

Atmel LED Drivers

MSL3167/MSL3168

16-string, White LED Drivers with Adaptive Power Control,
Simple PWM Dimming Interface, and Fault Handling

Datasheet Brief



Atmel LED Drivers-MSL3167/MSL3168

16-string, White LED Drivers with Adaptive Power Control, Simple PWM Dimming Interface, and Fault Handling

General Description

The Atmel® LED Drivers-MSL3167 and MSL3168 compact, high-power, 16 parallel string LED drivers feature internal current control MOSFETs that can sink up to 30mA per LED string with better than 3% accuracy. These devices drive up to 10 white LEDs per string, for up to 160 LEDs per MSL3167/8. A single PWM input controls the PWM period and duty cycle for all strings.

Note: This MSL3167/8 Datasheet Brief explains direct drive PWM use of the device, including control of a single, external string power supply. The device is configured to operate this way automatically at power-up. The MSL3187/8 offer extended features not explained in this Datasheet Brief that include additional fault reporting and management, an I²C serial interface, and programmable power-up state. For information about these and other MSL3187/8 features, refer to the full MSL3187/8 Datasheet.

The MSL3167/8 includes automatic fault management of string open circuit, short circuit and over-temperature conditions. Faults are alerted on the FLT pin, and fault status is optionally available through the I²C/SMBus-compatible serial interface.

The MSL3167/8 adaptively controls the DC-DC converter that powers the LED strings using Atmel Adaptive SourcePower® technology. This Efficiency Optimizer minimizes power use while maintaining LED current accuracy.

A single, external resistor provides the global reference current for all the LED strings. The MSL3167 operates all 16 strings in phase, while the MSL3168 calculates and applies a 1/16th PWM period delay to successive strings to evenly spread the string power supply load across time.

The MSL3167/8 are offered in a wave-solderable, 32-pin SOP package (1.27mm pin pitch) and operate over a -40°C to +105°C temperature range.

Applications

Long Life, Efficient LED Backlighting for:

- Televisions and Desktop Monitors
- Medical and Industrial Instrumentation
- Automotive Audio-visual Displays

Ordering Information

| PART | DESCRIPTION | PACKAGE |
|-----------|---|---------------------------------|
| MSL3167GU | 16-Ch LED driver with in-phase strings | 32-pin SOP, 1.27mm pin pitch |
| MSL3168GU | 16-Ch LED driver with auto-phased strings | 32-pin SOP, 1.27mm pin pitch |

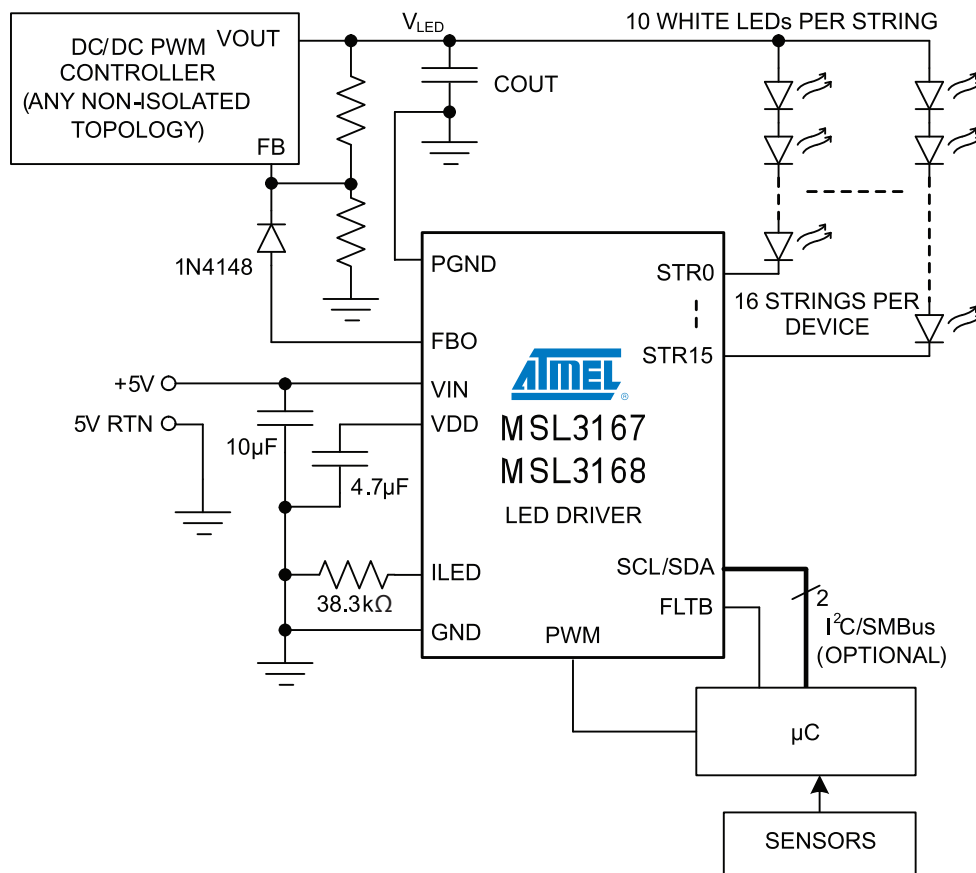
Atmel LED Drivers-MSL3167/MSL3168

16-string, White LED Drivers with Adaptive Power Control, Simple PWM Dimming Interface, and Fault Handling

Key Features

- Drives 16 Parallel LED Strings of 10 White LEDs Each
- Up to 30mA LED String Current
- Adaptive Power Optimizer Minimizes Power Use
- Automatic Open Circuit and Short Circuit Fault Management
- Single Resistor Sets Maximum Current for all Strings
- $\pm 3\%$ Current Accuracy and Current Balance
- Less than $10\mu\text{A}$ String-off Leakage Current
- LED Intensity Controlled by PWM Input
- Single PWM Input Sets LED Period and Duty Cycle
- Automatic LED String Phase Delay of 1/16th PWM Period per String Spreads LED String Power Supply Load (MSL3168)
- Enable Input Allows Low-power Shutdown
- 1MHz I²C/Smbus-compatible Interface Monitors Status, but is not Required for Operation
- Wave-solderable SOP Package (1.27mm Pitch)
- -40°C To $+105^{\circ}\text{C}$ Operating Temperature Range
- Over-temperature Shutdown with Automatic Wake-up

