

Atmel LED Driver-MSL3162

16-string, RGB and White LED Drivers with Adaptive Power Control and 1MHz I²C/SMBus Serial Interface

Datasheet Brief



Atmel LED Driver-MSL3162

16-string, RGB and White LED Drivers with Adaptive Power Control and 1MHz I²C/SMBus Serial Interface

General Description

Atmel LED Driver-MSL3162 is a compact, high-power, 16-parallel-string LED driver. It uses internal current control MOSFETs to sink up to 100mA per LED string with better than 3% accuracy and with up to 10 series white LEDs per string, or 160 LEDs per MSL3162.

The advanced PWM engine is easily synchronized to the video signal and refresh timing using a built-in DLL multiplier and sync dividers. Per-string phase adjustment reduces unwanted LCD artifacts such as motion blur. Up to 16 MSL3162s can share the same 1MHz I²C/SMBus-compatible serial interface, which is fast enough for frame-by-frame LED string intensity control of 16 MSL3162s, or 2560 white LEDs in total.

The MSL3162 adaptively controls the voltage powering the LED strings using patented Atmel's Efficiency Optimizer control. The Efficiency Optimizer minimizes LED driver power losses while maintaining high current accuracy.

The MSL3162 uses 6-bit analog (LED current) dimming as well as 10-bit PWM dimming control. PWM dimming is derived from the product of the 8-bit individual string PWM setting, the 6-bit global intensity, and the 8-bit thermal derating. One external resistor provides the global reference current for all the LED strings.

The MSL3162 features fault monitoring of open circuit, short circuit, and over-temperature conditions, with fault status available through the dedicated FLTB output as well as the I²C/SMBus serial interface. It supports both individual device I²C read/write and broadcast write commands, allowing multiple MSL3162s to be configured simultaneously.

The MSL3162 includes on-chip user EEPROM, allowing customization of the internal register power-up defaults.

The MSL3162 is offered in a lead-free, halogen-free, RoHS-compliant package with a -40°C to +85°C temperature range.

Applications

Long Life, Efficient LED Backlighting for:

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

Digital Signage

Solid-State Lighting

Ordering Information

| PART | DESCRIPTION | PACKAGE |
|-----------|------------------|-------------------------|
| MSL3162BT | 16-ch LED driver | 40-pin, 6x6x0.75mm TQFN |

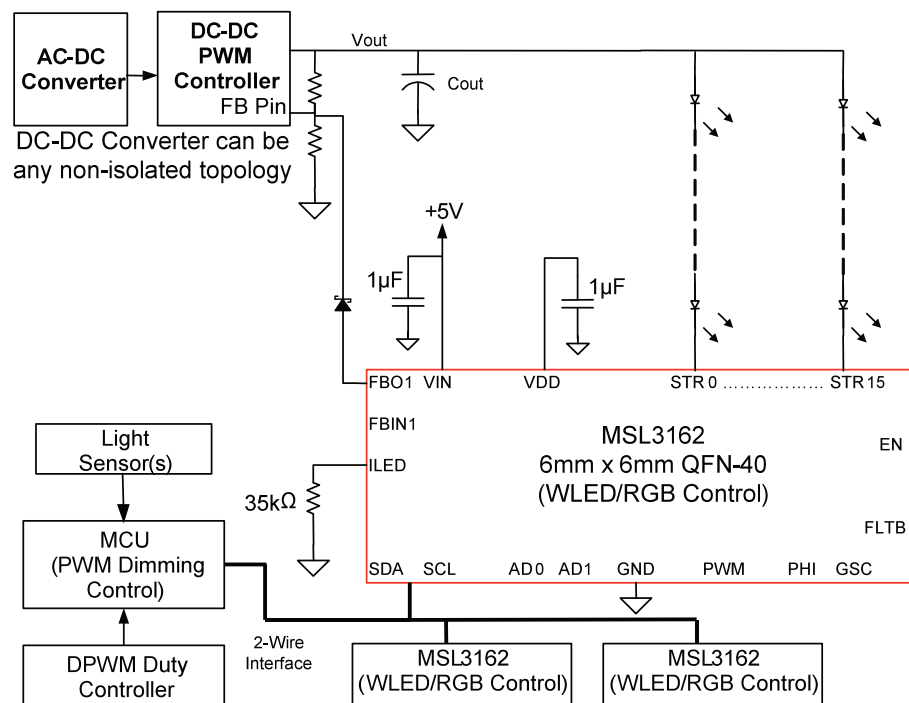
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Key Features

