

### DESCRIPTION

The MP3399 is a step-up controller with 12-channel current sources designed for driving the WLED arrays for large size LCD panel backlighting applications. The MP3399 is flexible for extending LED channels with two or more MP3399s in parallel while operating from a single Inductor power source.

The MP3399 uses current mode, fixed frequency architecture. The switching frequency is programmable by an external frequency setting resistor. It drives an external MOSFET to boost up the output voltage from a 5V to 28V input supply. The MP3399 regulates the current in each LED string to the programmed value set by an external current setting resistor.

The MP3399 applies 12 internal current sources for current balance. And the current matching can achieve 2.5% regulation accuracy between strings. Its low 600mV regulation voltage on LED current sources reduces power loss and improves efficiency.

PWM dimming is implemented with external PWM input signal or DC input signal. The dimming PWM signal can be generated internally, and the dimming frequency is programmed by an external setting capacitor.

### FEATURES

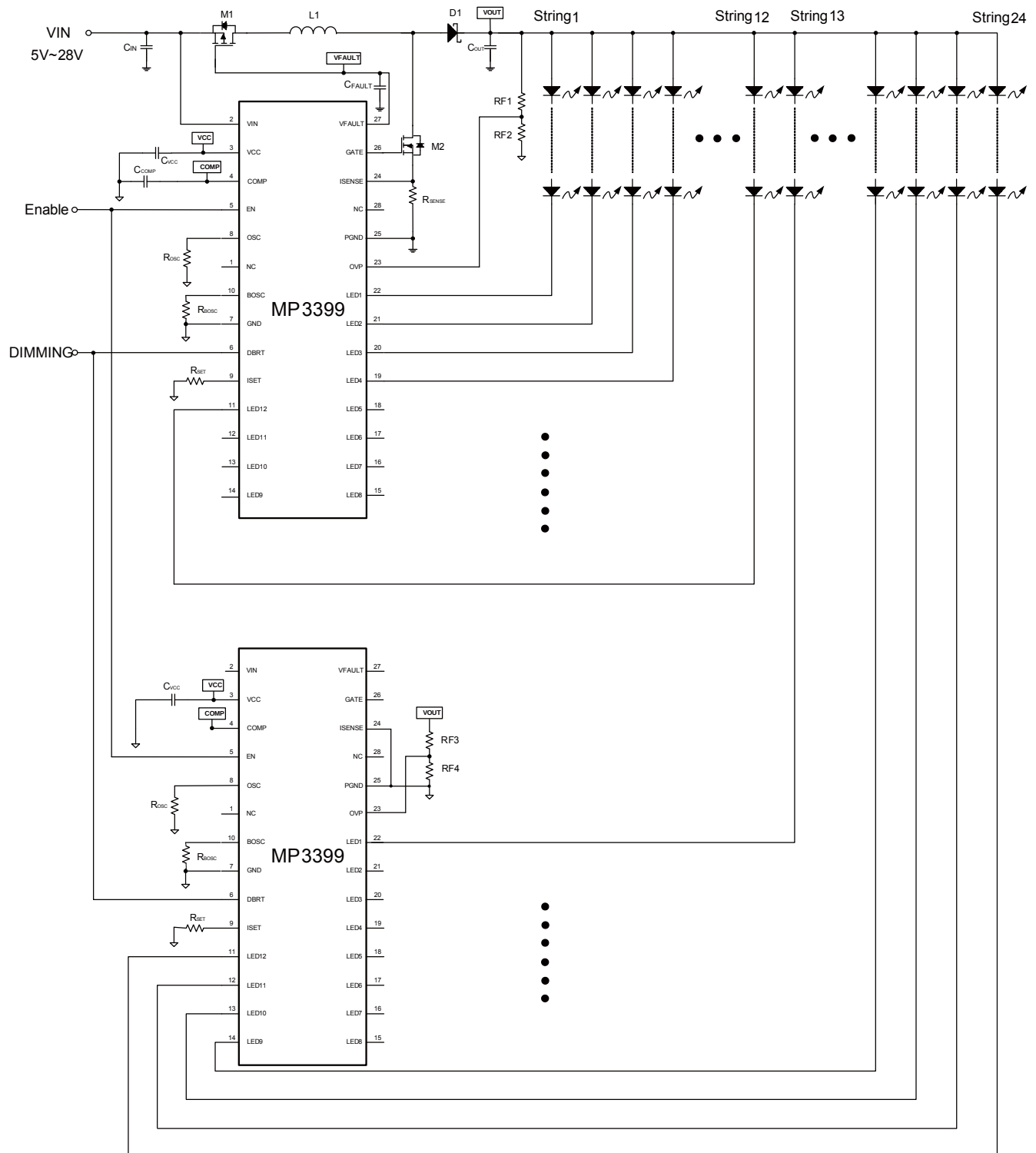
- 12 String, 60mA/String WLED Driver
- Cascading Capability with a single Power Source
- 5V to 28V Input Voltage Range
- Maximum 60mA for Each String
- 2.5% Current Matching Accuracy Between Strings
- Programmable Switching Frequency
- PWM or DC Input Burst PWM Dimming
- Open and Short LED Protection
- Programmable Over-voltage Protection
- Under Voltage Lockout
- Thermal Shutdown
- 28-pin TSSOP and 28-pin SOIC Package

### APPLICATIONS

- Desktop LCD Flat Panel Displays
- Flat Panel Video Displays
- LCD TVs and Monitors

All MPS parts are lead-free and adhere to the RoHS directive. For MPS green status, please visit MPS website under Quality Assurance. "MPS" and "The Future of Analog IC Technology" are Registered Trademarks of Monolithic Power Systems, Inc.

## TYPICAL APPLICATION



## ORDERING INFORMATION

| Part Number | Package | Top Marking | Free Air Temperature (T <sub>A</sub> ) |
|-------------|---------|-------------|----------------------------------------|
| MP3399EF*   | TSSOP28 | 3399EF      | -20°C to +85°C                         |
| MP3399EY**  | SOIC28  | 3399EY      | -20°C to +85°C                         |

\*For Tape & Reel, add suffix -Z (eg. MP3399EF-Z).

For RoHS compliant packaging, add suffix -LF (eg. MP3399EF-LF-Z)

\*\*For Tape & Reel, add suffix -Z (eg. MP3399EY-Z).

For RoHS compliant packaging, add suffix -LF (eg. MP3399EY-LF-Z)

## PACKAGE REFERENCE

|                                              |                                             |
|----------------------------------------------|---------------------------------------------|
| <p><b>TOP VIEW</b></p> <p><b>TSSOP28</b></p> | <p><b>TOP VIEW</b></p> <p><b>SOIC28</b></p> |
|----------------------------------------------|---------------------------------------------|

### ABSOLUTE MAXIMUM RATINGS <sup>(1)</sup>

|                                                                      |                 |
|----------------------------------------------------------------------|-----------------|
| V <sub>IN</sub> .....                                                | -0.3V to +30V   |
| V <sub>GATE</sub> .....                                              | -0.5V to 6.8V   |
| V <sub>VCC</sub> .....                                               | -0.5V to 6.8V   |
| V <sub>LED1</sub> to V <sub>LED12</sub> .....                        | -1V to +50V     |
| All Other Pins .....                                                 | -0.3V to +6.3V  |
| Continuous Power Dissipation (T <sub>A</sub> = +25°C) <sup>(2)</sup> |                 |
| TSSOP28.....                                                         | 3.9 W           |
| SOIC28.....                                                          | 2.1W            |
| Junction Temperature .....                                           | 150°C           |
| Lead Temperature .....                                               | 260°C           |
| Storage Temperature.....                                             | -65°C to +150°C |

### Recommended Operating Conditions <sup>(3)</sup>

|                                               |              |
|-----------------------------------------------|--------------|
| Supply Voltage V <sub>IN</sub> .....          | 5V to 28V    |
| LED Current (Backlight) .....                 | 10mA to 60mA |
| Maximum Junction Temp. (T <sub>J</sub> )..... | +125°C       |

### Thermal Resistance <sup>(4)</sup> θ<sub>JA</sub> θ<sub>JC</sub>

|               |    |    |      |
|---------------|----|----|------|
| TSSOP28 ..... | 32 | 6  | °C/W |
| SOIC28 .....  | 60 | 30 | °C/W |

#### Notes:

- Exceeding these ratings may damage the device.
- The maximum allowable power dissipation is a function of the maximum junction temperature T<sub>J</sub> (MAX), the junction-to-ambient thermal resistance θ<sub>JA</sub>, and the ambient temperature T<sub>A</sub>. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P<sub>D</sub> (MAX) = (T<sub>J</sub> (MAX)-T<sub>A</sub>)/θ<sub>JA</sub>. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- The device is not guaranteed to function outside of its operation conditions.
- Measured on JESD51-7, 4-layer PCB.