Application Circuit





Package Pin-outs and Dimensions

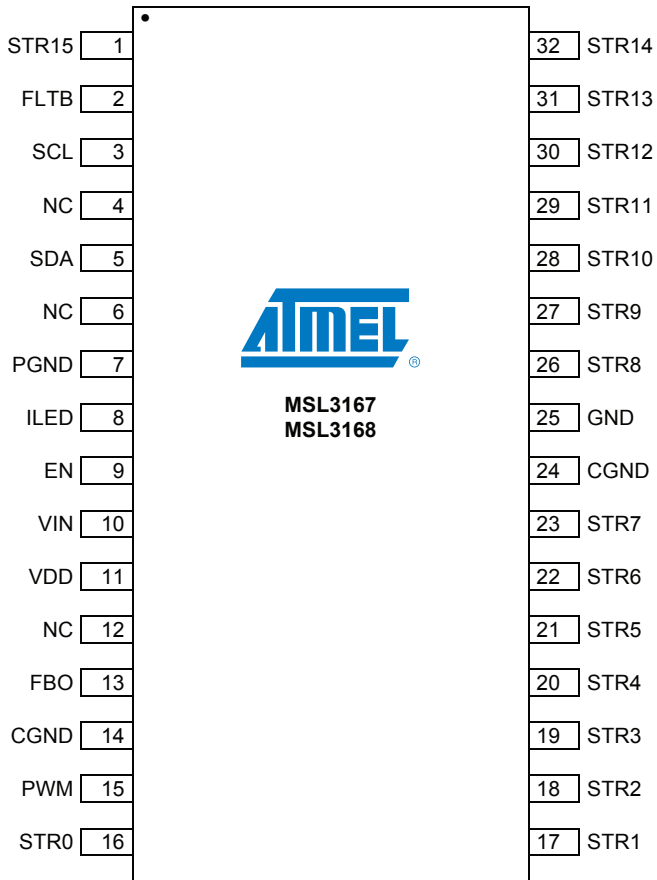


Figure 1. Atmel LED Drivers-MSL3167/8 Pin-out, 32-pin SOP.

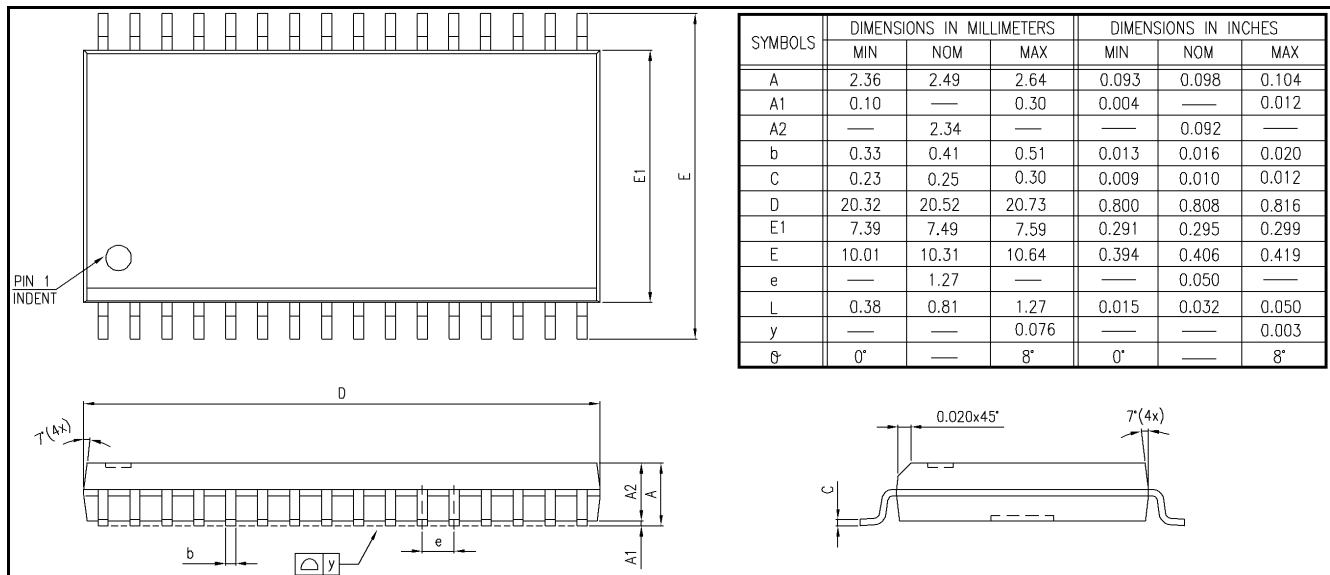


Figure 2. Package Dimensions: 32-pin, 20.52mm x 7.49mm x 2.49mm SOP (1.27mm Pin Pitch).

Atmel LED Drivers-MSL3167/MSL3168

16-string, White LED Drivers with Adaptive Power Control,
Simple PWM Dimming Interface, and Fault Handling

Pin Description

Table 1. Pin Descriptions

| PIN # | NAME | DESCRIPTION |
|---------------------------|-----------------------|---|
| 1, 16 - 23, 26 - 32 | STR0 thru STR15 | LED strings STR0 thru STR15 current sink outputs Connect the cathode of the n th string's bottom LED to STRn. Connect unused STRn outputs to GND. |
| 2 | FLT B | Fault indication output, active low FLT B sinks current to GND whenever the MSL3167/8 detect a string fault. When active, FLT B remains low until EN is forced low or power is cycled. |
| 3 | SCL | I²C serial clock input SCL is the clock input for the I ² C serial interface. Connect to GND if unused. |
| 4, 6, 12 | NC | No connection Factory test. Make no connection to NC. |
| 5 | SDA | I²C serial data I/O SDA is the data I/O for the I ² C serial interface. Connect to GND if unused. |
| 7 | PGND | Power ground PGND is the path that the STRn sink currents take to ground. Connect PGND to the ground of the string power supply with wide traces. Also, connect PGND to EP for the TQFN packaged device. |
| 8 | I _{LED} | String maximum current setting input Connect a resistor from I _{LED} to GND to set the full-scale LED string current. See the section, "Setting the Maximum LED String Current with R _{I_{LED}} " on page 11 for information about sizing the resistor. |
| 9 | EN | Enable input (active high) Force EN high to turn on the MSL3167/8. Force EN low to turn off the MSL3167/8 and to clear FLT B. For automatic start-up, connect EN to VIN. |
| 10 | VIN | Supply voltage input Connect a 5V supply to VIN. Bypass VIN to GND with a ceramic capacitor of at least 10µF placed close to VIN. |
| 11 | VDD | 2.5V internal LDO regulator output VDD is the output of an internal linear regulator powered from VIN. VDD powers internal logic. Bypass VDD to GND with a ceramic capacitor of at least 4.7µF placed close to VDD. |
| 13 | FBO | Efficiency Optimizer output FBO sources current to the voltage divider of an external DC-DC converter to dynamically adjust the LED power supply for optimal efficiency. |
| 14, 24 | CGND | Connect to GND Connect CGND to GND. |
| 15 | PWM | PWM dimming input Drive PWM with a pulse-width modulated signal with duty ratio ranging from 0% to 100% and frequency from 20Hz to 50kHz to control the brightness of all LED strings. |
| 25 | GND | Signal ground GND is the ground reference for VDD, VIN, and the serial interface. |
| - | EP | Exposed pad Connect EP to PGND with a short, wide trace. EP provides a path to ground for the string currents, and also provides thermal relief for the die. |



