## Features

- High current capability: 1.5a
- Low-dropout voltage: 350mv
- Low ground current
- Accurate 1% guaranteed tolerance
- Extremely fast transient response
- Reverse-battery and “load dump” protection
- Zero-current shutdown mode (5-pin versions)
- Error flag signals output out-of-regulation (5-pin versions)
- Also characterized for smaller loads with industry- leading performance specifications
- Fixed voltage and adjustable versions

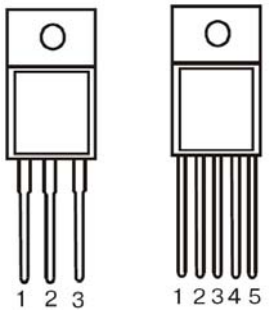
## Applications

- Battery powered equipment
- High-efficiency “green” computer systems
- Automotive electronics
- High-efficiency linear power supplies
- High-efficiency post-regulator for switching supply

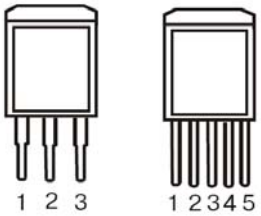
## General Description

The LD6356 are high current, high accuracy, low-dropout voltage regulators. Using process with a PNP pass element, these regulators feature 350mV (full load) dropout voltages and very low ground current. These devices also find applications in lower current, low drop-out-critical systems, where their tiny dropout voltage and ground current values are important attributes.
The LD6356 are fully protected against over current faults, reversed input polarity, reversed lead insertion, over temperature operation, and positive and negative transient voltage spikes. Five pin fixed voltage versions feature logic level ON/OFF control and an error flag which signals whenever the output falls out of regulation.
On the MIC29151 and MIC29152, the ENABLE pin maybe tied to $V_{IN}$ if it is not required for ON/OFF control. The LD6356 are available in 3 and 5 pin TO-220 and surface mount TO-263 packages.

## Package Pin Out




LD6356 — LD6356B, LD6356C, LD6356D




LD6356 — LD6356B, LD6356C, LD6356D

**LD6356** Three Terminal Devices:
Pin1 = Input, 2= Ground, 3= Output
**LD6356B** Five Terminal Fixed Voltage Devices:
Pin1 = Enable, 2= Input, 3= Ground, 4= Output, 5= Flag
**LD6356C** Adjustable with ON/OFF Control
Pin1= Enable, 2= Input, 3= Ground, 4= Output, 5= Adjust
**LD6356D** Adjustable with Flag
Pin1= Flag, 2= Input, 3= Ground, 4= Output, 5= Adjust

## Ordering Information

| | | Packing Options | |
|---|---|---|---|
| Part No. | Package | Tube (TU) | Tape & Reel (TR) |
| LD6356 | TO220 | LD6356T4-TU | LD6356T4-TR |
| | TO263 | LD6356T9-TU | LD6356T9-TR |

- Package material default is “Green” package.

## Product Marking

LD8888
SSSSS…
●

- Line 1 – “LD” is a fixed character
  8888: product name
- Line 2 – SSSSS…: lot number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## Absolute Maximum Ratings

| Parameter | Maximum | Unit |
|---|---|---|
| Input Supply Voltage (Note 1) | -20 to +60 | V |
| Maximum Operating Input Voltage | 26 | V |
| Operating Junction Temperature | -40 to +125 | °C |
| Storage Temperature Range | -65 to +150 | °C |
| Lead Temperature (Soldering, 5 seconds) | 260 | °C |
| Power Dissipation | Internally Limited | |

The values beyond the boundaries of absolute maximum rating may cause the damage to the device. Functional operation in this context is not implied. Continuous use of the device at the absolute rating level might influence device reliability. All voltages have their reference to device ground.

## Electrical Characteristics

All measurements at $T_J$ = 25°C unless otherwise noted. **Bold** values are guaranteed across the operating temperature range. Adjustable versions are programmed to 5.0V.