## ELECTRICAL CHARACTERISTICS

$V_{IN} = 12V$ ,  $V_{EN} = 5V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.

| Parameters                       | Symbol           | Condition                                                | Min  | Typ  | Max   | Units    |
|----------------------------------|------------------|----------------------------------------------------------|------|------|-------|----------|
| Operating Input Voltage          | $V_{IN}$         |                                                          | 4.5  |      | 28    | V        |
| Supply Current (Quiescent)       | $I_Q$            | $V_{IN}=12V$ , $V_{EN}=5V$ , no load with switching      |      | 4    |       | mA       |
| Supply Current (Shutdown)        | $I_{ST}$         | $V_{EN}=0V$ , $V_{IN}=12V$                               |      |      | 2     | $\mu A$  |
| LDO Output Voltage               | $V_{CC}$         | $V_{EN}=5V$ , $7V < V_{IN} < 28V$ , $0 < I_{VCC} < 10mA$ | 5.5  | 6    | 6.5   | V        |
| Input UVLO Threshold             | $V_{IN\_UVLO}$   | Rising Edge                                              | 3.4  | 3.9  | 4.3   | V        |
| Input UVLO Hysteresis            |                  |                                                          |      | 200  |       | mV       |
| EN High Voltage                  | $V_{EN\_HIGH}$   | $V_{EN}$ Rising                                          | 1.8  |      |       | V        |
| EN Low Voltage                   | $V_{EN\_LOW}$    | $V_{EN}$ Falling                                         |      |      | 0.6   | V        |
| <b>STEP-UP CONVERTER</b>         |                  |                                                          |      |      |       |          |
| Gate Driver Impedance (Sourcing) |                  | $V_{CC}=6V$ , $V_{GATE}=6V$                              |      | 4    |       | $\Omega$ |
| Gate Driver Impedance (Sinking)  |                  | $V_{CC}=6V$ , $I_{GATE}=10mA$                            |      | 2    |       | $\Omega$ |
| GATE Voltage                     | $V_{GATE}$       |                                                          |      | 6    |       | V        |
| Switching Frequency              | $f_{SW}$         | $R_{OSC} = 115k\Omega$                                   | 510  | 570  | 630   | kHz      |
|                                  |                  | $R_{OSC} = 374k\Omega$                                   | 150  | 170  | 190   | kHz      |
| OSC Voltage                      | $V_{OSC}$        |                                                          | 1.18 | 1.23 | 1.28  | V        |
| Minimum On Time                  | $T_{ON\_MIN}$    | PWM Mode, when no pulse skipping happens                 |      | 100  |       | ns       |
| Maximum Duty Cycle               | $D_{MAX}$        |                                                          | 90   |      |       | %        |
| ISENSE Limit                     |                  | Max Duty Cycle                                           | 175  | 220  | 265   | mV       |
| COMP Source Current Limit        | $I_{COMP\_SOLI}$ |                                                          |      | 65   |       | $\mu A$  |
| COMP Sink Current Limit          | $I_{COMP\_SILI}$ |                                                          |      | 15   |       | $\mu A$  |
| <b>PWM DIMMING</b>               |                  |                                                          |      |      |       |          |
| DBRT Leakage Current             | $I_{DBRT\_LK}$   |                                                          | -5   |      | 5     | $\mu A$  |
| BOSC Frequency                   | $F_{BOSC}$       | $C_{BOSC}=2.2nF$                                         | 1.2  | 1.6  | 2     | kHz      |
| BOSC Output Current              | $I_{BOSC}$       |                                                          | 6.37 | 7.5  | 8.63  | $\mu A$  |
| <b>LED CURRENT REGULATION</b>    |                  |                                                          |      |      |       |          |
| ISET Voltage                     | $V_{ISET}$       |                                                          | 1.20 | 1.22 | 1.245 | V        |
| LEDX Average Current             | $I_{LED}$        | $R_{ISET}=40k\Omega$                                     | 29.6 | 30.5 | 31.4  | mA       |
| Current Matching <sup>(5)</sup>  |                  | $I_{LED}=30.5mA$                                         |      |      | 2.5   | %        |

# ELECTRICAL CHARACTERISTICS *(continued)*

$V_{IN} = 12V$ ,  $V_{EN} = 5V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.

| Parameters                                           | Symbol         | Condition                             | Min  | Typ  | Max | Units       |
|------------------------------------------------------|----------------|---------------------------------------|------|------|-----|-------------|
| LEDX Regulation Voltage                              | $V_{LEDX}$     | $I_{LED} = 30.5mA$                    |      | 600  |     | mV          |
| <b>PROTECTION</b>                                    |                |                                       |      |      |     |             |
| OVP Over Voltage Threshold                           | $V_{OVP\_OV}$  | Rising Edge                           | 1.17 | 1.23 | 1.3 | V           |
| OVP UVLO threshold                                   | $V_{OVP\_UV}$  | Step-up Converter Fails               | 50   | 70   | 90  | mV          |
| LEDX UVLO Threshold                                  | $V_{LEDX\_UV}$ |                                       | 156  | 196  | 236 | mV          |
| LEDX Over Voltage Threshold                          | $V_{LEDX\_OV}$ |                                       | 5.8  | 6.3  | 6.8 | V           |
| Thermal Shutdown Threshold                           | $T_{ST}$       |                                       |      | 150  |     | $^{\circ}C$ |
| VFAULT Pull Down Current                             | $I_{FAULT}$    |                                       | 40   | 55   | 70  | $\mu A$     |
| VFAULT Blocking-Off Voltage<br>(with Respect to VIN) | $V_{FAULT}$    | $V_{IN} = 12V$ , $V_{IN} - V_{FAULT}$ | 5.3  | 5.8  | 6.3 | V           |

## Notes:

5) Matching is defined as the difference of the maximum to minimum current divided by 2 times average currents.

## PIN FUNCTIONS

| Pin # | Name  | Description                                                                                                                                                                                                                                                                                                                                                                       |
|-------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | NC    | No Connect.                                                                                                                                                                                                                                                                                                                                                                       |
| 2     | VIN   | Supply Input. VIN supplies the power to the chip, as well as the step-up converter switch. Drive VIN with a 5V to 28V power source. Must be locally bypassed.                                                                                                                                                                                                                     |
| 3     | VCC   | The Internal 6V Linear Regulator Output. VCC provides power supply for the internal MOSFET switch gate driver and the internal control circuitry. Bypass VCC to GND with a ceramic capacitor.                                                                                                                                                                                     |
| 4     | COMP  | Step-up Converter Compensation Pin. This pin is used to compensate the regulation control loop. Connect a ceramic capacitor from COMP to GND.                                                                                                                                                                                                                                     |
| 5     | EN    | Enable Control Input. Do not let this pin float. It is recommended TO locally filter WITH a 0.1 $\mu$ F ceramic capacitor.                                                                                                                                                                                                                                                        |
| 6     | DBRT  | Brightness Control Input. To use external PWM dimming mode, apply a PWM signal on this pin for brightness control. To use DC input PWM dimming mode, apply a DC voltage range from 0.2V to 1.2V on this pin linearly to set the internal dimming duty cycle from 0% to 100%. The MP3399 has positive dimming polarity on DBRT.                                                    |
| 7     | GND   | Analog Ground.                                                                                                                                                                                                                                                                                                                                                                    |
| 8     | OSC   | Switching Frequency Set. Connect a resistor between OSC and GND to set the step-up converter switching frequency. The voltage at this pin is regulated to 1.23V. The clock frequency is proportional to the current sourced from this pin.                                                                                                                                        |
| 9     | ISSET | LED Current Set. Tie a current setting resistor from this pin to ground to program the current in each LED string. The MP3399 regulates the voltage across the current setting resistor. The regulation voltage is 1.22V. The proportion of the current through the ISSET resistor and the LED current is 1:1000.                                                                 |
| 10    | BOSC  | Dimming Repetition Set. This is the timing pin for the oscillator to set the dimming frequency. To use DC input PWM dimming mode, connect a capacitor from this pin to GND to set the internal dimming frequency. A saw-tooth waveform is generated on this pin. To use external PWM dimming mode, connect a resistor from this pin to GND, and apply the PWM signal on DBRT pin. |
| 11    | LED12 | LED String 12 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 12 cathode to this pin.                                                                                                                                                                                                                              |
| 12    | LED11 | LED String 11 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 11 cathode to this pin.                                                                                                                                                                                                                              |
| 13    | LED10 | LED String 10 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 10 cathode to this pin.                                                                                                                                                                                                                              |
| 14    | LED9  | LED String 9 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 9 cathode to this pin.                                                                                                                                                                                                                                |
| 15    | LED8  | LED String 8 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 8 cathode to this pin.                                                                                                                                                                                                                                |

