{IN(H)}$ | Input current | $V_{IN}$ = 2.4 V | - | <1 | 20 | uA |
| $I_{IN(L)}$ | Input current | $V_{IN}$ = 0.84 V | - | -3 | -200 | uA |
| $V_{REF}$ | Reference voltage | Operating [1] | 1.5 | - | 7.5 | V |
| $I_{SS(ON)}$ | Total logic supply current | $I_O$ = $I_1$ = 0.8 V, no load | - | 64 | 74 | mA |
| $I_{SS(OFF)}$ | Total logic supply current | $I_O$ = $I_1$ = 2.4 V, no load | - | 10 | 14 | mA |
| **Comparators** | | | | | | |
| $V_{REF}$/ $V_{sense}$ | Current limit threshold (at trip point) | $I_O$ = $I_1$ = 0.8 V | 9.5 | 10 | 10.5 | - |
| | | $I_O$ = 2.4 V, $I_1$ = 0.8 V | 13.5 | 15 | 16.5 | - |
| | | $I_O$ = 0.8 V, $I_1$ = 2.4 V | 25.5 | 30 | 34.5 | - |
| $t_{off}$ | Cutoff time | $R_t$ = 56 K　　$C_t$ = 820 pF | - | 50 | | us |
| $t_d$ | Turn off delay | Figure 1 | - | 1 | | us |
| **Protection** | | | | | | |
| $T_J$ | Thermal shutdown temperature | | - | 170 | - | °C |

## Functional description

The circuit is intended to drive both windings of a bipolar stepper motor.

The peak current control is generated through switch mode regulation. There is a choice of three different current levels with the two logic inputs I01 - I11 for winding 1 and I02 - I12 for winding 2.

The current can also be switched off completely.

### Input logic ($I_0$ and $I_1$)

The current level in the motor winding is selected with these inputs. (See figure 4). If any of the logic inputs is left open, the circuit will treat it has a high level input.

### Current levels

| I0 | I1 | Current level |
|---|---|---|
| H | H | No current |
| L | H | Low current 1/3 IO max |
| H | L | Medium current 2/3 IO max |
| L | L | Maximum current IO max |

### Phase

This input determines the direction of current flow in the windings, depending on the motor connections. The signal is fed through a schmidt-trigger for noise immunity, and through a time delay in order to guarantee that no short-circuit occurs in the output stage during phase-shift. High level on the phase input causes the motor current flow from out A through the winding to out B.

### Current sensor

This part contains a current sensing resistor ($R_S$), a low pass filter ($R_C$, $C_C$) and three comparators. Only one comparator is active at a time. It is activated by the input logic according to the current level chosen with signals $I_O$ and $I_1$. The motor current flows through the sensing resistor $R_S$. When the current has increased so that the voltage across $R_S$ becomes higher than the reference voltage on the other comparator input, the comparator goes high, which triggers the pulse generator.

The max peak current Imax can be defined by:

$$I_{max} = V_{ref} / 10R_S$$

## Single-pulse generator

The pulse generator is a monostable triggered on the positive going edge of the comparator output. The monostable output is high during the pulse time, toff, which is determined by the time components Rt and Ct.

$$t_{off} = 1.1 \cdot R_t C_t$$

The single pulse switches off the power feed to the motor winding, causing the winding current to decrease during $t_{off}$. If a new trigger signal should occur during $t_{off}$, it is ignored.

## Output stage

The output stage contains four darlington transistors (source drivers) four saturated transistors (sink drivers) and eight diodes, connected in two H bridge.