| Parameter | Symbol | Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| **Input** | | | | | | |
| Output voltage | $V_{OUT}$ | $I_O$=10mA | -1 | – | 1 | % |
| | | 10mA≤$I_O$≤ $I_{FL}$, ($V_{OUT}$+1V)≤$V_{IN}$≤26V *2*11 | -2 | – | 2 | |
| Line regulation | $R_{LINE}$ | $I_O$=10mA, ($V_{OUT}$+1V)≤$V_{IN}$≤26V | – | 0.06 | 0.5 | % |
| Load regulation *2*6 | $R_{LOAD}$ | $V_{IN}$=$V_{OUT}$+5V, 10mA≤$I_{OUT}$≤$I_{FULLOAD}$ | – | 0.2 | 1 | % |
| Output voltage temperature coefficient | $\Delta V_{OUT}/\Delta T$ | *6 | – | 20 | 100 | ppm/°C |
| Dropout voltage *3 | $V_{DO}$ | $\Delta V_{OUT}$=-1%, $I_O$=100mA | – | 80 | **200** | mV |
| | | $\Delta V_{OUT}$=-1%, $I_O$=750mA | – | 220 | – | |
| | | $\Delta V_{OUT}$=-1%, $I_O$=1.5A | – | 350 | **600** | |
| Ground current | $I_{GND}$ | $I_O$=750mA, $V_{IN}$=$V_{OUT}$+1V | – | 8 | **20** | mA |
| | | $I_O$=1.5A | – | 22 | – | |
| Ground pin current at dropout | $I_{GNDDO}$ | $V_{IN}$=0.5V less than specified $V_{OUT}$. $I_{OUT}$=10mA | – | 2 | – | mA |
| Current limit *4 | $I_{OUT\ (lim)}$ | LD6356 $V_{OUT}$=0V | – | 2.1 | **3.5** | A |
| Output noise voltage (10Hz to 100khz) | $V_{NOISE}$ | $I_L$=100mA, $C_L$=10µF | – | 400 | – | µVRMS |
| | | $I_L$=100mA, $C_L$=33µF | – | 260 | – | |
| **Reference LD6356C** | | | | | | |
| Reference voltage | $V_{REF}$ | | 1.228 | 1.240 | 1.252 | V |
| | | *11 | 1.215 | – | 1.265 | |
| | | *8*11 | 1.20 | – | 1.277 | |
| Adjust pin current | $I_{ADJBIAS}$ | | 40 | – | 80 | nA |
| | | *11 | – | – | 120 | |
| Reference voltage temperature coefficient | $\Delta V_{REF}/\Delta T$ | *7 | – | 20 | – | ppm/°C |
| Adjust pin bias current temperature coefficient | $\Delta I_{ADJ}/\Delta T$ | | – | 0.1 | – | nA/°C |
| **Flag Output (Error Comparator) LD6356B/LD6356D** | | | | | | |
| Output leakage current | $I_{FLG\ (leak)}$ | $V_{OH}$=26V | – | 0.001 | 1.00 | µA |
| | | $V_{OH}$=26V*11 | – | – | 2.00 | |
| Output low voltage | $V_{FLG\ (do)}$ | Device set for 5V. $V_{IN}$=4.5V,$I_{OL}$=250µA | – | 220 | 300 | mV |
| | | Device set for 5V. $V_{IN}$=4.5V,$I_{OL}$=250µA*11 | – | – | 400 | |
| Upper threshold voltage | $V_{FLG}$ | Device set for 5V, % of $V_{OUT}$ | – | – | 99.2 | % |
| Lower threshold voltage | | Device set for 5V, % of $V_{OUT}$ | 93 | – | – | |
| Hysteresis | | Device set for 5V, % of $V_{OUT}$ | – | 1 | – | |


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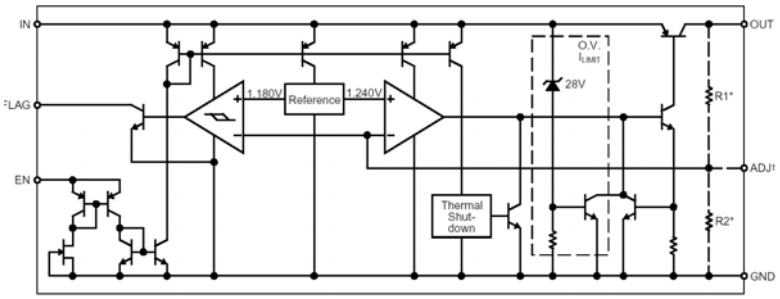
| ENABLE Input LD6356B/LD6356C | | | | | | |
|---|---|---|---|---|---|---|
| Input logic voltage | $V_{EN}$ | Low (off)*11 | – | – | 0.8 | V |
| | | High (on)*11 | 2.4 | – | – | |
| Enable pin input current | $I_{EN}$ | VEN=26V | – | 100 | 600 | μA |
| | | VEN=26V*11 | – | – | 750 | |
| | | VEN=0.8V | – | – | 2.5 | |
| | | VEN=0.8V*11 | – | – | 5 | |
| Regulator output current shutdown*9 | $I_{SD}$ | | – | 10 | – | μA |
| | | *11 | – | – | 500 | |