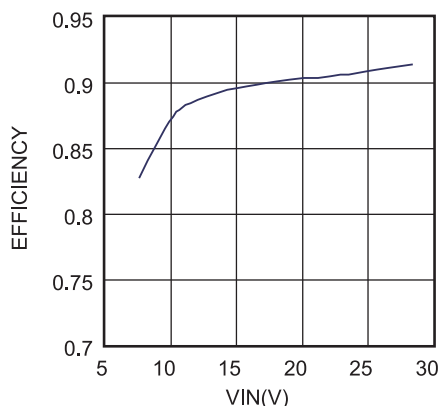
## PIN FUNCTIONS *(continued)*

| Pin # | Name   | Description                                                                                                                                                                                                                                                                                                                                                                   |
|-------|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 16    | LED7   | LED String 7 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 7 cathode to this pin.                                                                                                                                                                                                                            |
| 17    | LED6   | LED String 6 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 6 cathode to this pin.                                                                                                                                                                                                                            |
| 18    | LED5   | LED String 5 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 5 cathode to this pin.                                                                                                                                                                                                                            |
| 19    | LED4   | LED String 4 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 4 cathode to this pin.                                                                                                                                                                                                                            |
| 20    | LED3   | LED String 3 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 3 cathode to this pin.                                                                                                                                                                                                                            |
| 21    | LED2   | LED String 2 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 2 cathode to this pin.                                                                                                                                                                                                                            |
| 22    | LED1   | LED String 1 Current Input. This pin is the open-drain output of an internal dimming control switch. Connect the LED String 1 cathode to this pin.                                                                                                                                                                                                                            |
| 23    | OVP    | Over-voltage Protection Input. Connect a resistor divider from output to this pin to program the OVP threshold. When this pin voltage reaches 1.23V, the MP3399 triggers OV Protection mode.                                                                                                                                                                                  |
| 24    | ISENSE | Current Sense Input. During normal operation, this pin senses the voltage across the external inductor current sensing resistor for peak current mode control and also to limit the inductor current during every switching cycle. If this pin is not used in extending application with other master MP3399, tie this pin to GND, do not let this pin floating.              |
| 25    | PGND   | Step-up Converter Power Ground.                                                                                                                                                                                                                                                                                                                                               |
| 26    | GATE   | Step-up Converter Power Switch Gate Output. This pin drives the external power N-MOS device.                                                                                                                                                                                                                                                                                  |
| 27    | VFAULT | Fault Disconnection Switch Gate Output. When the system starts up normally, this pin smoothly turns on the external PMOS. When the MP3399 is disabled, the external PMOS is turned off to disconnect the input and output. A ceramic cap is recommended to add from this pin to GND to control the PMOS turn on speed so as to control the inrush current at system start up. |
| 28    | NC     | No Connect.                                                                                                                                                                                                                                                                                                                                                                   |

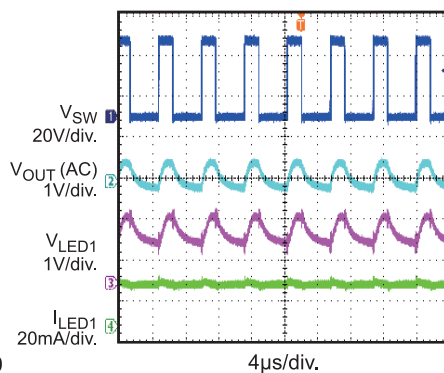
# TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 12V$ , 12 LEDs in series, 24 strings parallel, 20mA/string, unless otherwise noted.

