LM4570 Single-Ended Input Motor Driver

Check for Samples: LM4570

FEATURES

- **Output Short Circuit Protection**
- **High Output Current Capability**
- **Wide Output Voltage Range**
- **Fast Turn on Time**
- **Output Short Circuit Protection**
- **Low Power Shutdown Mode**
- **Minimum External Components**
- **Available in Space-Saving WSON Package**

APPLICATIONS

- **Mobile Phones**
- **PDAs**
- **Video Game Systems**

KEY SPECIFICATIONS

- **High Output Current @ V_{DD} = 3V: 192 mA**
- **Fast Turn On Time @ 3V: 2.4 ms**
- **Quiescent Power Supply Current @ 3V: 1.9 mA**
- **Shutdown Current: 0.1 µA (Typ)**

DESCRIPTION

The LM4570 is a single supply motor driver for improved sensory experience in mobile phones and other handheld devices. The LM4570 is capable of driving up to 192mA while operating from a 3V supply. Near rail-to-rail output swing under load ensures sufficient voltage drive for most DC motors, while the differential output drive allows the voltage polarity across the motor to be reversed quickly. Reversing the voltage gives the LM4570 the ability to drive a motor both clock-wise and counter clock-wise from a single supply.

The LM4570 features fast turn on time, and a wide input voltage range for precise speed control. A low power shutdown mode minimizes power consumption.

Thermal and output short circuit protection prevents the device from being damaged during fault conditions.

Typical Application

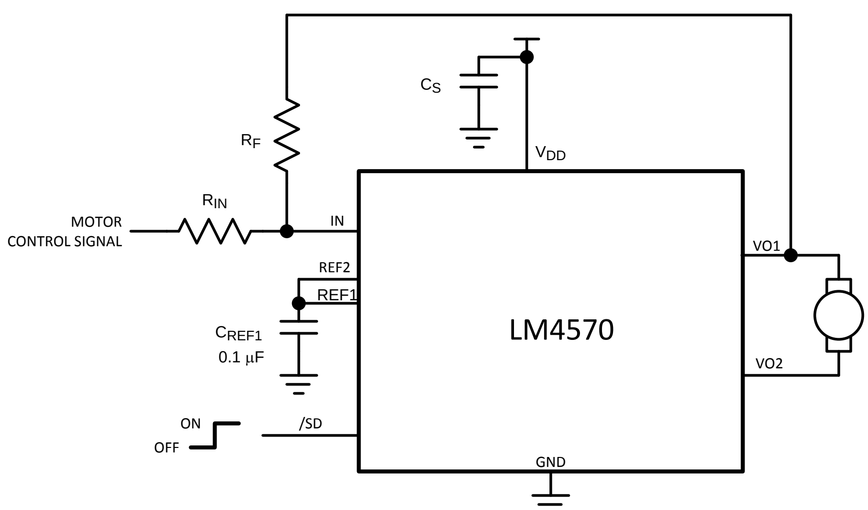


Figure 1. Typical Motor Driver Application Circuit

Connection Diagram

Top View

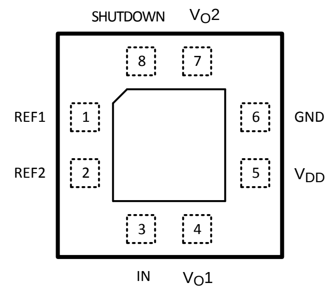


Figure 2. Leadless Leadframe WSON Package
See Package Number NGP0008A

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Absolute Maximum Ratings[(1)(2)]

Supply Voltage[(3)]		6.0V
Storage Temperature		−65°C to +150°C
Voltage at Any Input Pin		−0.3V ≥ to V_{DD} +0.3V
Power Dissipation[(4)]		Internally Limited
ESD Susceptibility[(5)]		2000V
ESD Susceptibility[(6)]		200V
Junction Temperature (T_{JMAX})		150°C
Thermal Resistance	θ_{JA} (WSON)	140°C/W

(1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not specify specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which specify specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not specified for parameters where no limit is given; however, the typical value is a good indication of device performance.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(3) All voltages are measured with respect to the ground pin, unless otherwise specified.
(4) The maximum power dissipation must be de-rated at elevated temperatures and is dictated by T_{JMAX}, θ_{JC}, and the ambient temperature T_A. The maximum allowable power dissipation is $P_{DMAX} = (T_{JMAX} - T_A)/\ \theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4570, T_{JMAX} = 150°C and the typical θ_{JA} for the WSON package is 140°C/W.
(5) Human body model, 100pF discharged through a 1.5kΩ resistor.
(6) Machine Model, 220pF–240pF discharged through all pins.