Absolute Maximum Ratings

Voltage (With Respect to GND, PGND = GND)

| | |
|------------------------|-----------------------|
| VIN, EN..... | -0.3V to +6V |
| VDD..... | -0.3V to +2.75V |
| SDA, SCL, FLTB..... | -0.3V to +6V |
| PWM, FBO..... | -0.3V to (VIN + 0.3V) |
| I _{LED} | -0.3V to (VDD + 0.3V) |
| STR0 thru STR15..... | -0.3V to +40V |
| CGND..... | -0.3V to +0.3V |

Current (Into Pin)

| | |
|----------------------|--------|
| VIN..... | 50mA |
| STR0 thru STR15..... | 45mA |
| PGND..... | -720mA |
| All other pins..... | 20mA |

Continuous Power Dissipation

32-pin SOP (derate 28.7mW/°C above T_A = +70°C) 1576mW

Ambient Operating Temperature Range T_A = T_{MIN} to T_{MAX} **-40°C to +85°C**

Junction Temperature **+125°C**

Storage Temperature Range..... **-65°C to +125°C**

Lead Soldering Temperature, 10s **+300°C**

Electrical Characteristics

Typical application circuit, VIN = 5V, T_A = T_{MIN} to T_{MAX}, unless otherwise noted. Typical values are at VIN = 5V, T_A = +25°C

| PARAMETER | SYMBOL | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT | |
|--------------------------------------|--------------------|---|-----------|-----|------|------|----|
| DC ELECTRICAL CHARACTERISTICS | | | | | | | |
| VIN operating supply voltage | VIN | | 4.75 | 5 | 5.50 | V | |
| VIN operating supply current | I _{VIN} | EN = VIN, SLEEP = 0, R _{I_{LED}} = 38.3kΩ, ISTR = 0xFF, PWMDIRECT = 1, PWMGLBLEN = 0 | 50% duty | | 15 | 25 | mA |
| | | | 100% duty | | 19 | 29 | |
| VIN shutdown supply current | I _{SHDN} | EN = GND, SDA, SCL and PWM = GND | | 10 | | μA | |
| VIN sleep current | I _{SLEEP} | EN = 1, SLEEP = 1, SDA, SCL, PWM = GND or VDD | | 1.5 | | mA | |
| VDD regulation voltage | VDD | | 2.4 | 2.5 | 2.6 | V | |

Atmel LED Drivers-MSL3 167/MSL3 168

16-string, White LED Drivers with Adaptive Power Control,
Simple PWM Dimming Interface, and Fault Handling

| PARAMETER | SYMBOL | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|---|------------|--|-----------|-------|-----------|-------------|
| Input high voltage SDA, SCL, PWM | V_{IH} | | 0.7 x VDD | | | V |
| Input low voltage SDA, SCL, PWM | V_{IL} | | | | 0.3 x VDD | V |
| Input high voltage: EN | | | 1.22 | | | V |
| Input low voltage: EN | | | | | 0.8 | V |
| Output low voltage: SDA, FLTB | V_{OL} | $I_{SINK} = 5mA$ | | | 0.4 | V |
| I _{LED} regulation voltage | | $R_{ILED} = 38.3k\Omega$ | | 350 | | mV |
| FBO feedback output current | | $V_{FBO} \leq VIN - 0.5V$ | 0 | | 365 | μA |
| FBO feedback output current step size | | | | 1.1 | | μA |
| STR0 thru STR15 sink current | | $R_{ILED} = 38.3k\Omega$, ISTR = 0xFF, $V_{STRn} = 1V$ | 18 | 20 | 22 | mA |
| STR0 to STR15 string sink current maximum | | $R_{ILED} = 25.5k\Omega$, ISTR = 0xFF (Note 1) | | 30 | | mA |
| STR0 to STR15 string-off leakage current | | | | | 10 | μA |
| STR0 thru STR15 current load regulation | | $R_{ILED} = 38.3k\Omega$, ISTR = 0xFF, FLDBKEN = 0, $V_{STRn} = 1V$ to 5V | | 0.033 | | %/V |
| STR0 to STR15 current matching | | ISTR = 0xFF, $R_{ILED} = 38.3k\Omega$, $V_{STRn} = 1V$ | -5 | | 5 | % |
| STR0 to STR15 minimum headroom | V_{STR} | $R_{ILED} = 38.3k\Omega$, ISTR = 0xFF | | 150 | | mV |
| STR0 to STR15 short circuit fault detection threshold | SC_{REF} | | | 8.4 | | V |
| STR0 thru STR15 current slew rate | | Current rising (Note 2) | | 200 | | mA/ μs |
| | | Current falling (Note 2) | | 8,000 | | |
| Thermal shutdown temperature | | (Note 2) | | 135 | | $^{\circ}C$ |