Notes:

1. Maximum positive supply voltage of 60V must be of limited duration (<100msec) and duty cycle (≤1%). The maximum continuous supply voltage is 26V.
2. Full Load current (IFL) is defined as 1.5A.
3. Dropout voltage is defined as the input-to-output differential when the output voltage drops to 99%of its nominal value with VOUT to VIN
4. VIN = VOUT (nominal) + 1V. For example, use VIN = 4.3V for a 3.3V regulator or use 6V for a 5Vregulator. Employ pulse-testing procedures to minimize temperature rise.
5. Ground pin current is the regulator quiescent current. The total current drawn from the source is the sum of the load current plus the ground pin current.
6. Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.
7. Thermal regulation is defined as the change in output voltage at a time T after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 200mA load pulse at VIN = 20V (a 4W pulse) for T = 10ms.
8. VREF ≤ VOUT ≤ (VIN-1V), 2.3V ≤ VIN ≤ 26V, 10mA < IL IFL, TJ < TJ MAX.
9. VEN ≤0.8V and VIN ≤26V, VOUT=0
10. When used in dual supply systems where the regulator load is returned to a negative supply, the output voltage must be diode clamped to ground.
11. Values are guaranteed across the operating temperature range.

## Block Diagram




*Feedback network in fixed versions only
**Adjustable version only

## Typical Application Circuit

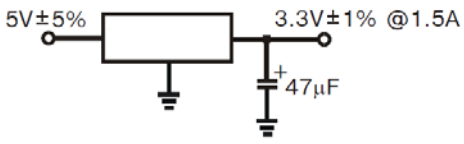
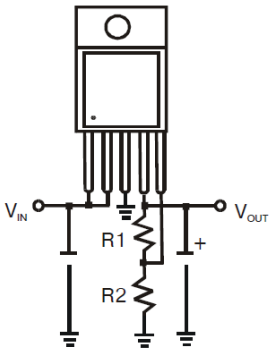



Figure1. Fixed output voltage




$V_{OUT}$=1.240V x [1+(R1/R2)]

Figure2. Adjustable output voltage configuration. For best results, the total series resistance should be small enough to pass the minimum regulator load current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## Applications Information

The LD6356 are high performance low-dropout voltage regulators suitable for all moderate to high current voltage regulator applications. Their 350mV dropout voltage at full load make them especially valuable in battery powered systems and as high efficiency noise filters in “post-regulator” applications.

Unlike older NPN-pass transistor designs, dropout performance of the PNP output of these devices is limited merely by the low $V_{CE}$ saturation voltage.

The LD6356 family of regulators is fully protected from damage due to fault conditions. Current limiting is provided. This limiting is linear; output current under overload conditions is constant. Thermal shutdown disables the device when the die temperature exceeds the 125°C maximum safe operating temperature.

Transient protection allows device survival even when the input voltage spikes between -20V and +60V.

When the input voltage exceeds about 35V to 40V, the over voltage sensor temporarily disables the regulator.

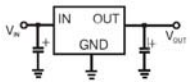



Figure 3. Linear regulators require only two capacitors for operation.

## Thermal Design

Linear regulators are simple to use. The most complicated design parameters to consider are thermal characteristics. Thermal design requires the following application-specific parameters:

- Maximum ambient temperature, $T_A$
- Output Current, $I_{OUT}$
- Output Voltage, $V_{OUT}$
- Input Voltage, $V_{IN}$

First, we calculate the power dissipation of the regulator from these numbers and the device parameters from this datasheet.

$P_D = I_{OUT}(1.01V_{IN} - V_{OUT})$

Where the ground current is approximated by 1% of $I_{OUT}$. Then the heat sink thermal resistance is determined with this formula:

$$\theta_{SA} = \frac{T_{J\,MAX} - T_A}{P_D} - (\theta_{JC} + \theta_{CS})$$

Where $T_{J\,MAX} \leq 125^0C$ and $\theta_{CS}$ is between 0 and $2^0C/W$.

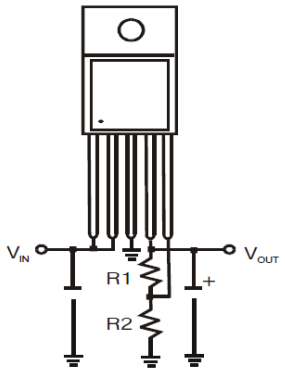
## Capacitor Requirements

For stability and minimum output noise, a capacitor on the regulator output is necessary. The value of this capacitor is dependent upon the output current; lower currents allow smaller capacitors. LD6356 regulators are stable with the 10 $\mu$F minimum capacitor values at full load.