Operating Ratings

Temperature Range ($T_{MIN} \le T_A \le T_{MAX}$)	−40°C ≤ T_A ≤ 85°C
Supply Voltage	2.4V ≤ V_{DD} ≤ 5.5V

Electrical Characteristics V_{DD} = 5V

(1)(2)

The following specifications apply for V_{DD} = 5V, $A_{V\text{-}BTL}$ = 6dB unless otherwise specified. Limits apply for T_A = 25°C.

Parameter		Test Conditions	LM4570		Units (Limits)
			Typ (3)	Limit (4)(5)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_L = 0A, No Load	2.5	5.5	mA (max)
		V_{IN} = 0V, I_L = 0A, R_L = 30Ω	2.6	5.5	mA (max)
I_{SD}	Shutdown Current	V_{SD} = GND	0.1	1.5	µA (max)
V_{IH}	Logic Input High			1.4	V (min)
V_{IL}	Logic Input Low			0.4	V (max)
V_{OS}	Output Offset Voltage		5	±35	mV (max)
I_{OUT}	Output Current	V_{OH}, V_{OL} ≤ 250mV	268		mA
T_{WU}	Wake-up time		2.5		ms (max)
V_{OH}	Output High Voltage	R_L = 30Ω specified as $\|V_{DD}$ - $V_{OH}\|$	146	200	mV (max)
V_{OL}	Output Low Voltage	R_L = 30Ω specified as $\|GND + V_{OH}\|$	106	200	mV (max)

(1) All voltages are measured with respect to the ground pin, unless otherwise specified.
(2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not specify specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which specify specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not specified for parameters where no limit is given; however, the typical value is a good indication of device performance.
(3) Typicals are measured at 25°C and represent the parametric norm.
(4) Limits are ensured to AOQL (Average Outgoing Quality Level).
(5) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.

Electrical Characteristics V_{DD} = 3V

(1)(2)

The following specifications apply for V_{DD} = 3V, $A_{V\text{-}BTL}$ = 6dB unless otherwise specified. Limits apply for T_A = 25°C.

Parameter		Test Conditions	LM4570		Units (Limits)
			Typ (3)	Limit (4)(5)	
I_{DD}	Quiescent Power Supply Current	V_{IN} = 0V, I_L = 0A, No Load	1.9	4	mA (max)
		V_{IN} = 0V, I_L = 0A, R_L = 30Ω	1.95	4	
I_{SD}	Shutdown Current (6)	V_{SD} = GND	0.1	1.0	µA (max)
V_{IH}	Logic Input High			1.4	V (min)
V_{IL}	Logic Input Low			0.4	V (max)
V_{OS}	Output Offset Voltage		5	±35	mV (max)
I_{OUT}	Output Current	V_{OH}, V_{OL} ≤ 200mV	192		mA
T_{WU}	Wake-up time		2.4		ms (max)
V_{OH}	Output High Voltage	R_L = 30Ω specified as $\|V_{DD}$ - $V_{OH}\|$	90	110	mV (max)
V_{OL}	Output Low Voltage	R_L = 30Ω specified as $\|V_{DD}$ - $V_{OH}\|$	63	110	mV (max)

(1) All voltages are measured with respect to the ground pin, unless otherwise specified.
(2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not specify specific performance limits. Electrical Characteristics state DC and AC electrical specifications under particular test conditions which specify specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not specified for parameters where no limit is given; however, the typical value is a good indication of device performance.
(3) Typicals are measured at 25°C and represent the parametric norm.
(4) Limits are ensured to AOQL (Average Outgoing Quality Level).
(5) Datasheet min/max specification limits are ensured by design, test, or statistical analysis.
(6) Shutdown current is measured in a normal room environment. Exposure to direct sunlight will increase I_{SD} by a maximum of 2µA.

Typical Performance Characteristics

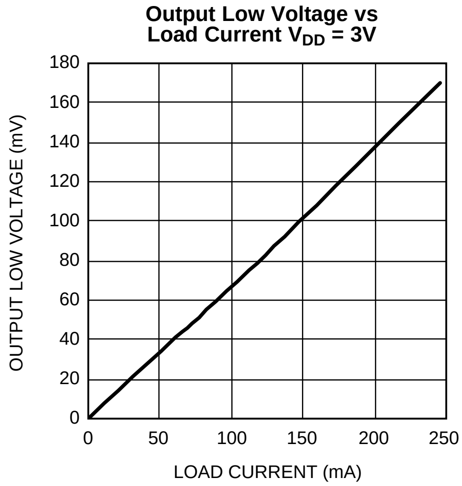


Figure 3.