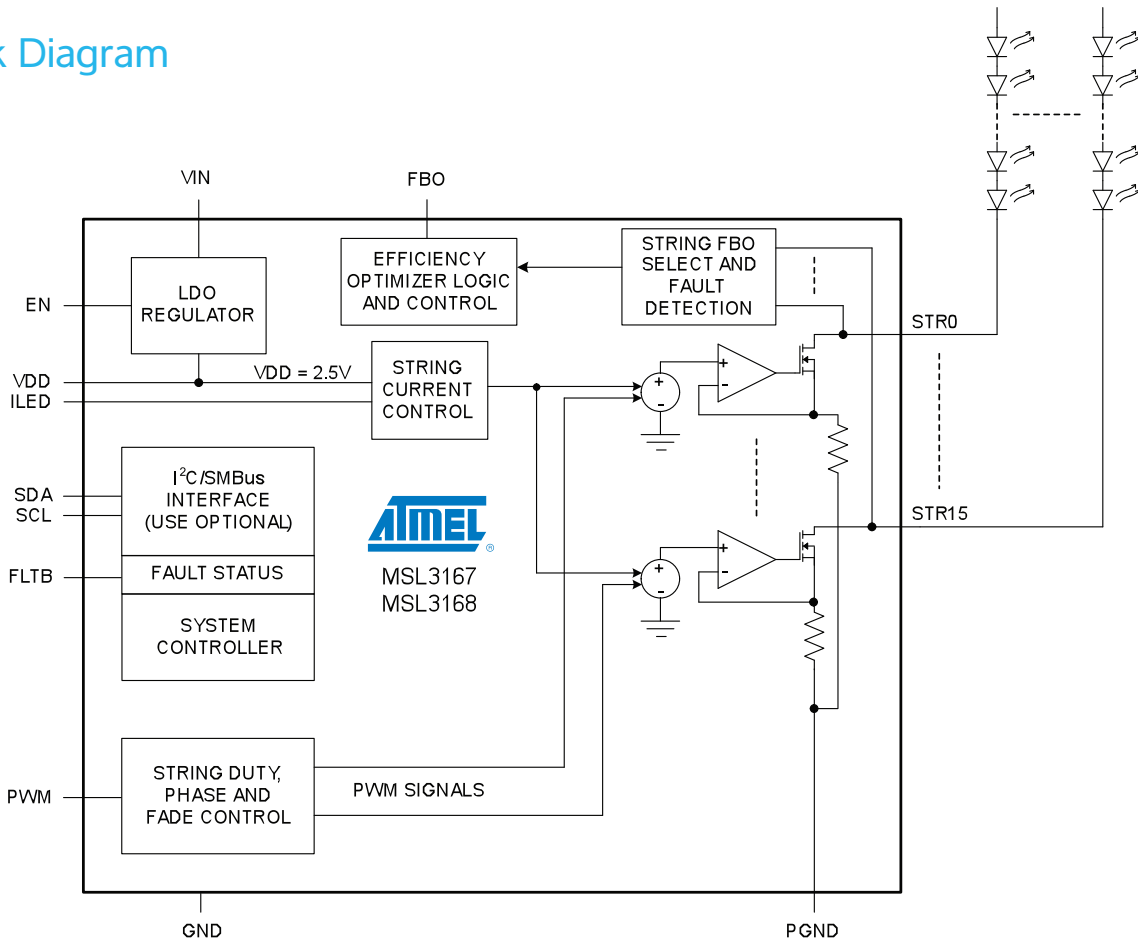
| PARAMETER | SYMBOL | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|--|---------------|-------------------------------|------|---------------------|------|---------|
| AC ELECTRICAL CHARACTERISTICS | | | | | | |
| PWM frequency | f_{PWM} | | | | 50 | kHz |
| PWM duty cycle | | | 0 | | 100 | % |
| I²C TIMING CHARACTERISTICS | | | | | | |
| SCL clock frequency | $1/t_{SCL}$ | Bus timeout disabled (Note 3) | 0 | | 1 | MHz |
| Bus timeout period | $t_{timeout}$ | OSCCTRL = 0x04 | | 30 | | ms |
| | | $f_{OSC} = 16MHz$ to 23MHz | | $600,000 / f_{OSC}$ | | s |
| STOP to START condition bus free time | t_{BUF} | | 0.5 | | | μs |
| Repeated START condition hold time | $t_{HD:STA}$ | | 0.26 | | | μs |
| Repeated START condition setup time | $t_{SU:STA}$ | | 0.26 | | | μs |
| STOP condition set-up time | $t_{SU:STOP}$ | | 0.26 | | | μs |
| SDA data hold time | $t_{HD:DAT}$ | | 0 | | | ns |
| SDA data valid acknowledge time | $t_{VD:ACK}$ | (Note 4) | 0.05 | | 0.45 | μs |
| SDA data valid time | $t_{VD:DAT}$ | (Note 5) | 0.05 | | 0.45 | μs |



| PARAMETER | SYMBOL | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|--|--------------|----------------------|------|-----|-----|---------|
| SDA data set-up time | $t_{SU:DAT}$ | | 100 | | | ns |
| SCL clock low period | t_{LOW} | | 0.5 | | | μs |
| SCL clock high period | t_{HIGH} | | 0.26 | | | μs |
| SDA, SCL fall time | t_f | (Note 6, Note 7) | | | 120 | ns |
| SDA, SCL rise time | t_r | | | | 120 | ns |
| SDA, SCL input suppression filter period | t_{SP} | (Note 7) | | 50 | | ns |

- Note 1. Subject to thermal dissipation characteristics of the device.
- Note 2. Guaranteed by design, and not production tested.
- Note 3. Minimum SCL clock frequency is limited by the bus timeout feature, which resets the serial bus interface if either SDA or SCL is held low for $t_{timeout}$. Disable bus timeout via the power control register, 0x02[6].
- Note 4. t_{VDACK} = SCL low to SDA (out) low acknowledge time.
- Note 5. t_{VDDAT} = minimum SDA output data-valid time following SCL low transition.
- Note 6. A master device must provide an SDA hold time of at least 300ns to ensure an SCL low state.
- Note 7. The maximum SDA and SCL rise and fall time specifications are influenced by the speed of operation required. The original Philips Corp. I²C specification allows slower values, but because the MSL3167/8 interface is designed to operate at speeds exceeding the original specification, these timing values have tightened up. Maximum bus speed is also influenced by bus capacitance. Lay out bus traces to minimize capacitance when high-speed operation is required.
- Note 8. MSL3167/8 include input filters on SDA and SCL inputs that suppress noise less than 50ns.