## Figure 2. Principle operating sequence
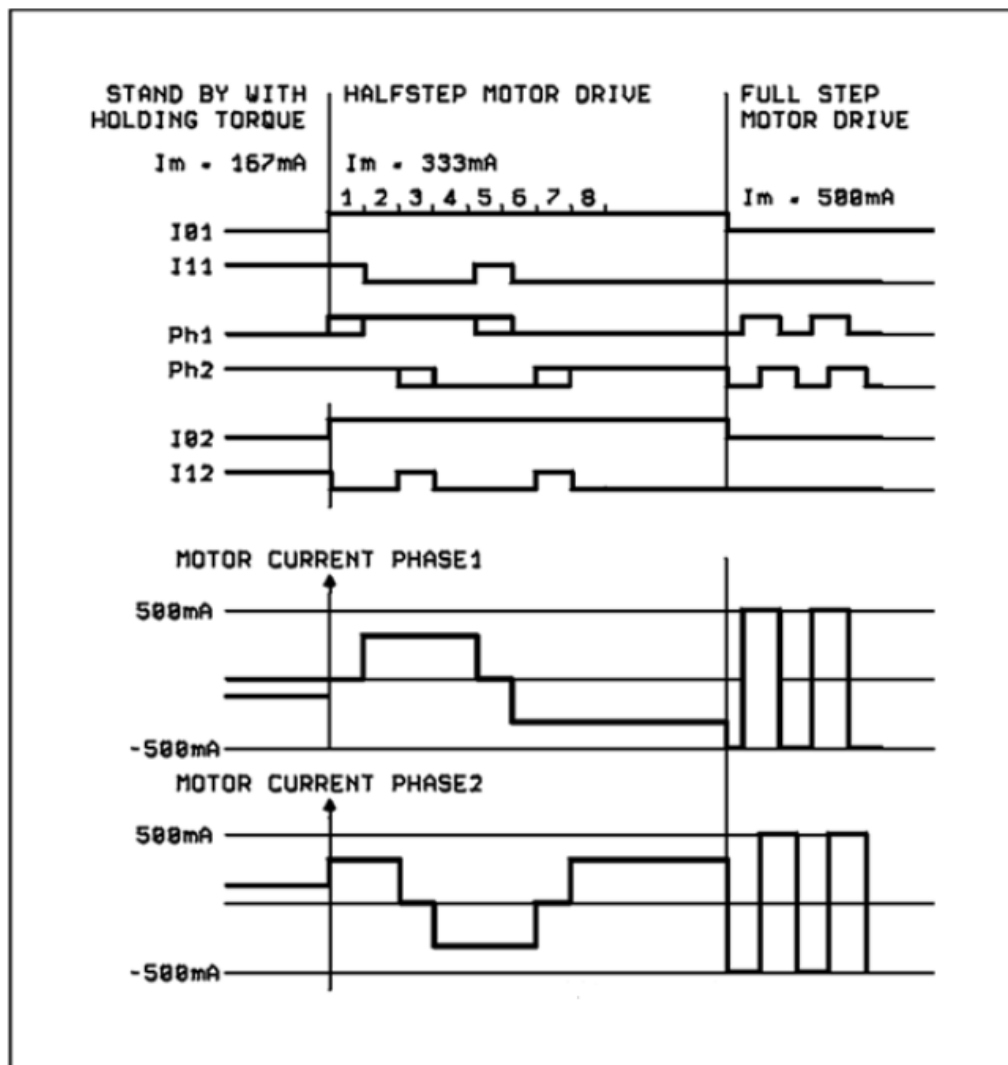
The source transistors are used to switch the power supplied to the motor winding, thus  driving a constant current through the winding. It should be noted however, that is not  permitted to short circuit the outputs

Internal circuitry is added in order to increase the accuracy of the motor current particularly with low current levels

## $V_S$, $V_{SS}$, $V_{Ref}$

The circuit will stand any order of turn-on or turn-off the supply voltages $V_S$ and $V_{SS}$. Normal dV/dt values are then assumed.

Preferably, $V_{Ref}$ should be tracking $V_{SS}$ during power-on and power-off if $V_S$ is established

## Application information

Some stepper motors are not designed for contin-uous operation at maximum current. As  the circuit drives a constant current through the motor, its temperature might increase exceedingly both at low and high speed operation. Also, some stepper motors have such  high core losses that they are not suited for switch mode current regulation.