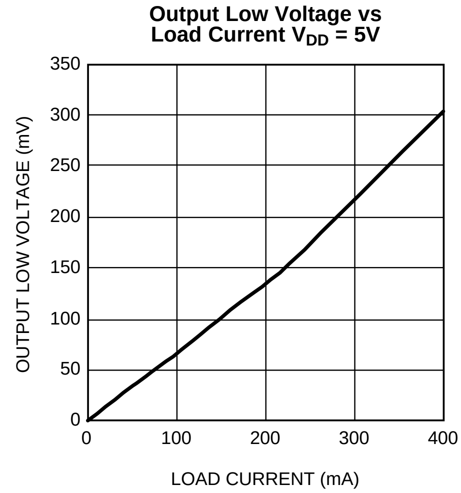


Figure 4.

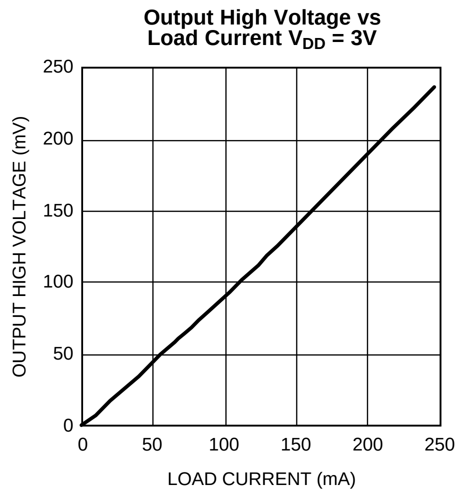


Figure 5.

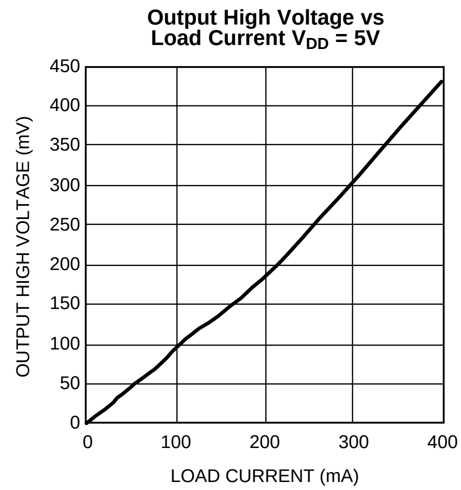


Figure 6.

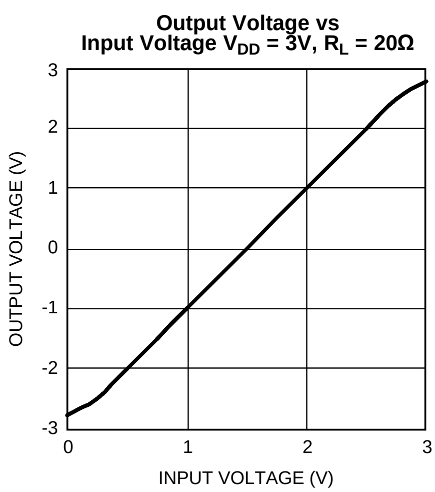


Figure 7.

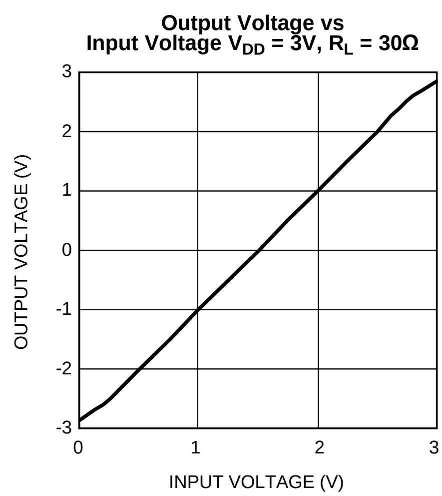


Figure 8.

Typical Performance Characteristics (continued)

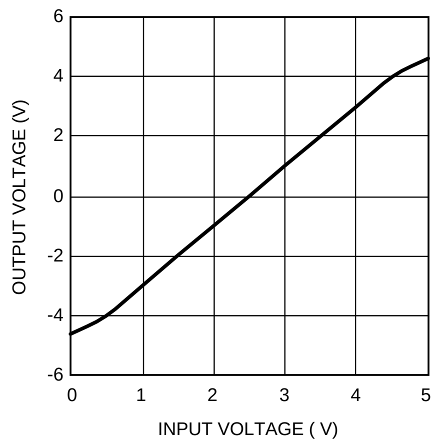


Figure 9.