Block Diagram



Atmel LED Drivers-MSL3 167/MSL3 168

16-string, White LED Drivers with Adaptive Power Control, Simple PWM Dimming Interface, and Fault Handling

Typical Application Circuit

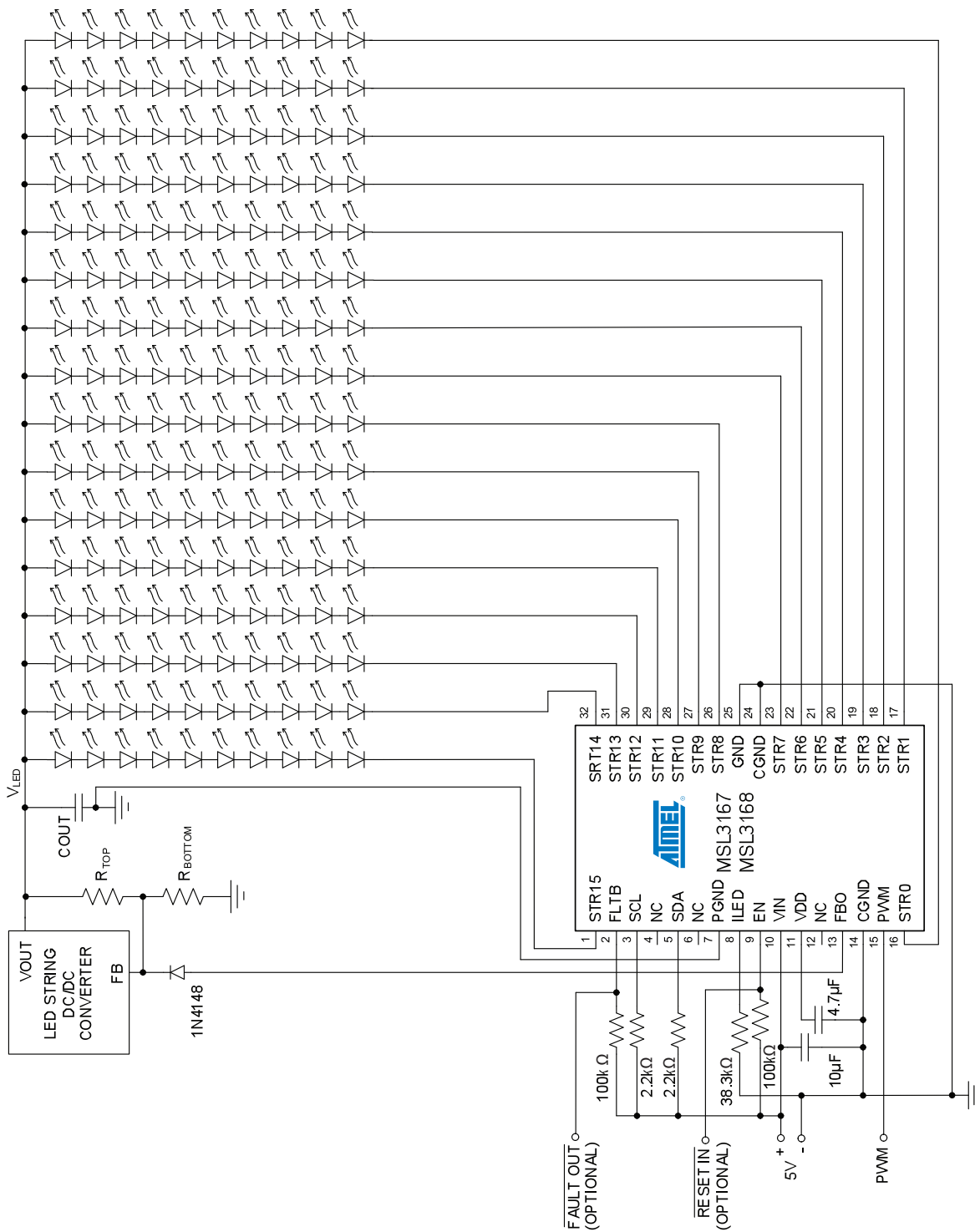


Figure 3. Atmel LED Drivers-MSL3 167/8 Driving 160 White LEDs in 16 Strings at 20mA per String.



Detailed Description

The MSL3167/8 are multi-string LED drivers with power supply control that continually optimize system efficiency. A pulse width modulated signal applied to the PWM input sets the PWM frequency and duty cycle of all LED string drivers. The MSL3168 automatically calculates a phase delay of 1/16th of the PWM period and implements the delay successively to each string driver to reduce the transient load on the LED power supply. The MSL3167 applies the PWM input signal to all LED string outputs without phase delays.

The MSL3167/8 controls a wide range of external DC-DC and AC-DC converter architectures, and allows design of the string power supply for the worst case LED forward voltage drop (V_f) without concern about excessive power dissipation issues. At start-up, the MSL3167/8 automatically reduces the power supply voltage to the minimum voltage required to keep the LEDs in current regulation. The MSL3167/8 then continually re-optimize the string power supply voltage to compensate for the changes in the LED strings' forward voltage drop due to temperature and aging.

The MSL3167/8 handles string and over-temperature faults automatically, and optionally interface to a host system with an I²C/SMBus-compatible interface for detailed fault monitoring and string control.

Internal Regulators

The MSL3167/8 includes an internal 2.5V linear regulator (VDD), powered by VIN, which powers the low-voltage internal circuitry. Bypass VDD to GND with a ceramic capacitor of at least 4.7µF. Bypass VIN to GND with a ceramic capacitor of at least 10µF.

The Enable Input

The MSL3167/8 enables input, EN, enables the device. Drive EN low to turn off all strings, to clear the fault output, FLTB, and to enter low power operation, which lowers quiescent current draw to 1.5mA (typical). With EN low, the serial interface is ignored and the FBO output current is zero. Drive EN high with a 5V logic signal to turn on the MSL3167/8. When EN changes from low to high, all bits in the control registers revert to their power-up default values, the fault registers are cleared, and the Efficiency Optimizer performs an initial calibration cycle. If unused, connect EN to VIN.

String Phase Delay

The MSL3168 automatically calculates a phase delay of 1/16th of the PWM period and implements the delay successively to the string drive signals (Figure 4) to reduce the transient load on the LED power supply. The MSL3167 applies the PWM input signal to all LED string outputs without phase delays.