Unused inputs should be connected to proper voltage levels in order to get the highest noise immunity. As the circuit operates with switch mode current regulation, interference  generation problems might arise in some applications. A good measure might then be to  decouple the circuit with a 100 nF capacitor, located near the package between power line  and ground. The ground lead between Rs, and circuit GND should be kept as short as  possible. A typical application circuit is shown in Figure 3. Note that $C_t$ must be NPO type or  similar else. To sense the winding current, paralleled metal film resistors are recommended   ($R_S$).

**Figure 3.    Typical application circuit**
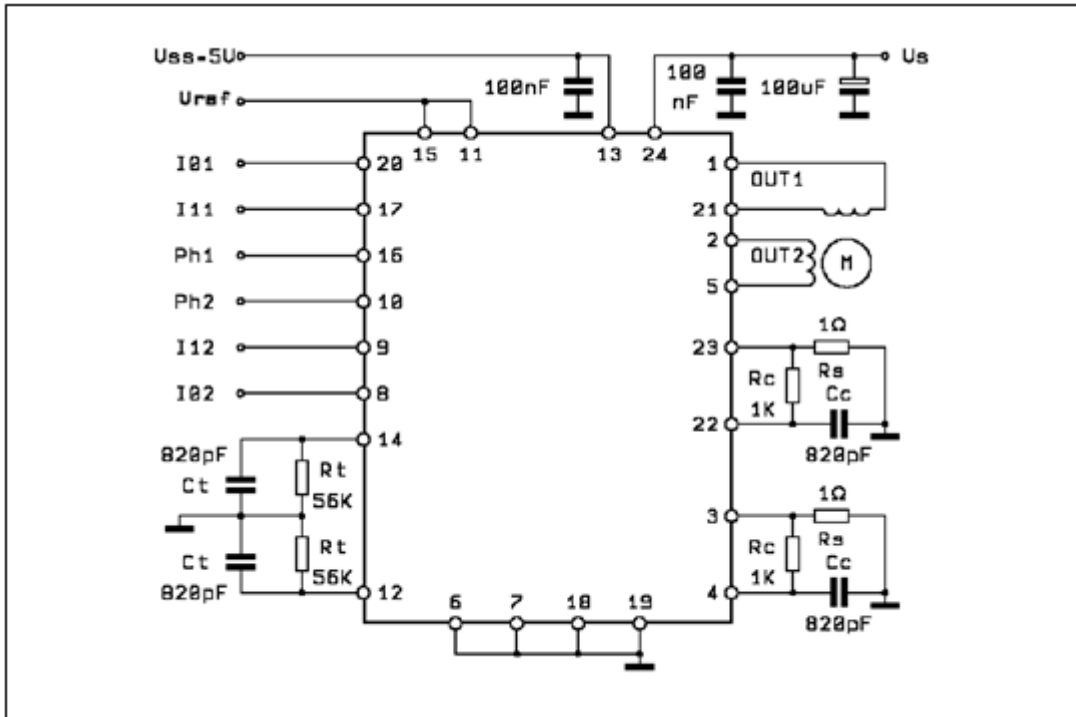
# Package information

## SO24 mechanical data and package dimensions

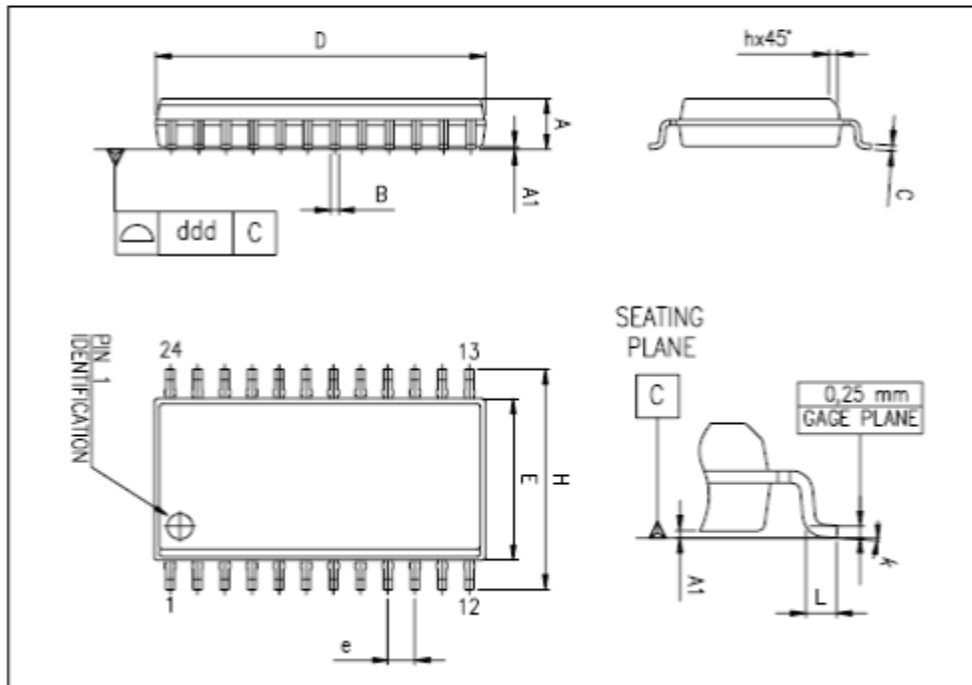| DIM. | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | 2.35 | | 2.65 | 0.093 | | 0.104 |
| A1 | 0.10 | | 0.30 | 0.004 | | 0.012 |
| B | 0.33 | | 0.51 | 0.013 | | 0.200 |
| C | 0.23 | | 0.32 | 0.009 | | 0.013 |
| D (1) | 15.20 | | 15.60 | 0.598 | | 0.614 |
| E | 7.40 | | 7.60 | 0.291 | | 0.299 |
| e | | 1.27 | | | 0.050 | |