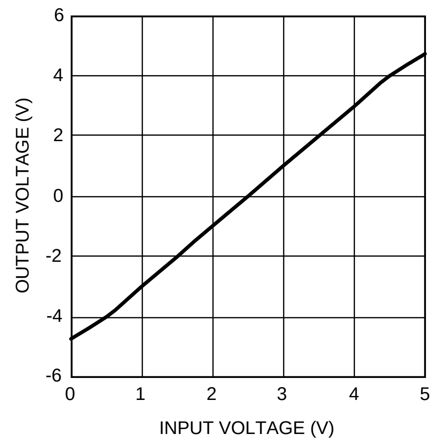


Figure 10.

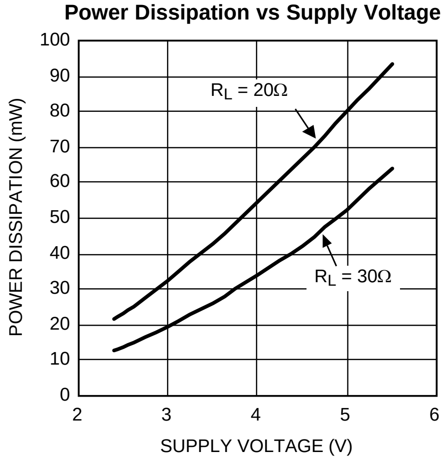


Figure 11.

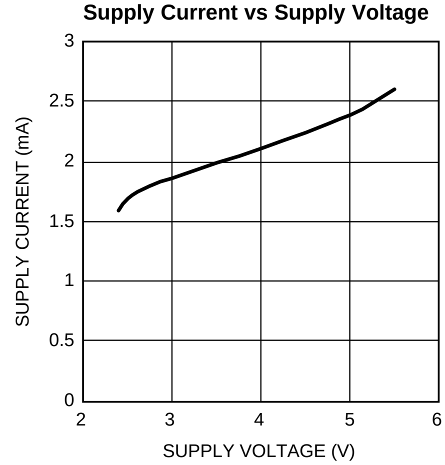


Figure 12.

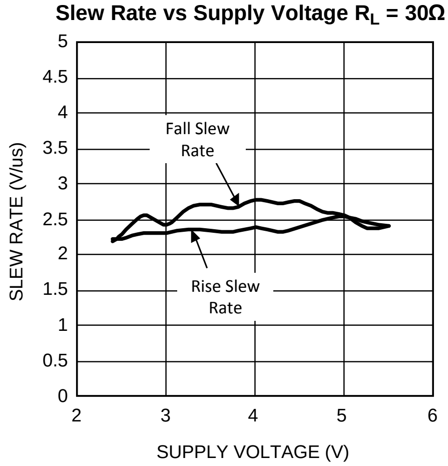


Figure 13.

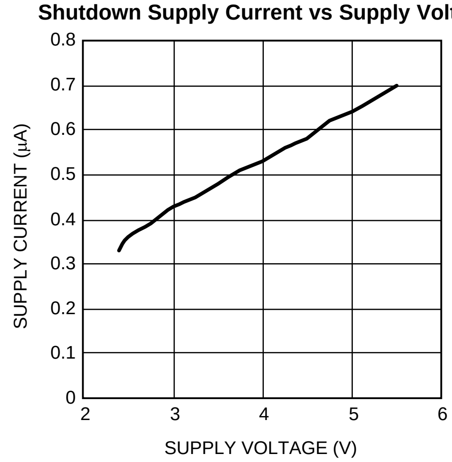


Figure 14.

Typical Performance Characteristics (continued)

Output Transition High to Low, Low to High
V_{DD} = 3V, 1V/div, 400ns/div

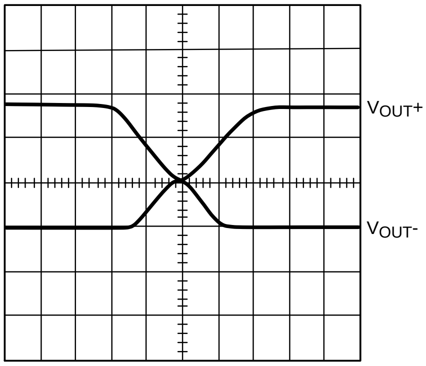


Figure 15.

Output Transition High to Low, Low to High
V_{DD} = 5V, 1V/div, 1μs/div

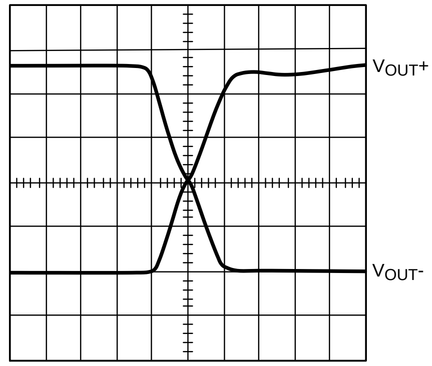


Figure 16.