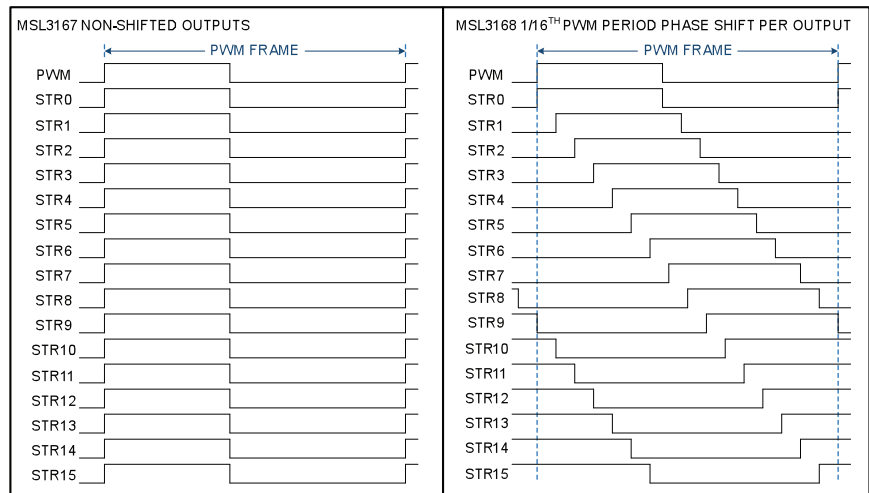


Figure 4. Atmel LED Drivers-MSL3167/8 Examples of Non-shifted and Phase Shifted String Drive Signals.

Atmel LED Drivers-MSL3167/MSL3168

16-string, White LED Drivers with Adaptive Power Control,
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Setting the Maximum LED String Current with R_{ILED}

The maximum string current, I_{ILED} , for all 16 LED strings is set by a single external resistor, R_{ILED} , placed from ILED to GND. Determine the value for R_{ILED} using:

$$R_{ILED} = \frac{762}{I_{ILED}}, \text{ where } I_{ILED} \text{ is in mA and } R_{ILED} \text{ is in k}\Omega.$$

For example, a full-scale maximum LED string current of 19.9mA returns $R_{ILED} = 38.3\text{k}\Omega$.

Efficiency Optimizer

The Efficiency Optimizer (EO) improves power efficiency by injecting a current of between 0 and 255 μA into the voltage divider of the external power supply (Figure 5), dynamically adjusting the power supply's output to the minimum voltage required by the LED strings. This ensures that there is sufficient voltage available for LED current control and good power supply noise rejection, while minimizing power dissipation. The power supply must have a nominal feedback voltage of no more than 3.5V, and the voltage setting resistor divider must be accessible (sizing the resistors is covered in the next section).

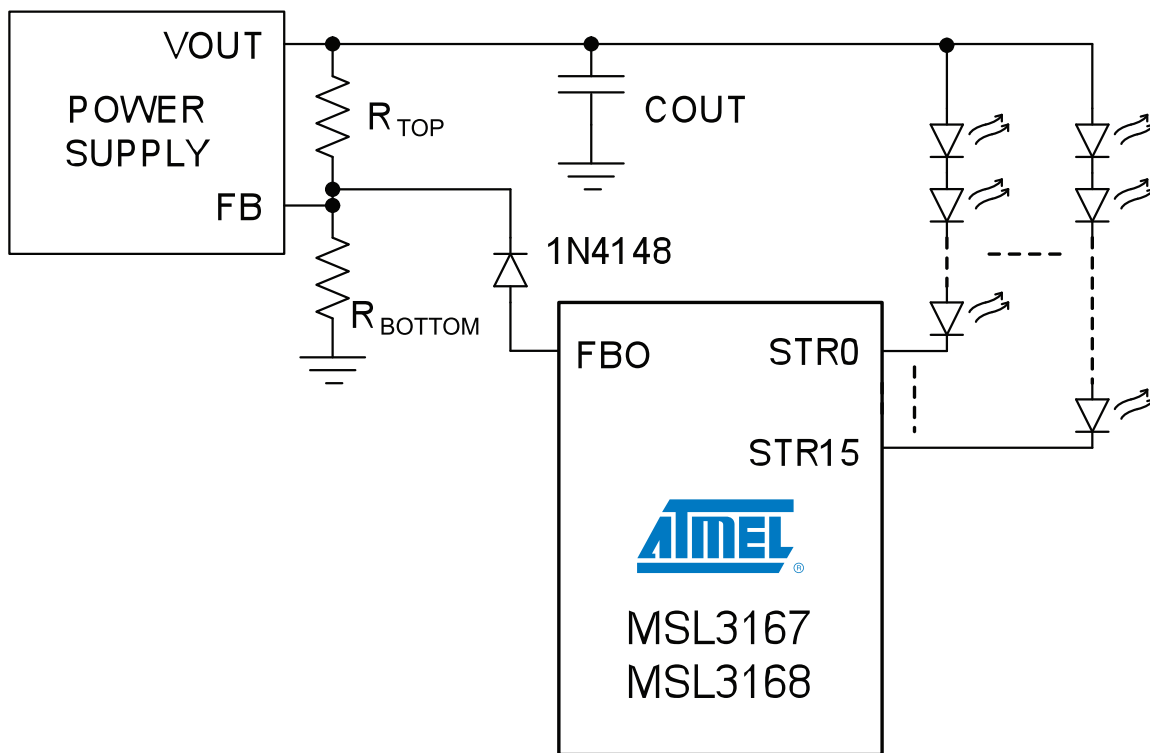


Figure 5. Atmel LED Drivers-MSL3167/8 FBO Connection to Power Supply Voltage Divider