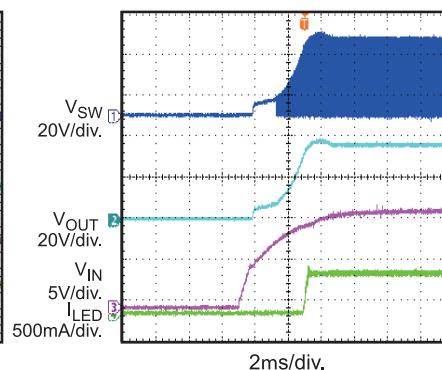
Efficiency vs. Input Voltage



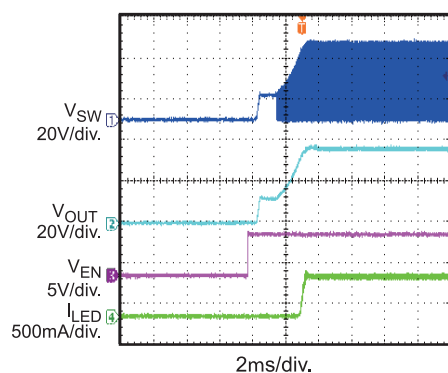
Steady State



Vin Startup

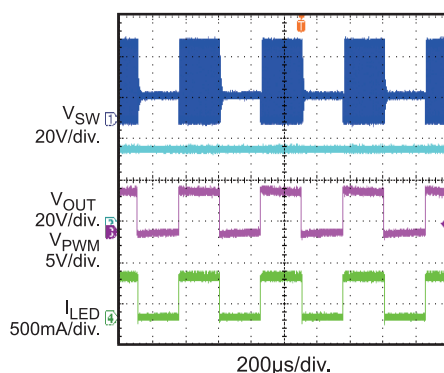


Ven Startup



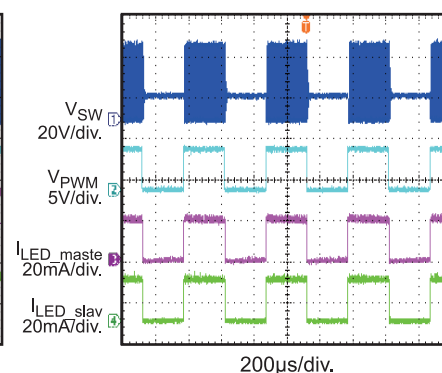
External PWM Dimming

$f_{PWM} = 2kHz$ ,  $D_{PWM} = 50\%$



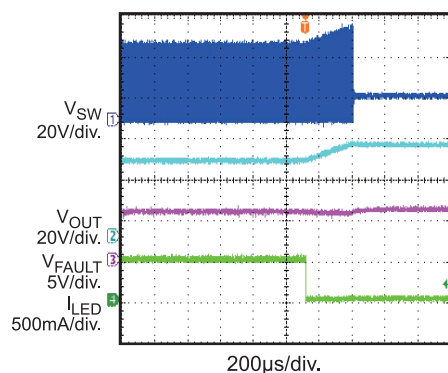
External PWM Dimming

$f_{PWM} = 2kHz$ ,  $D_{PWM} = 50\%$



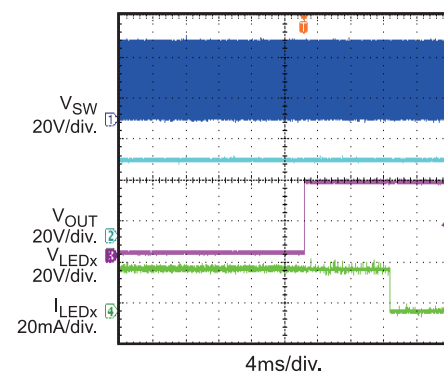
Open LED Protection

open all LED strings at working



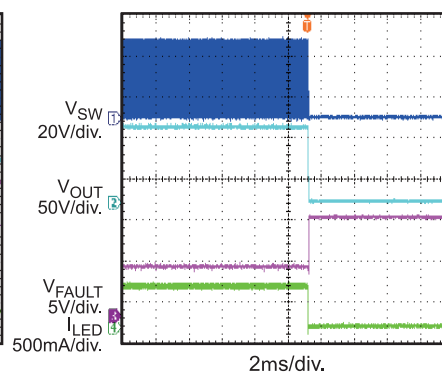
Short LED Protection

short  $V_{OUT}$  to LEDx at working



Short LED Protection

short  $V_{OUT}$  to GND at working



## FUNCTION DIAGRAM

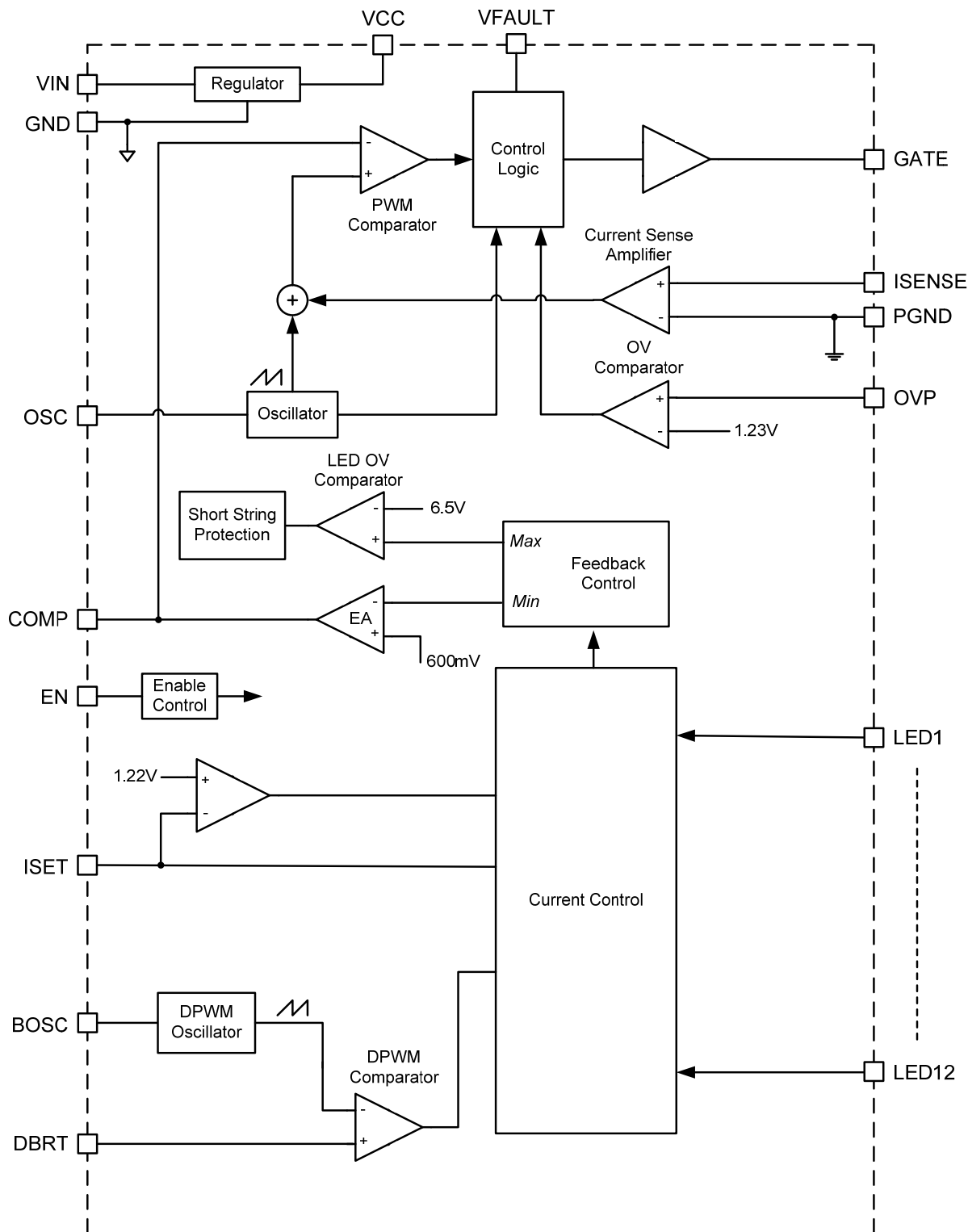


Figure 1—MP3399 Function Block Diagram

## OPERATION

The MP3399 employs a programmable constant frequency, peak current mode step-up converter and 12-channels regulated current sources to regulate the array of 12 strings white LEDs. The operation of the MP3399 can be understood by referring to the block diagram of Figure 1.

### Internal 6V Regulator

The MP3399 includes an internal linear regulator (VCC). When VIN is greater than 6.5V, this regulator offers a 6V power supply for the internal MOSFET switch gate driver and the internal control circuitry. The VCC voltage drops to 0V when the chip shuts down. In the application of VIN smaller than 6.5V, tie VCC and VIN together. The MP3399 features Under Voltage Lockout. The chip is disabled until VCC exceeds the UVLO threshold. And the hysteresis of UVLO is approximately 200mV.

### System Startup

When the MP3399 is enabled, the chip checks the topology connection first. The VFAULT pin drives the external Fault Disconnection PMOS to turn on slowly. Then the chip monitors the OVP pin to see if the Schottky diode is not connected or the boost output is short to GND. If the OVP voltage is lower than 70mV, the chip will be disabled and the external PMOS is turned off together. The MP3399 will also check other safety limits, including UVLO and OTP after the OVP test is passed. If they are all in function, it then starts boosting the step-up converter with an internal soft-start.

It is recommended on the start up sequence that the enable signal comes after input voltage and PWM dimming signal established.

### Step-up Converter

The converter operation frequency is programmable (from 150kHz to 500kHz) with an external set resistor on OSC pin, which is helpful for optimizing the external components sizes and improving the efficiency.

At the beginning of each cycle, the external MOSFET is turned with the internal clock. To prevent sub-harmonic oscillations at duty cycles

greater than 50 percent, a stabilizing ramp is added to the output of the current sense amplifier and the result is fed into the PWM comparator. When this result voltage reaches the output voltage of the error amplifier ( $V_{COMP}$ ) the external MOSFET is turned off.

The voltage at the output of the internal error amplifier is an amplified signal of the difference between the 600mV reference voltage and the feedback voltage. The converter automatically chooses the lowest active LEDX pin voltage for providing enough bus voltage to power all the LED arrays.

If the feedback voltage drops below the 600mV reference, the output of the error amplifier increases. It results in more current flowing through the power FET, thus increasing the power delivered to the output. In this way it forms a close loop to make the output voltage in regulation.

At light-load or Vout near to Vin operation, the converter runs into the pulse-skipping mode, the FET is turned on for a minimum on-time of approximately 100ns, and then the converter discharges the power to the output in the remain period. The external MOSFET will keep off until the output voltage needs to be boosted again.

### Dimming Control

The MP3399 provides two PWM dimming methods: external PWM signal or DC input PWM Dimming mode (see Figure 2). Both methods results in PWM chopping of the current in the LEDs for all 12 channels to provide LED control.