Turn-Off Time V_{DD} = 5V, 2V/div, 1ms/div

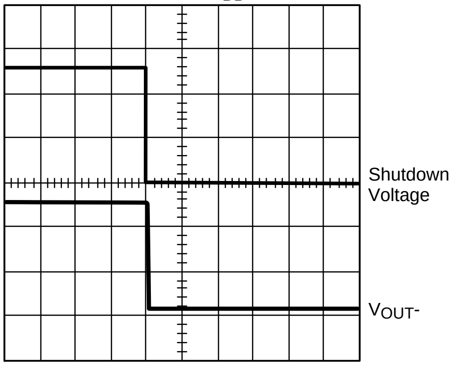


Figure 17.

Turn-On Time V_{DD} = 5V, 2V/div, 1ms/div

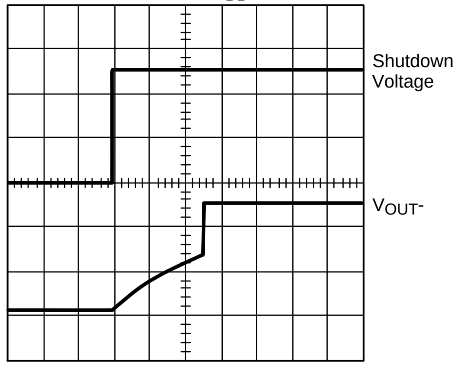


Figure 18.

APPLICATION INFORMATION

BRIDGE CONFIGURATION EXPLANATION

The LM4570 uses a bridged architecture that drives a load differentially. The BTL design offers several advantages over a single-ended design. The device outputs, V_O1 and V_O2, both source and sink current, which means that the polarity of the voltage across the motor can be reversed quickly (Figure 19). A single-ended device would need to operate from split supplies to achieve this behavior. The ability to reverse the voltage polarity is necessary in applications where a negative (reverse polarity) pulse is used to quickly stop the motor. If the drive voltage is just removed from the motor (not reversed) then the motor will continue to spin until the residual energy stored in the windings has dissipated.

The output voltage of the LM4570 is determined by the difference between the input voltage and V_{REF1}, as well as the differential gain of the device. The output voltage is given by the following:

$$V_O1 – V_O2 = A_{VD}(V_{IN} – V_{REF1}) \quad (1)$$

For input voltages that are less than the reference voltage, the differential output voltage is negative. For input voltages that are greater than the reference voltage, the differential output voltage is positive. For example, when operating from a 5V supply (V_{REF1} = 2.5V) and with a differential gain of 6dB, with a 1V input, the voltage measured across V_O1 and V_O2 is -3V, with a 4V input, the differential output voltage is +3V.

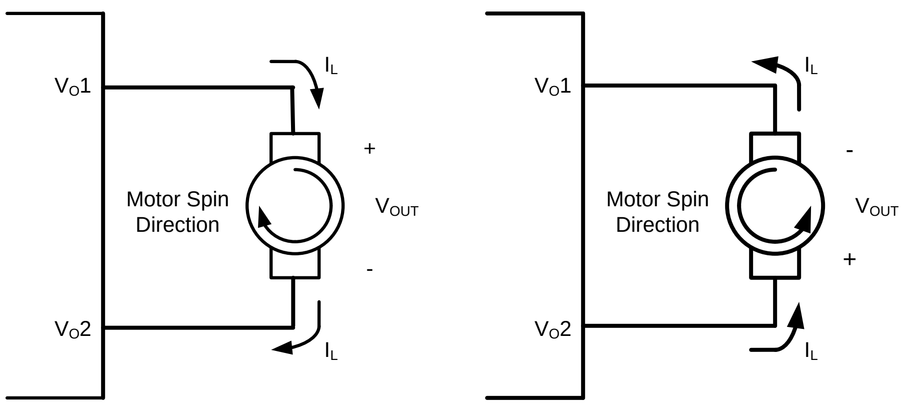


Figure 19. Voltage Polarity and Motor Direction

GAIN SETTING

The resistors R_{IN} and R_F set the gain of the LM4570, given by:

$$V_{VD} = 2 \times (R_F / R_{IN}) \quad (2)$$

Where A_{VD} is the differential gain. A_{VD} differs from single-ended gain by a factor of 2. This doubling is due to the differential output architecture of the LM4570. Driving the load differentially doubles the output voltage compared to a single-ended output amplifier under the same conditions.