Determining the String Power Supply Feedback Resistors

The MSL3167/8 are designed to control LED string power supplies that use a voltage divider (R_{TOP} and R_{BOTTOM} in Figure 5) to set output voltage, and whose regulation feedback voltage is not more than 3.5V. To select the resistors, first determine $V_{OUT(MIN)}$ and $V_{OUT(MAX)}$, the minimum and maximum string supply voltage limits, using:

$$V_{OUT(MIN)} = (V_{f(MIN)} * [\#ofLEDs]) + 0.5, \text{ and}$$

$$V_{OUT(MAX)} = (V_{f(MAX)} * [\#ofLEDs]) + 0.5,$$

where $V_{f(MIN)}$ and $V_{f(MAX)}$ are the LED's minimum and maximum forward voltage drops at the peak current set by R_{ILED} (page 9). For example, if the LED data are $V_{f(MIN)} = 3.5V$ and $V_{f(MAX)} = 3.8V$, and 10 LEDs are used in a string, then the total minimum and maximum voltage drops across a string are 35V and 38V, respectively. Adding an allowance of 0.5V for the string drive MOSFET headroom brings $V_{OUT(MIN)}$ to 35.5V and $V_{OUT(MAX)}$ to 38.5V. Do not to exceed the 40V maximum specification of string drivers STR1 to STR15. Then, determine R_{TOP} using:

$$R_{TOP} = \frac{V_{OUT(MAX)} - V_{OUT(MIN)}}{I_{FBO(MAX)}}$$

where $I_{FBO(MAX)}$ is the 255 μ A maximum output current of the Efficiency Optimizer output. Finally, determine R_{BOTTOM} using:

$$R_{BOTTOM} = R_{TOP} * \frac{V_{FB}}{V_{OUT(MAX)} - V_{FB}}$$

where V_{FB} is the regulation feedback voltage of the power supply. Place a diode (1N4148 or similar) between FBO and the supply's feedback node to protect the MSL3167/8 against current flow into FBO (Figure 5).

Register Map and the EEPROM

Register Map Summary

The MSL3167/8 are controlled using the 96 registers in the range 0x00 - 0x5F. It may be convenient, and it is allowed, to read and write to unused bits in this range when accessing registers, but do not change the default values of unused bits. Three additional registers, 0x90, 0x91, and 0x93, allow access to the EEPROM and provide Efficiency Optimizer status. The power-up default values for all control registers are stored within the on-chip EEPROM, and any of these EEPROM values may be changed through the serial interface, as detailed in the full MSL3187/8 datasheet.

Table 2. Atmel LED Drivers-MSL3167/8 Register Map

| ADDRESS AND REGISTER NAME | | FUNCTION | REGISTER DATA | | | | | | | |
|---------------------------|----------|--------------------|---------------|---------|---------|---------|---------|---------|--------|--------|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x00 | CONTROL0 | LED string enables | STR7EN | STR6EN | STR5EN | STR4EN | STR3EN | STR2EN | STR1EN | STR0EN |
| 0x01 | CONTROL1 | | STR15EN | STR14EN | STR13EN | STR12EN | STR11EN | STR10EN | STR9EN | STR8EN |

Atmel LED Drivers-MSL3 167/MSL3 168

16-string, White LED Drivers with Adaptive Power Control,
Simple PWM Dimming Interface, and Fault Handling

| ADDRESS AND REGISTER NAME | | FUNCTION | REGISTER DATA | | | | | | | |
|---------------------------|-----------|--|---------------|----------------------|---------------|-------------|--------------|--------------|--------------|---------|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x02 | POWERCTRL | Fault configuration | SLEEP | I ² CTOEN | PHIMINFEN | GSCMAXFEN | STRSCFEN | STROCFEN | FBOOCEN | FBOEN |
| 0x03 | FLTSTATUS | Fault status, global | - | - | PHIMINFLT | GSCMAXFLT | STRSCDET | STROCDDET | FBOOC | FLTDET |
| 0x04 | OCSTAT0 | String open circuit fault status | OC7 | OC6 | OC5 | OC4 | OC3 | OC2 | OC1 | OC0 |
| 0x05 | OCSTAT1 | | OC15 | OC14 | OC13 | OC12 | OC11 | OC10 | OC9 | OC8 |
| 0x06 | SCSTAT0 | String short circuit fault status | SC7 | SC6 | SC5 | SC4 | SC3 | SC2 | SC1 | SC0 |
| 0x07 | SCSTAT1 | | SC15 | SC14 | SC13 | SC12 | SC11 | SC10 | SC9 | SC8 |
| 0x08 | FLTMASK0 | String fault masks | FLTEN7 | FLTEN6 | FLTEN5 | FLTEN4 | FLTEN3 | FLTEN2 | FLTEN1 | FLTEN0 |
| 0x09 | FLTMASK1 | | FLTEN15 | FLTEN14 | FLTEN13 | FLTEN12 | FLTEN11 | FLTEN10 | FLTEN9 | FLTEN8 |
| 0x0A | FBOCTRL0 | Efficiency Optimizer control | HDRMSTEP[1:0] | | FBCLDLY[1:0] | | FBSLDLY[1:0] | | FBCFDLY[1:0] | |
| 0x0B | FBOCTRL1 | | SCCDLY[1:0] | | DECRSTEP[1:0] | | INITPWM | ACAL100 | ACALEN | ICHKDIS |
| 0x0C | FBODAC | Efficiency Optimizer DAC readback | FBODAC[7:0] | | | | | | | |
| 0x0D– 0x0E | | UNUSED | UNUSED | | | | | | | |
| 0x0F | ISTR | 8-bit global string current | ISTR[7:0] | | | | | | | |
| 0x10 | OSCCTRL | Oscillator frequency | - | - | - | - | - | OSCCTRL[2:0] | | |
| 0x11 | GSCCTRL | GSC processing control | GSCCHK-SEL | - | - | - | GSCMAXEN | - | - | - |
| 0x12 | GSCGEN | GSC clock generator | GSCGEN[7:0] | | | | | | | |
| 0x13 | | | GSCGEN[15:8] | | | | | | | |
| 0x14 | GSCMUL | GSC multiplier | - | - | - | GSCMUL[4:0] | | | | |
| 0x15 | GSCDIV | GSC divider | - | - | - | - | GSCDIV[3:0] | | | |
| 0x16 | GSCMAX | Max oscillator cycles between GSC pulses | GSCMAX[7:0] | | | | | | | |
| 0x17 | | | GSCMAX[15:8] | | | | | | | |
| 0x18 | PHICTRL | PHI processing control | - | - | - | - | - | PHIMINEN | - | - |
| 0x19 | PHIGEN | PHI clock generator | PHIGEN[7:0] | | | | | | | |
| 0x1A | | | PHIGEN[15:8] | | | | | | | |
| 0x1B | | UNUSED | UNUSED | | | | | | | |
| 0x1C | PHIMIN | Min GSC pulses over PHI period | PHIMIN[7:0] | | | | | | | |
| 0x1D | | | PHIMIN[11:8] | | | | | | | |
| 0x1E | PWMCTRL | PWM control | FLDBKEN | - | GINTEN | PWM-OFLOWEN | PWMGLBLEN | PHADLYEN | PWM-DIRECT | PWMEN |
| 0x1F | GINT | Global PWM scaling | GINT[7:0] | | | | | | | |