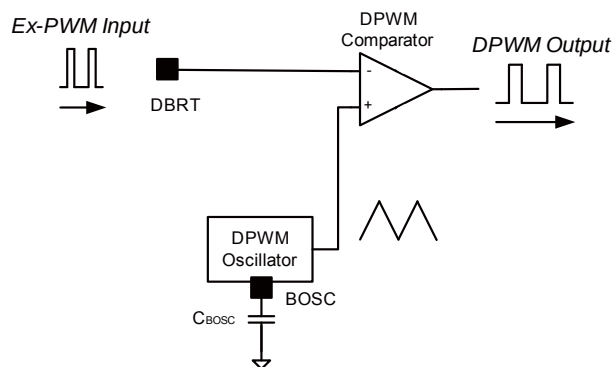


Figure 2—PWM Dimming Method

When bias the BOSC pin to a DC level by a resistor, applying an external PWM signal to the DBRT pin to achieve the PWM dimming. A DC analog signal can be directly applied to the DBRT pin to modulate the LED current. And the DC signal is then converted to a DPWM dimming signal at the setting oscillation frequency.

The brightness of the LED array is proportional to the duty cycle of the DPWM signal. The DPWM signal frequency is set by the cap at the BOSC pin.

### **Open String Protection**

The open string protection is achieved through the over voltage protection. If one or more strings are open, the respective LEDX pins are pulled to ground and the IC keeps charging the output voltage until it reach OVP threshold. Then the part will mark off the open strings whose LEDX pin voltage is less than 180mV. Once the mark-off operation completes, the remaining LED strings will force the output voltage back into tight regulation. The string with the highest voltage drop is the ruling string during output regulation.

The MP3399 always tries to light at least one string and if all strings in use are open, the MP3399 shuts down the step-up converter. The part will maintain mark-off information until the part shuts down.

### **Short String Protection**

The MP3399 monitors the LEDX pin voltage to judge if the short string occurs. If one or more strings are short, the respective LEDX pins will be pulled up to the boost output and tolerate high voltage stress. If the LEDX pin voltage is higher than 6.5V, the short string condition is detected on the respective string. When the short string fault (LEDX over-voltage fault) continues for greater than 2048 switching clocks, the string is marked off and disabled. Once a string is marked off, its current regulation is forced to disconnect from the output voltage loop regulation. The marked-off LED strings will be shut off totally until the part restarts. If all strings in use are short, the MP3399 will shut down the step-up converter.

## APPLICATION INFORMATION

### Selecting the Switching Frequency

The switching frequency of the step-up converter is programmable from 150kHz to 500kHz. A oscillator resistor on OSC pin sets the internal oscillator frequency for the step-up converter according to the equation:

$$f_{SW} = 67850 / R_{OSC} \text{ (k}\Omega\text{)}$$

For  $R_{OSC}=191\text{k}\Omega$ , the switching frequency is set to 355 kHz.

### Setting the LED Current

The LED string currents are identical and set through the current setting resistor on the ISET pin.

$$I_{LED} = 1000 \times 1.22V / R_{SET}$$

For  $R_{SET}=60.4\text{k}\Omega$ , the LED current is set to 20mA. The ISET pin can not be open.

### Selecting the Input Capacitor

The input capacitor reduces the surge current drawn from the input supply and the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current from passing through the input. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a  $4.7\mu\text{F}$  ceramic capacitor paralleled a  $220\mu\text{F}$  electrolytic capacitor is sufficient.

### Selecting the Inductor and Current Sensing Resistor

The inductor is required to force the higher output voltage while being driven by the input voltage. A larger value inductor results in less ripple current, resulting in lower peak inductor current and reducing stress on the internal N-Channel MOSFET. However, the larger value inductor has a larger physical size, higher series resistance, and lower saturation current.

Choose an inductor that does not saturate under the worst-case load conditions. A good rule for determining the inductance is to allow the peak-to-peak ripple current to be approximately 30% to 40% of the maximum input current. Calculate the required inductance value by the equation:

$$L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{V_{OUT} \times f_{SW} \times \Delta I}$$

$$I_{IN(MAX)} = \frac{V_{OUT} \times I_{LOAD(MAX)}}{V_{IN} \times \eta}$$

$$\Delta I = (30\% \sim 40\%) \times I_{IN(MAX)}$$

Where  $V_{IN}$  is the minimum input voltage,  $f_{SW}$  is the switching frequency,  $I_{LOAD(MAX)}$  is the maximum load current,  $\Delta I$  is the peak-to-peak inductor ripple current and  $\eta$  is the efficiency.

The switch current is usually used for the peak current mode control. In order to avoid hitting the current limit, the voltage across the sensing resistor  $R_{SENSE}$  should be less than 80% of the worst case current limit voltage, 220mV.

$$R_{SENSE} = \frac{0.8 \times 0.22V}{I_{L(PEAK)}}$$

Where  $I_{L(PEAK)}$  is the peak value of the inductor current.

### Selecting the Power MOSFET

The MP3399 is capable of driving a wide variety of N-Channel power MOSFETS. The critical parameters of selection of a MOSFET are:

1. Maximum drain to source voltage,  $V_{DS(MAX)}$
2. Maximum current,  $I_{D(MAX)}$
3. On-resistance,  $R_{DS(ON)}$
4. Gate source charge  $Q_{GS}$  and gate drain charge  $Q_{GD}$
5. Total gate charge,  $Q_G$

Ideally, the off-state voltage across the MOSFET is equal to the output voltage. Considering the voltage spike when it turns off,  $V_{DS(MAX)}$  should be greater than 1.5 times of the output voltage.

The maximum current through the power MOSFET happens when the input voltage is minimum and the output power is maximum. The maximum RMS current through the MOSFET is given by

$$I_{RMS(MAX)} = I_{IN(MAX)} \times \sqrt{D_{MAX}} \text{ Where:}$$

$$D_{MAX} \approx \frac{V_{OUT} - V_{IN(MIN)}}{V_{OUT}}$$

The current rating of the MOSFET should be greater than 1.5 times  $I_{RMS}$

The on resistance of the MOSFET determines the conduction loss, which is given by:

$$P_{\text{cond}} = I_{\text{RMS}}^2 \times R_{\text{DS(on)}} \times k$$

Where k is the temperature coefficient of the MOSFET.

The switching loss is related to  $Q_{\text{GD}}$  and  $Q_{\text{GS1}}$  which determine the commutation time.  $Q_{\text{GS1}}$  is the charge between the threshold voltage and the plateau voltage when a driver charges the gate, which can be read in the chart of  $V_{\text{GS}}$  vs.  $Q_{\text{G}}$  of the MOSFET datasheet.  $Q_{\text{GD}}$  is the charge during the plateau voltage. These two parameters are needed to estimate the turn on and turn off loss.

$$P_{\text{SW}} = \frac{Q_{\text{GS1}} \times R_{\text{G}}}{V_{\text{DR}} - V_{\text{TH}}} \times V_{\text{DS}} \times I_{\text{IN}} \times f_{\text{SW}} + \frac{Q_{\text{GD}} \times R_{\text{G}}}{V_{\text{DR}} - V_{\text{PLT}}} \times V_{\text{DS}} \times I_{\text{IN}} \times f_{\text{SW}}$$

Where  $V_{\text{TH}}$  is the threshold voltage,  $V_{\text{PLT}}$  is the plateau voltage,  $R_{\text{G}}$  is the gate resistance,  $V_{\text{DS}}$  is the drain-source voltage. Please note that the switching loss is the most difficult part in the loss estimation. The formula above provides a simple physical expression. If more accurate estimation is required, the expressions will be much more complex.

For extended knowledge of the power loss estimation, readers should refer to the book "Power MOSFET Theory and Applications" written by Duncan A. Grant and John Gowar.

The total gate charge,  $Q_{\text{G}}$ , is used to calculate the gate drive loss. The expression is

$$P_{\text{DR}} = Q_{\text{G}} \times V_{\text{DR}} \times f_{\text{SW}}$$

Where  $V_{\text{DR}}$  is the drive voltage.

### Selecting the Output Capacitor

The output capacitor keeps the output voltage ripple small and ensures feedback loop stability. The output capacitor impedance should be low at the switching frequency. Ceramic capacitors with X7R dielectrics are recommended for their low ESR characteristics. For most applications, a 4.7μF ceramic capacitor paralleled 10μF electrolytic capacitor will be sufficient.