POWER DISSIPATION

Figure 11 shows the power dissipation of the LM4570 with the input equal to the supply voltage, meaning the outputs swing rail-to-rail. This configuration results in the output devices of the LM4570 operating in the linear region, essentially very small resistors determined by the $R_{DS(ON)}$ of the output devices. Under these conditions, the power dissipation is dominated by the I*R drop associated with the output current across the $R_{DS(ON)}$ of the output transistors, thus the power dissipation is very low (60mW for a 800mW output).

When the input voltage is not equal to GND or V_{DD}, the power dissipation of the LM4570 increases (Figure 20). Under these conditions, the output devices operate in the saturation region, where the devices consume current in addition to the current being steered to the load, increasing the power dissipation. Power dissipation for typical motor driving applications should not be an issue since the most of the time the device outputs will be driven rail-to-rail.

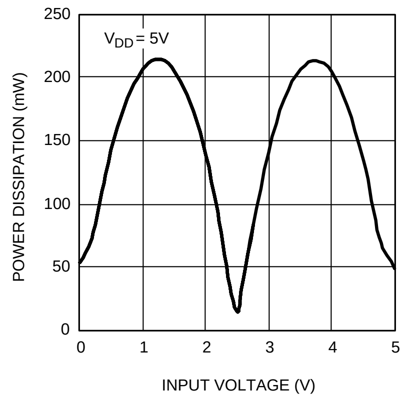


Figure 20. Power Dissipation vs. Input Voltage

EXPOSED-DAP MOUNTING CONSIDERATIONS

The LM4570 is available in an 8-pin WSON package which features an exposed DAP (die attach paddle). The exposed DAP provides a direct thermal conduction path between the die and the PCB, improving the thermal performance by reducing the thermal resistance of the package. Connect the exposed DAP to GND through a large pad beneath the device, and multiple vias to a large unbroken GND plane. For best thermal performance, connect the DAP pad to a GND plane on an outside layer of the PCB. Connecting the DAP to a plane on an inner layer will result in a higher thermal resistance. Ensure efficient thermal conductivity by plugging and tenting the vias with plating and solder mask, respectively.

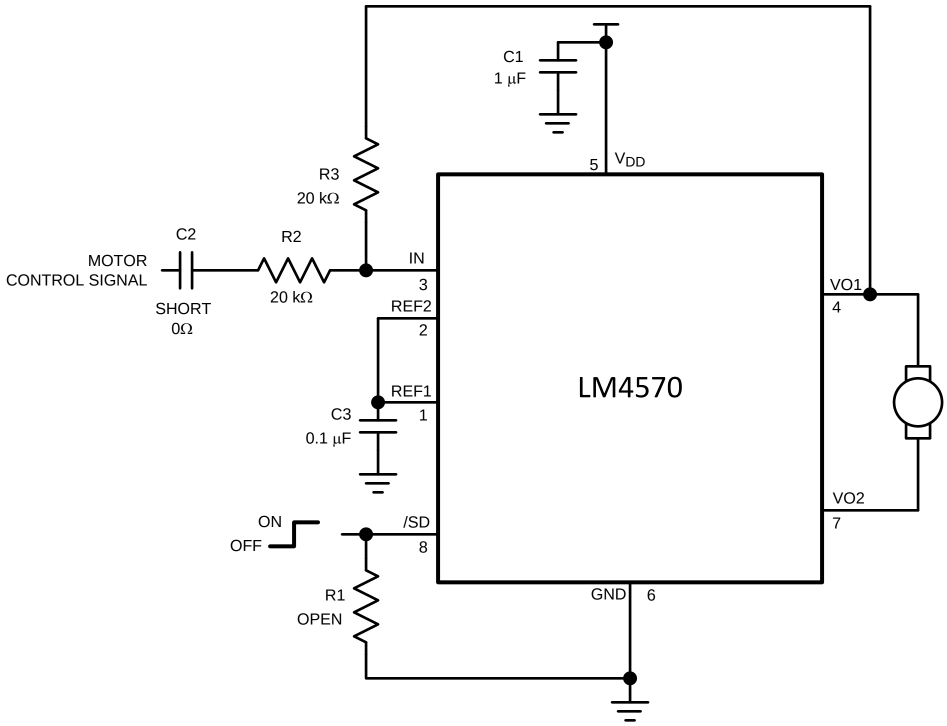
POWER SUPPLY BYPASSING

Good power supply bypassing is critical for proper operation. Locate both the REF1 and V_{DD} bypass capacitors as close to the device as possible. Typical applications employ a regulator with a 10µF tantalum or electrolytic capacitor and a ceramic bypass capacitor which aid in supply stability. This does not eliminate the need for bypass capacitors near the LM4570. Place a 1µF ceramic capacitor as close to V_{DD} as possible. Place a 0.1µF capacitor as close to REF1 as possible. Smaller values of C_{REF1} may be chosen for decreased turn on times.