| ADDRESS AND REGISTER NAME | | FUNCTION | REGISTER DATA | | | | | | | |
|--|-----------|---|---------------|-------------|---------|-------------|-------------|-------------|--------|------------|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x20 | STR0SET | Phase delay and EO assignment for string 0 | PHDLY0[7:0] | | | | | | | |
| 0x21 | | | COLSTR0[1:0] | - | - | PHDLY[11:8] | | | | |
| ↓ | ↓ | ↓ | ↓ | | | | | | | |
| 0x3E | STR15SET | Phase delay and EO assignment for string 15 | PHDLY15[7:0] | | | | | | | |
| 0x3F | | | COLSTR15[1:0] | - | - | PHDLY[11:8] | | | | |
| 0x40 | PWM0 | 12-bit PWM setting for string 0 | PWM0[7:0] | | | | | | | |
| 0x41 | | | - | - | - | - | PWM0[11:8] | | | |
| ↓ | ↓ | ↓ | ↓ | | | | | | | |
| 0x5E | PWM15 | 12-bit PWM setting for string 15 | PWM15[7:0] | | | | | | | |
| 0x5F | | | - | - | - | - | PWM15[11:8] | | | |
| - DO NOT ACCESS ADDRESS RANGE 0X60 THRU 0X8F - | | | | | | | | | | |
| 0x90 | E2ADDR | EEPROM read/write access | - | E2ADDR[6:0] | | | | | | |
| 0x91 | E2CTRLSTA | | E2BUSY | BLDACT | E2ERR | - | - | RWCTRL[2:0] | | |
| 0x93 | FBOSTATUS | FBO status | - | - | FBOOPEN | - | - | FBOACTIVE | FBOCAL | FBOINITCAL |

Register Power-up Defaults

Register power-up default values are shown in Table 3.

Table 3. Atmel LED Drivers-MSL3167/8 Register Power-up Defaults

| REGISTER NAME AND ADDRESS | | POWER-UP CONDITION | REGISTER DATA | | | | | | | | |
|---|-----------|--|---------------|----|----|----|----|----|----|----|----|
| | | | HEX | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| REGISTERS INITIALIZED FROM E²PROM | | | | | | | | | | | |
| 0x00 | CONTROL0 | LED strings STR0 thru STR7 enabled | FF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x01 | CONTROL1 | LED strings STR8 thru STR15 enabled | FF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x02 | POWERCTRL | Efficiency Optimizer output enabled FBO open circuit detection disabled String open circuit detection enabled LED short circuit detection enabled GSC maximum fault detection disabled PHI minimum fault detection disabled I ² C bus timeout detection enabled Device awake | 4D | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 |
| 0x08 | FLTMASK0 | Fault detection enabled on all strings | FF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x09 | FLTMASK1 | | FF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Atmel LED Drivers-MSL3 167/MSL3 168

16-string, White LED Drivers with Adaptive Power Control,
Simple PWM Dimming Interface, and Fault Handling

| REGISTER NAME AND ADDRESS | | POWER-UP CONDITION | REGISTER DATA | | | | | | | | |
|---------------------------|----------|---|---------------|----|----|----|----|----|----|----|----|
| | | | HEX | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x0A | FBOCTRL0 | Current sink error confirmation delay = 4 μ S FBO power supply correction delay = 1ms Efficiency Optimizer recalibration delay = 1s Efficiency Optimizer correction steps = 3 | 44 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0x0B | FBOCTRL1 | Current sink error detection not disabled Auto recalibration enabled Auto recalibration does not force strings to 100% duty cycle Initial calibration does not force strings to 100% duty cycle Efficiency Optimizer operates using 1 μ A steps LED short circuit confirmation delay = 4 μ s | 4A | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 |
| 0x0F | ISTR | Strings current set to 50% of R _{ILED} setting | 7F | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x10 | OSCCTRL | f _{OSC} = 20MHz | 04 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0x11 | GSCCTRL | Although disabled, GSC max monitors pGSC | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0x12 | GSCGEN | Internal GSC frequency = 20MHz / (19 + 1) = 1MHz | 23 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0x13 | | | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x14 | GSCMUL | GSC multiplied by 4 | 03 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 0x15 | GSCDIV | GSC not divided | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x16 | GSCMAX | Although disabled, GSC max count is set to 19 clock cycles | 13 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 |
| 0x17 | | | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x18 | PHICTRL | PHI minimum pulse count detect is disabled | 01 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0x19 | PHIGEN | Internal PHI frequency = 20MHz / (8 * (10416 + 1)) = 240Hz | B0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0x1A | | | 28 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 0x1C | PHIMIN | Although PHI min check is disabled, PHI min = 0 | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x1D | | | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x1E | PWMCTRL | PWM operation enabled External signal at PWM Determines t _{ON} and t _{OFF} Phase delay enabled PWM input not used as gate for PWM engine output String on times allowed to extend beyond PWM frame GINT ignored String short circuit fault current foldback enabled | 97 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 |
| 0x1F | GINT | Although disabled, global intensity is set to (127 + 1) / 255 = 50.2% | 7F | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x20 | STR0SET | All strings set to zero phase delay | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x21 | | | 40 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| ↓ | ↓ | | | | | | | | | | |
| 0x3E | STR15SET | All strings set to zero phase delay | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x3F | | | 40 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |



| REGISTER NAME AND ADDRESS | | POWER-UP CONDITION | REGISTER DATA | | | | | | | | |
|-------------------------------------|-----------|--|---------------|----|----|----|----|----|----|----|----|
| | | | HEX | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x40 | PWM0 | Although disabled, all strings have PWM value = 512 GSC cycles | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x41 | | | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| ↓ | ↓ | | ↓ | | | | | | | | |
| 0x5E | PWM15 | | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x5F | | | 02 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| REGISTERS WITH FIXED INITIAL VALUES | | | | | | | | | | | |
| 0x90 | E2ADDR | EEPROM 7-bit address = 0x00 | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x91 | E2CTRLSTA | EEPROM read/write disabled | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x93 | FBOSTATUS | Feedback output status | 00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

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