### Setting the Over Voltage Protection

The open string protection is achieved through the over voltage protection (OVP). In some cases, an LED string failure results in the feedback voltage always zero. The part then keeps boosting the output voltage higher and higher. If the output voltage reaches the programmed OVP threshold, the protection will be triggered.

To make sure the chip functions properly, the OVP setting resistor divider must be set with a proper value. The recommended OVP point is about 1.2 times higher than the output voltage for normal operation.

$$V_{\text{OVP}} = 1.23V \times (R_1 + R_2) / R_2$$

### Selecting Dimming Control Mode

The MP3399 provides 2 different dimming methods

#### 1. Direct PWM Dimming

An external PWM dimming signal is employed to achieve PWM dimming control. Connect a 100kΩ resistor from BOSC pin to GND and apply the 100Hz to 2kHz PWM dimming signal to DBRT pin. The minimum recommended amplitude of the PWM signal is 1.2V (See Figure 3).

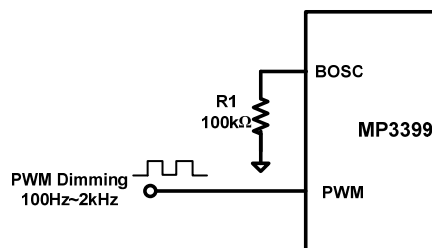


**Figure 3—Direct PWM Dimming**

#### 2. DC Input PWM Dimming

To apply DC input PWM dimming, apply an analog signal (range from 0 V to 1.2V) to the DBRT pin to modulate the LED current directly. If the PWM is applied with a zero DC voltage, the PWM duty cycle will be 0%. If the DBRT pin is applied with a DC voltage > 1.2V, the output will be 100% (See Figure 4). The capacitor on BOSC pin set the frequency of internal triangle waveform according to the equation,:

$$F_{\text{UNITE}} = 3.5\mu\text{F} / C_{\text{UNITE}}$$

The dimming frequency is recommended set from 100Hz to 2kHz.

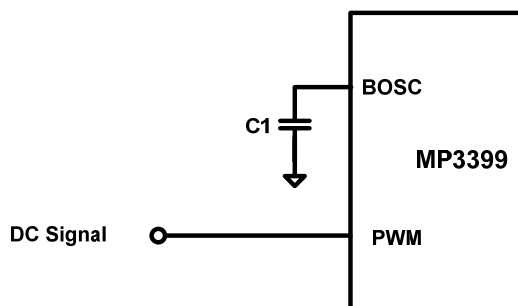


**Figure 4—DC input PWM Dimming**

### Extending LED Channels applications

The MP3399 is flexible for extending LED channels with two or more MP3399s in parallel. For the connection of two MP3399s extending 24 strings LEDs, please see the typical application diagram in page 2. Tie the VCC pins of the master IC and the slave IC together to provide the power of the slave IC internal logic circuitry. Also tie the COMP pins of the slave IC and the master IC together to regulate the voltage of all 24 strings LEDs. The MOS driving signals of the slave IC are not used, the boost converter can be only driven by the master IC. Do not let the Isense pin of the slave IC floating, tie it to GND. The EN and Dimming signals should be applied to both ICs. It is recommended to use external PWM dimming mode to achieve the accurate dimming synchronization of both parts.

### Layout Considerations

Careful attention must be paid to the PCB board layout and components placement. Proper layout of the high frequency switching path is critical to prevent noise and electromagnetic interference problems. The loop of external MOSFET (M2), output diode (D1), and output capacitor (C5) is flowing with high frequency pulse current. It must be as small as possible (See Figure 5).

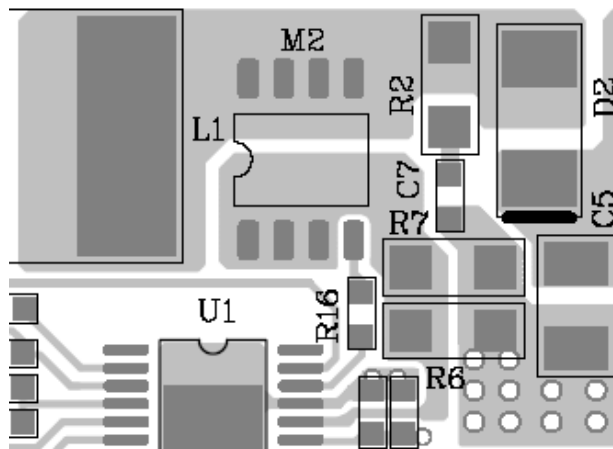


**Figure 5—Layout Consideration**

The IC exposed pad is internally connected to GND pin, and all logic signals are refer to the GND. The PGND should be externally connected to GND and is recommended to keep away from the logic signals.

### External MOSFET for Short Protection

When output voltage is higher than rating of LED1-12 pins, external MOSFET is needed for each LED channel to avoid destroying LED1 -12 pins. (See Figure 8 for 4 channels application) The rating of MOSFET must be higher than  $1.2 \cdot V_{OUT}$  and more than  $1.2 \cdot I_{LED}$ .