SHUTDOWN FUNCTION

The LM4570 features a low power shutdown mode that disables the device and reduces quiescent current consumption to 0.1µA. Driving /SD Low disables the amplifiers and bias circuitry, and drives $V_{REF1}$and the outputs to GND. Connect /SD to V_{DD} for normal operation.

DEMO BOARD LAYOUT



Revision History

Rev	Date	Description
1.0	04/13/06	Initial release.
1.01	07/28/09	Added the Ordering Information table.
C	04/08/13	Changed layout of National Data Sheet to TI format.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM4570LQ/NOPB	ACTIVE	WQFN	NGP	8	1000	Green (RoHS & no Sb/Br)	CU SN	Level-3-260C-168 HR	-40 to 85	GC8	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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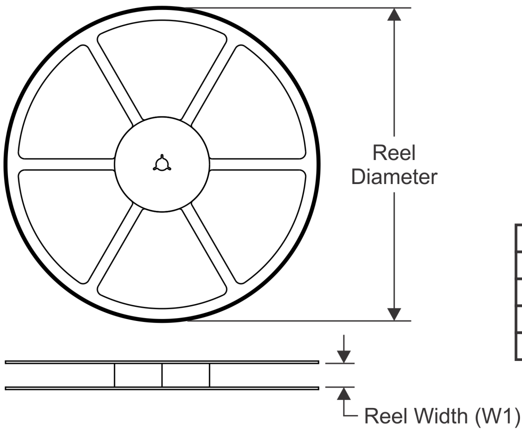
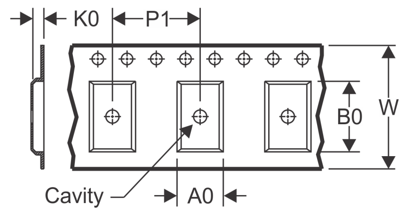
TAPE AND REEL INFORMATION

REEL DIMENSIONS

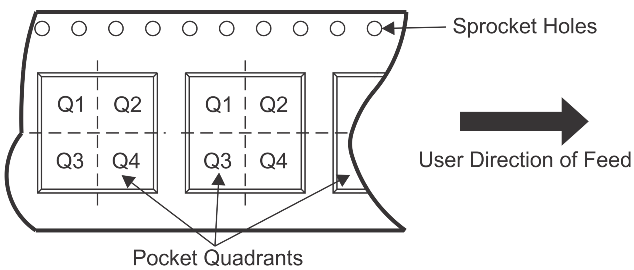


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

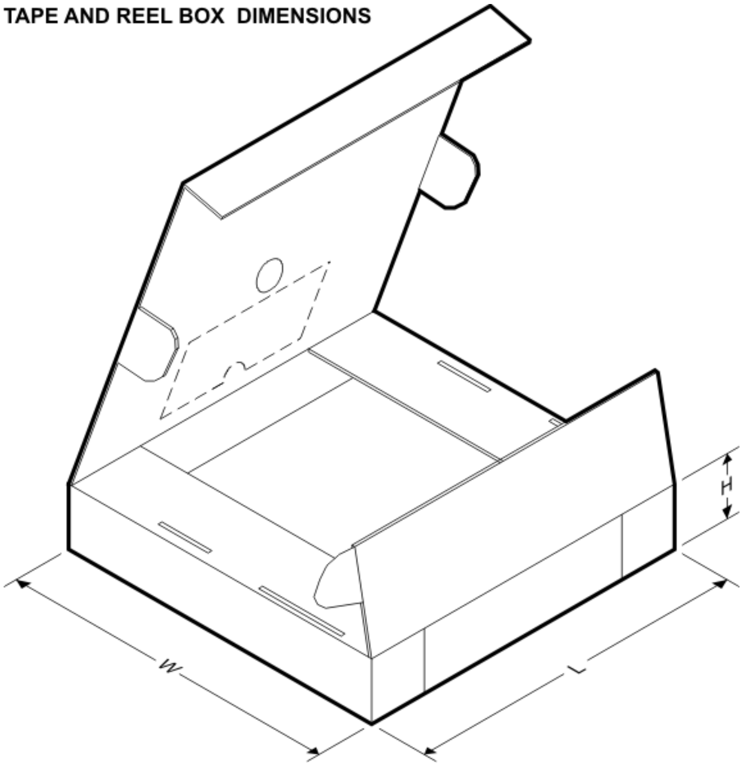
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