| H | 10.0 | | 10.65 | 0.394 | | 0.419 |
| h | 0.25 | | 0.75 | 0.010 | | 0.030 |
| L | 0.40 | | 1.27 | 0.016 | | 0.050 |
| k | 0° (min.), 8° (max.) | | | | | |
| ddd | | | 0.10 | | | 0.004 |

(1) "D" dimension does not include mold flash, protusions or gate burrs. Mold flash, protusions or gate burrs shall not exceed 0.15mm per side.

**OUTLINE AND MECHANICAL DATA**

Weight: 0.60gr
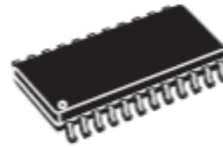
**SO24**

## PDIP24 mechanical data and package dimensions

| DIM. | mm | | | inch | | |
|------|------|------|------|------|------|------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 4.320 | | | 0.170 |
| A1 | 0.380 | | | 0.015 | | |
| A2 | | 3.300 | | | 0.130 | |
| B | 0.410 | 0.460 | 0.510 | 0.016 | 0.018 | 0.020 |
| B1 | 1.400 | 1.520 | 1.650 | 0.055 | 0.060 | 0.065 |
| c | 0.200 | 0.250 | 0.300 | 0.008 | 0.010 | 0.012 |
| D | 31.62 | 31.75 | 31.88 | 1.245 | 1.250 | 1.255 |
| E | 7.620 | | 8.260 | 0.300 | | 0.325 |
| e | | 2.54 | | | 0.100 | |
| E1 | 6.350 | 6.600 | 6.860 | 0.250 | 0.260 | 0.270 |
| e1 | | 7.620 | | | 0.300 | |
| L | 3.180 | | 3.430 | 0.125 | | 0.135 |
| M | 0° min, 15° max. | | | | | |

**OUTLINE AND MECHANICAL DATA**

**PDIP 24 (0.300")**

SDIP24L