## TYPICAL APPLICATION CIRCUIT

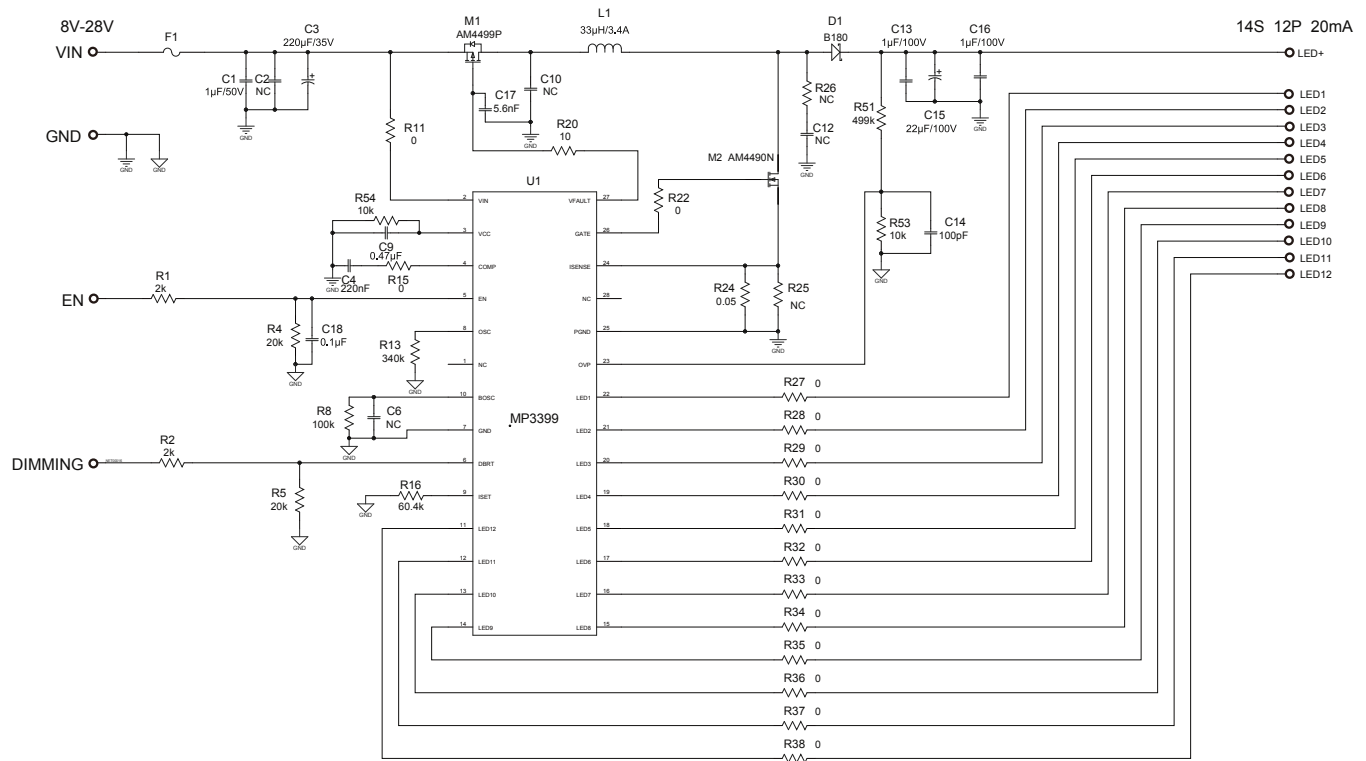


**Figure 6—Drive 14 LEDs in Series, 12 Strings 20mA/string**

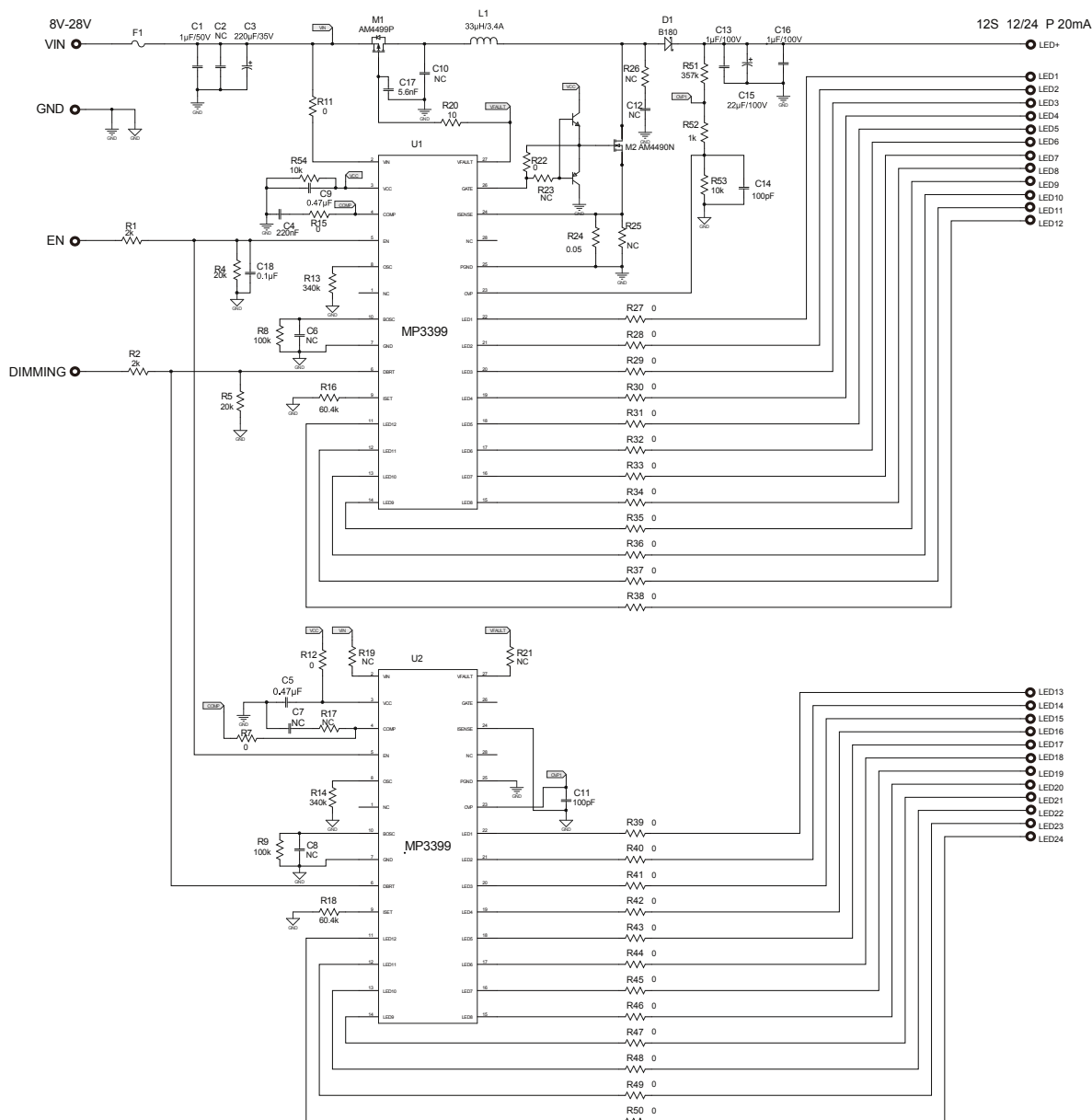


Figure 7—Drive 12 LEDs in Series, 24 Strings 20mA/string

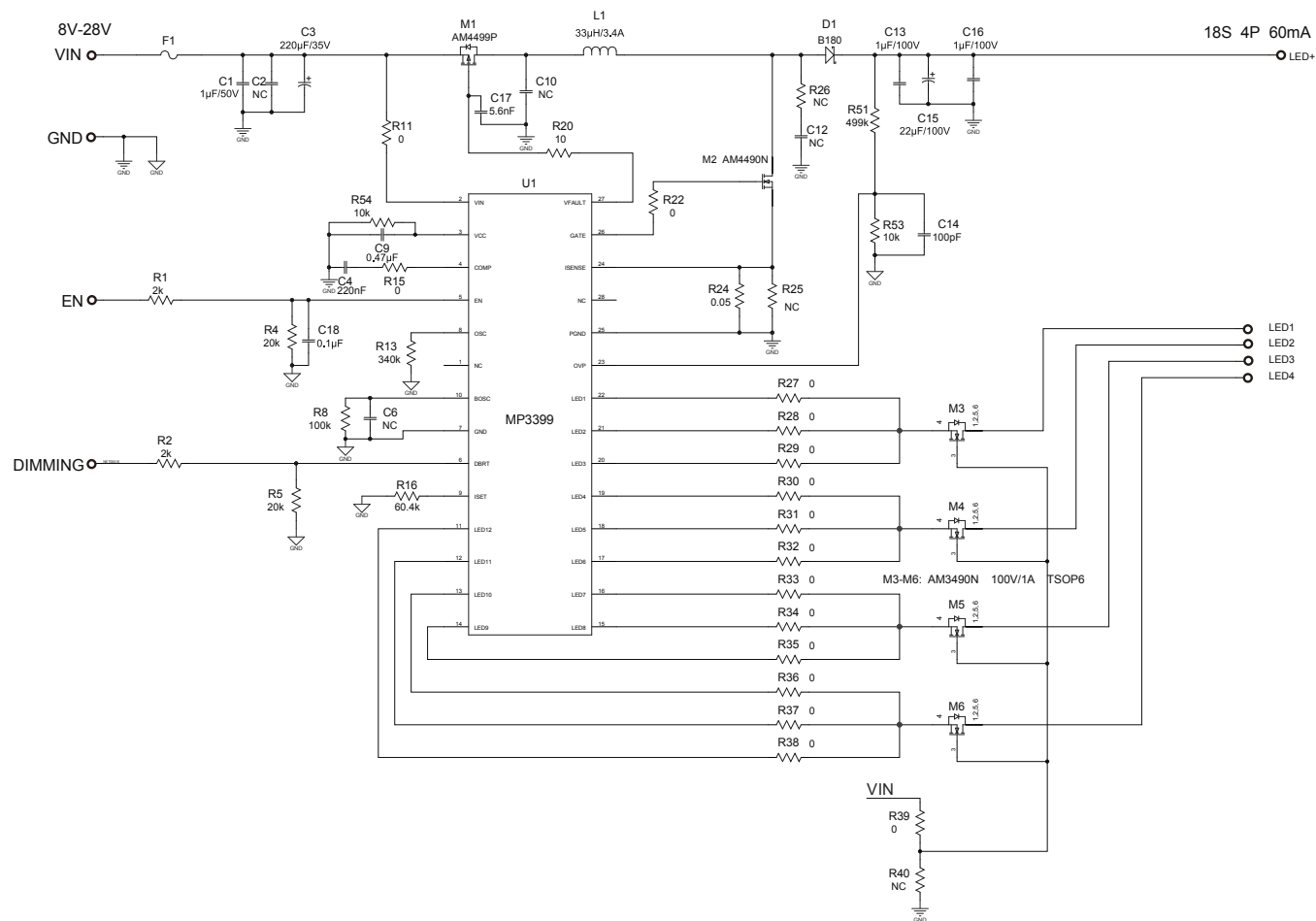
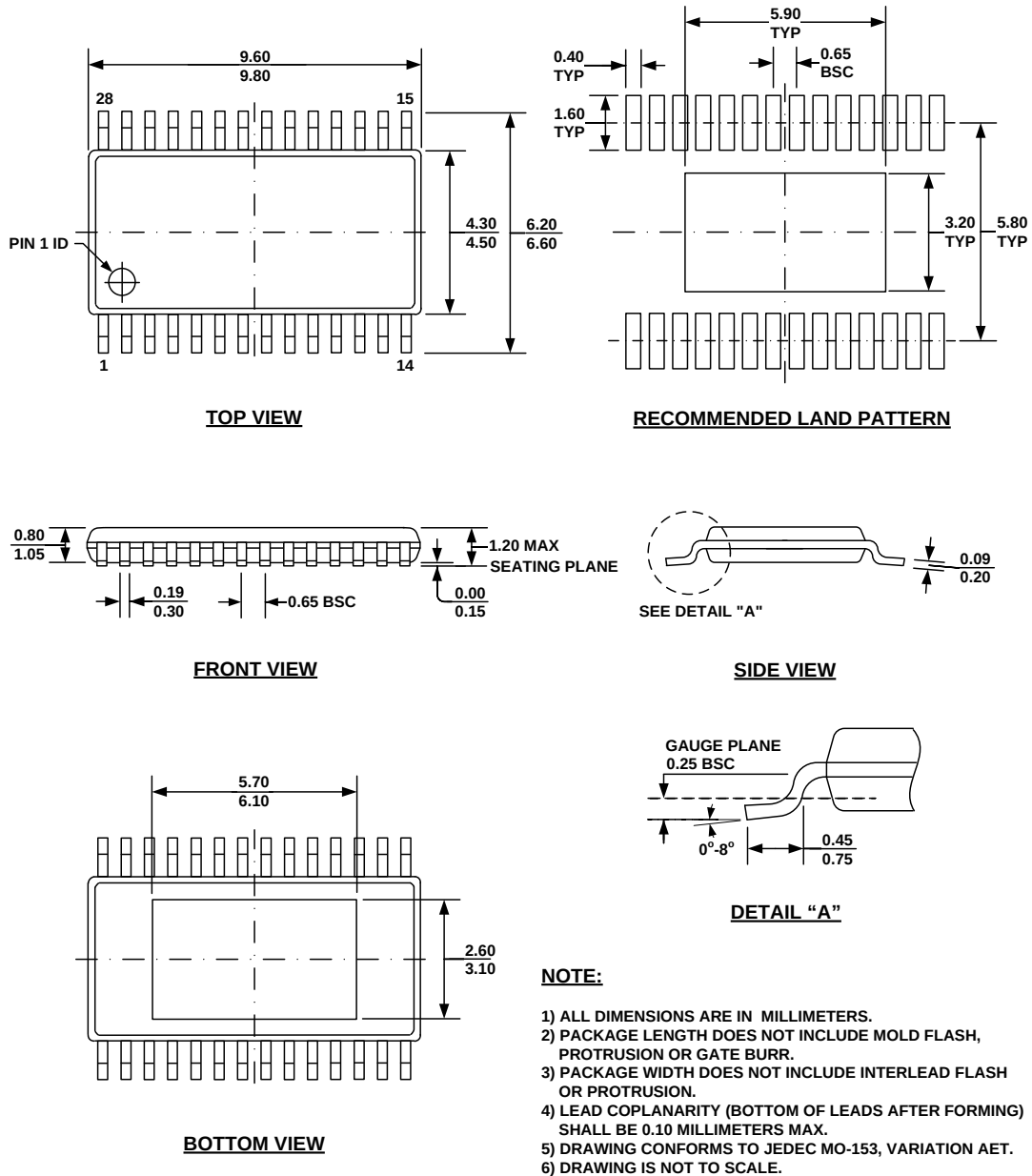