Where the regulator is powered from a source with a high AC impedance, a 0.1 $\mu$F capacitor connected between Input and GND is recommended. This capacitor should have good characteristics to above 250kHz.

## Minimum Load Current

The LD6356 regulators are specified between finite loads. If the output current is too small, leakage currents dominate and the output voltage rises. The 5mA minimum load current swamps any expected leakage current across the operating temperature range.




$V_{OUT} = 1.240V \times [1 + (R1/R2)]$

## Adjustable Regulator Design

Figure 4. Adjustable Regulator with Resistors The adjustable regulator versions, LD6356C and LD6356D, allow programming the output voltage anywhere between 1.25V and the 26V maximum operating rating of the family Two resistors are used. Resistors can be quite large, up to 1M$\Omega$, because of the very high input impedance and low bias current of the sense comparator: The resistor values are calculated by:

$$R_1 = R_2 \left(\frac{V_{OUT}}{1.240} - 1\right)$$

Where is $V_O$ the desired output voltage. Figure 4 shows component definition. Applications with widely varying load currents may scale the resistors to draw the minimum load current required for proper operation.

## Error Flag

LD6356B and LD6356D versions feature an Error Flag, which looks at the output voltage and signals an error condition when this voltage drops 5% below its expected value. The error flag is an open-collector output that pulls low under fault conditions. It may sink 10mA. Low output voltage signifies a number of possible problems, including an over-current fault (the device is in current limit) and low input voltage. The flag output is inoperative during over temperature shutdown conditions.

## Enable Input

LD6356B and LD6356C versions feature an enable (EN) input that allows ON/OFF control of the device.

Special design allows “zero” current drain when the device is disabled-only microamperes of leakage current flows. The EN input has TTL/CMOS compatible thresholds for simple interfacing with logic, or may be directly tied to $\leq$ 30V. Enabling the regulator requires approximately 20 $\mu$A of current.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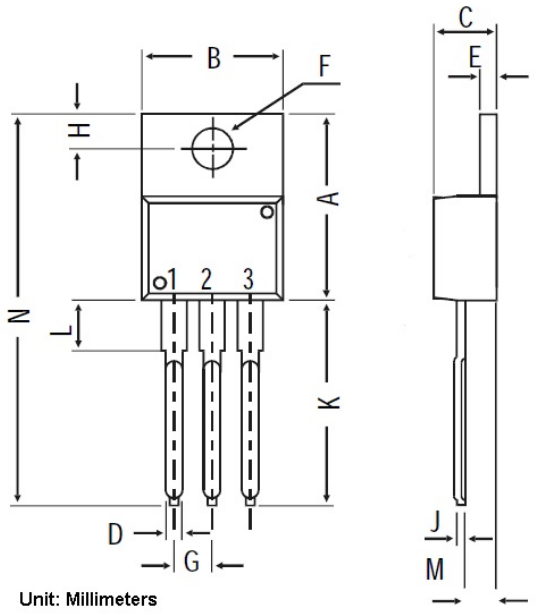
# Package Outline

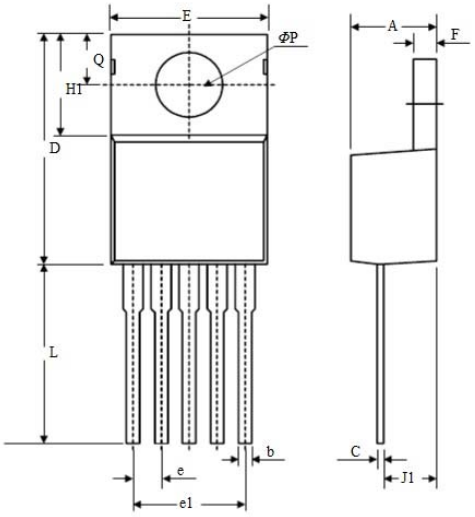
## TO-220-3:




Unit: Millimeters

| Symbols | Minimum | Normal | Maximum |
|---|---|---|---|
| A | 14.42 | 15.47 | 16.51 |
| B | 9.63 | 10.15 | 10.67 |
| C | 3.56 | 4.20 | 4.83 |
| D | - | 0.90 | - |
| E | 1.15 | 1.28 | 1.4 |
| F | 3.75 | 3.82 | 3.88 |
| G | 2.29 | 2.54 | 2.79 |
| H | 2.54 | 2.99 | 3.43 |
| J | - | 0.56 | - |
| K | 12.7 | 13.72 | 14.73 |
| L | 2.8 | 3.44 | 4.07 |
| M | 2.03 | 2.48 | 2.92 |
| N | - | 31.24 | - |