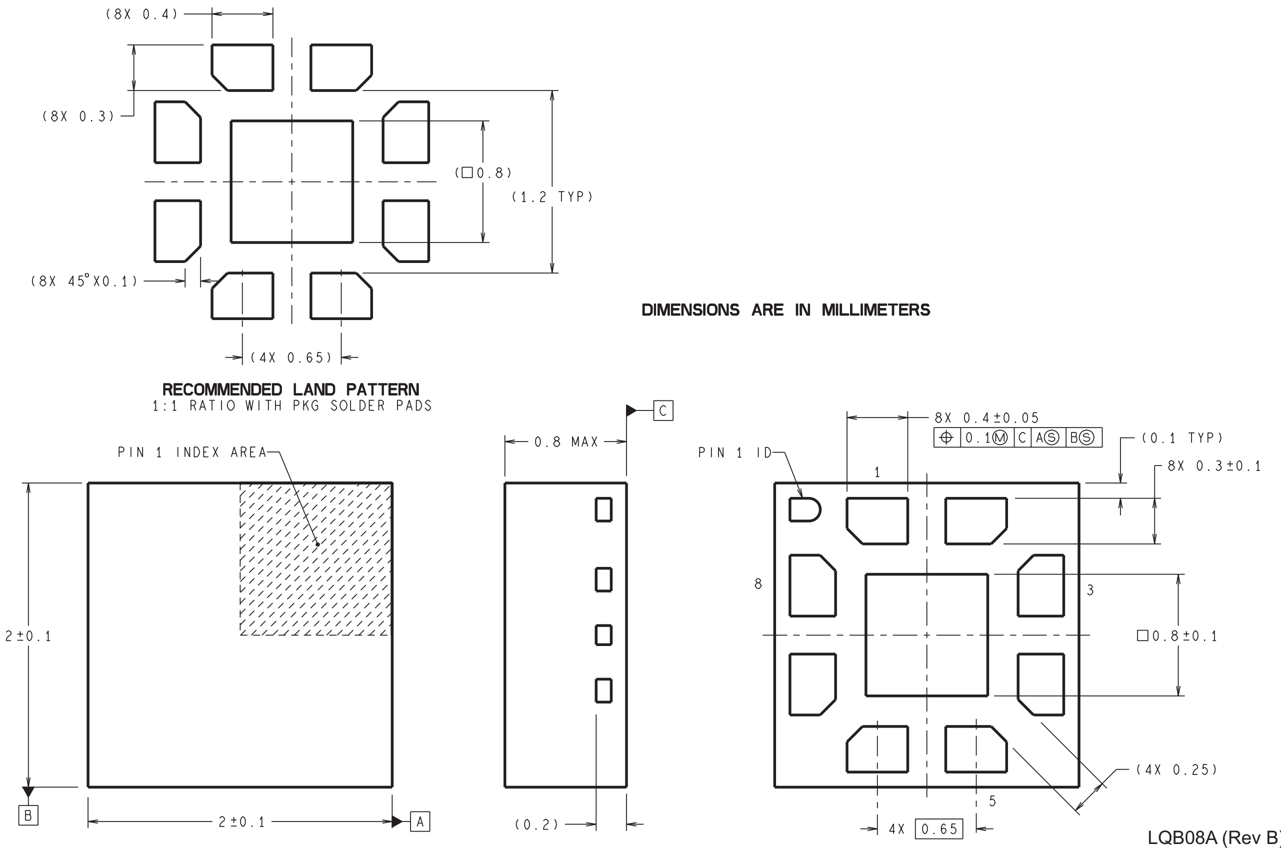
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LM4570LQ/NOPB	WQFN	NGP	8	1000	178.0	12.4	2.2	2.2	1.0	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM4570LQ/NOPB	WQFN	NGP	8	1000	213.0	191.0	55.0


(8X 0.4)
(8X 0.3)
(□0.8)
(1.2 TYP)
(8X 45°X0.1)
(4X 0.65)
RECOMMENDED LAND PATTERN
1:1 RATIO WITH PKG SOLDER PADS
DIMENSIONS ARE IN MILLIMETERS
PIN 1 INDEX AREA
2±0.1
B
2±0.1
A
0.8 MAX
C
(0.2)
PIN 1 ID
8X 0.4±0.05
0.1 M C A S B S
(0.1 TYP)
8X 0.3±0.1
1
8
3
□0.8±0.1
(4X 0.25)
5
4X 0.65

LQB08A (Rev B)

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