Figure 8 – Drive 18LEDs in Series, 4 strings 60mA/string

Note: For Vin>15V application, use R139 and R40(10kΩ) divider to make a 15V bias voltage for M3-M6.

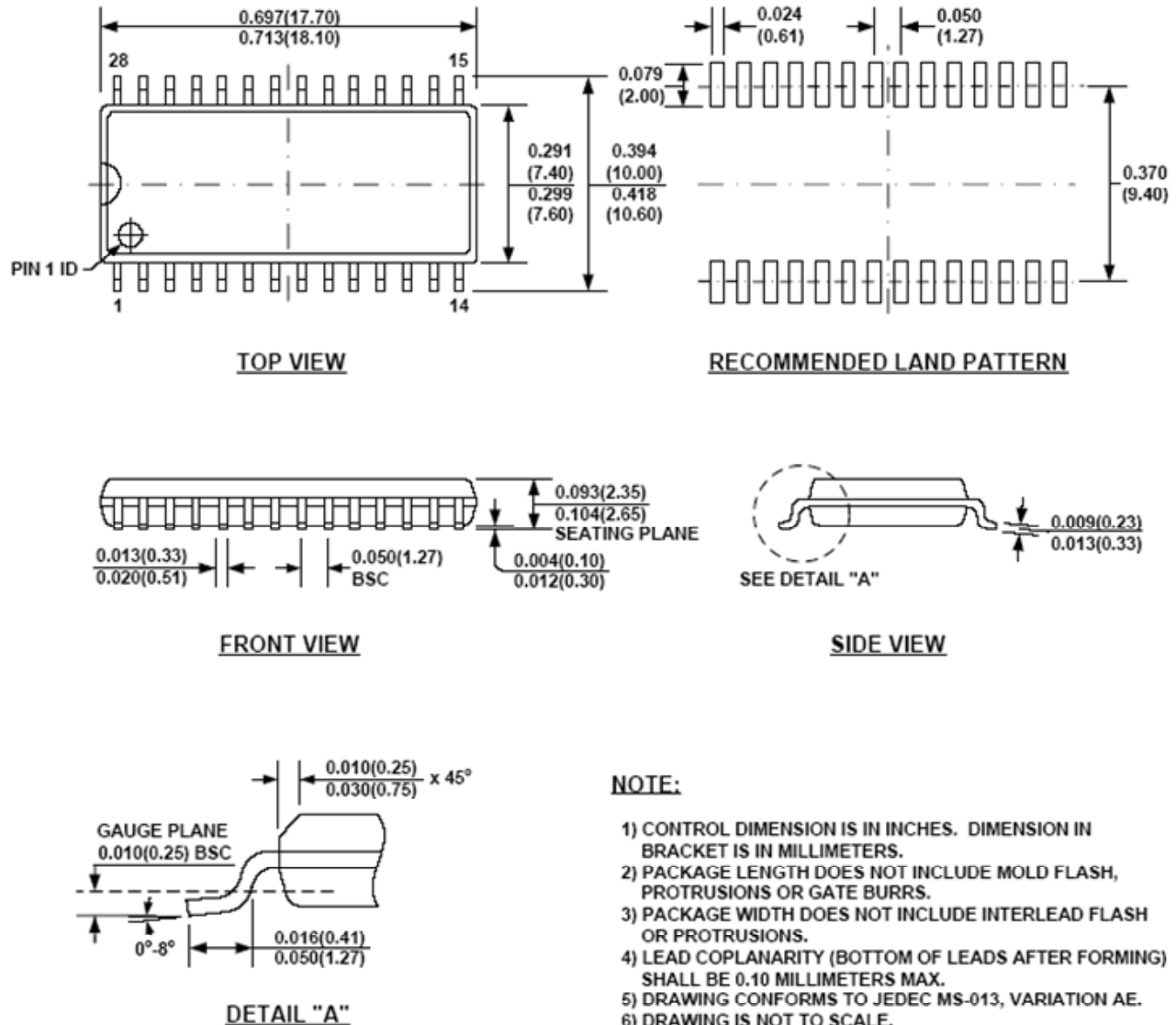
# PACKAGE INFORMATION

## PACKAGE OUTLINE DRAWING FOR 28-TSSOP w/ EXPOSED PADDLE



# PACKAGE INFORMATION

## SOIC28



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