## TO-220-5:




| Symbols | Dimensions in Millimeters | | |
|---|---|---|---|
| | Minimum | Normal | Maximum |
| A | 4.07 | 4.45 | 4.82 |
| b | 0.76 | 0.89 | 1.02 |
| C | 0.36 | 0.5 | 0.64 |
| D | 14.22 | 14.86 | 15.5 |
| E | 9.78 | 10.16 | 10.54 |
| e | 1.57 | 1.71 | 1.85 |
| e1 | 6.68 | 6.81 | 6.93 |
| F | 1.14 | 1.27 | 1.4 |
| H1 | 5.46 | 6.16 | 6.86 |
| J1 | 2.29 | 2.74 | 3.18 |
| L | 13.21 | 13.97 | 14.73 |
| ΦP | 3.68 | 3.81 | 3.94 |
| Q | 2.54 | 2.73 | 2.92 |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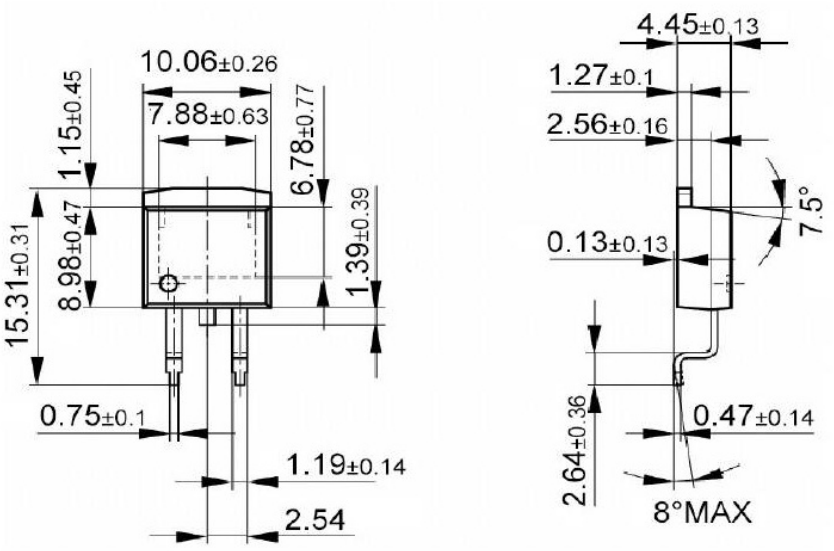
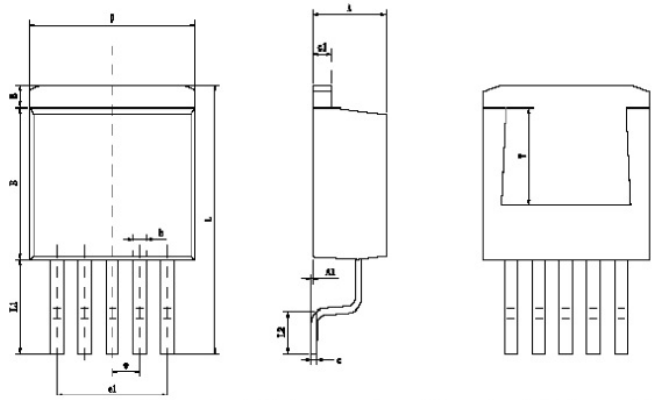
## Package Outline (Cont')

### TO-263-3:




### TO-263-5:



| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| A | 4.470 | 4.670 | 0.176 | 0.184 |
| A1 | 0.000 | 0.150 | 0.000 | 0.006 |
| B | 1.560 | 1.760 | 0.061 | 0.069 |
| b | 0.710 | 0.910 | 0.028 | 0.036 |
| c | 0.310 | 0.530 | 0.012 | 0.021 |
| c1 | 1.170 | 1.370 | 0.046 | 0.054 |
| D | 9.880 | 10.180 | 0.389 | 0.401 |
| E | 8.200 | 8.600 | 0.323 | 0.339 |
| e | 1.700TYP | | 0.067TYP | |
| e1 | 6.700 | 6.900 | 0.264 | 0.272 |
| L | 15.140 | 15.540 | 0.596 | 0.612 |
| L1 | 5.080 | 5.480 | 0.200 | 0.216 |
| L2 | 2.340 | 2.740 | 0.092 | 0.108 |

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