- 100ma Maximum Peak LED String Current
- Adaptive Power Correction Optimizes LED Supplies
- Multiple MSL3162s Can Share String Supplies
- MSL3162s Automatically Negotiate The Lowest Supply Voltage That Maintains Regulation Across All MSL3162s
- Better Than $\pm 3\%$ Current Accuracy and Balance
- Single Resistor Sets Peak Current For All LED Strings
- Individual LED String Intensity (Peak Current And PWM)
- Individual LED String Phase Controls
- Global LED Intensity Control – I²C Or PWM Input Pin
- Programmable String Phase Delays Reduce Motion Blur
- Supports Adaptive, Real-Time 2D Area Dimming For Highest Dynamic Range LCD TVs and Monitors
- Flexible Video Frame (VSYNC) And Line (HSYNC) Synchronization With DLL Multiplier and Dividers
- Sync Loss Detectors Optionally Disable LED Strings
- Open Circuit and Short Circuit Fault Detection
- Individual Fault Detection Enables For Each String
- 1Mhz I²C/SMBus Interface with 16 Slave Addresses
- I²C/SMBus Broadcast Mode Simplifies Configuration
- User EEPROM Saves Power-On Default Settings
- Die Over-Temperature Cutoff Protection
- $< 1\mu\text{A}$ LED String Current Sink Off Leakage Current
- Automatic LED Current Temperature Compensation
- -40°C To $+85^{\circ}\text{C}$ Operating Temperature Range
- Lead-Free, Halogen-Free, RoHs-Compliant Package

Application Circuit





Quick Start Guide

The MSL3162 is an LED string driver that drives, monitors, and dims up to 160 white LEDs (up to 10 series and up to 16 parallel) at high efficiency for LCD backlighting and signage applications. This section summarizes the capabilities of the MSL3162 for quick evaluation.

How Many LEDs and Drivers?

The MSL3162 drives 16 strings of series-connected LEDs. The maximum number of LEDs per string is limited to 10 white LEDs by the 40V maximum string voltage rating. More series LEDs can be driven if their forward voltage (V_F) is lower. When an LED string is turned off, the voltage across the LEDs does not drop to zero. This allows more series LEDs to be driven, but eliminates the MSL3162's ability to sustain a shorted LED string.

Sixteen MSL3162s can share an I²C/SMBus serial interface, with both individual and broadcast (all MSL3162s on a bus) addressing. The high total LED drive capability of multiple bussed MSL3162s makes the driver suitable for LCD TV and monitor backlights as well as LED signage and general lighting. The LED drive capability is summarized in Table 1.

Table 1. Atmel LED Driver MSL3162 LED Drive Capability

| LED TYPE | $V_{F(MAX)}$ | LEDs IN STRING | PER MSL3162 | 16 X MSL3162s | LED POWER PER MSL3162 | LED POWER 16 X MSL3162s |
|--------------------|--------------|----------------|-------------|---------------|---------------------------------|----------------------------------|
| White, Green, Blue | 3.6V | 10 LEDs | 160 LEDs | 2560 LEDs | 34W (at 60mA string current) | 544W (at 60mA string current) |
| Red | 2.4V | 15 LEDs | 240 LEDs | 3840 LEDs | | |
| RGB | - | 10 LEDs | 50 RGB LEDs | 800 RGB LEDs | 26W (at 60mA) | 415W (at 60mA) |

LEDs, Power Supplies (PSUs), and Efficiency Optimizers

The MSL3162 obtains high efficiency by adjusting up to three LED string power supplies to deliver the minimum necessary voltage to accurately drive all LED strings connected to each LED string supply via the three Efficiency Optimizers. Multiple MSL3162s sharing string supplies automatically negotiate the voltage among themselves using the FBI/FBO pins. No system intervention is needed after initial configuration. Use any appropriate LED string power supply topology, typically a DC-DC boost or buck converter with a controllable resistive feedback voltage divider.

The Efficiency Optimizer sets the LED voltage to maintain regulation on the highest voltage LED string. The better the LED string voltage matching, the lower the dissipation the MSL3162 absorbs, and, therefore, better LED matching improves efficiency. RGB LEDs should be driven by three separate string supplies. Also, consider using multiple string supplies for high-power, single-color systems, such as a white backlight.

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Timing, PWM, Intensity Controls and Synchronization

The internal PWM dimming is synchronized to the LCD's frame timing through the PHI input (typically VSYNC) and the GSC input (typically HSYNC) to eliminate beating artifacts and maintain high timing accuracy. Suitability for LED backlight architectures is shown in Table 2. LED area dimming for direct backlighting is supported for contrast improvement. Motion blur is reduced by setting each LED string's PWM phasing individually to synchronize PWM off times with the LCD refresh timing for the zone being lit.

Table 2. Atmel LED Driver-MSL3162 LED Common Backlight Drive Architectures

| BACKLIGHT TYPE | STRING SUPPLY OPTIONS | MOTION BLUR REMOVAL | LED ZONE MANAGEMENT |
|----------------------------------|---|-------------------------|---------------------------------------|
| White LED – Bottom, edge-lit | Up to three efficiency optimized supplies | No | No |
| White LED – Top/bottom, edge-lit | | No | No |
| White LED – Four sides, edge-lit | | No | No |
| White LED – Direct, back-lit | | Yes - LED strip phasing | Higher contrast ratio (area dimming) |
| RGB LED – Direct, back-lit | R, G, B efficiency optimized supplies | Yes - LED strip phasing | Higher contrast ratio and color gamut |



Package Pin-out

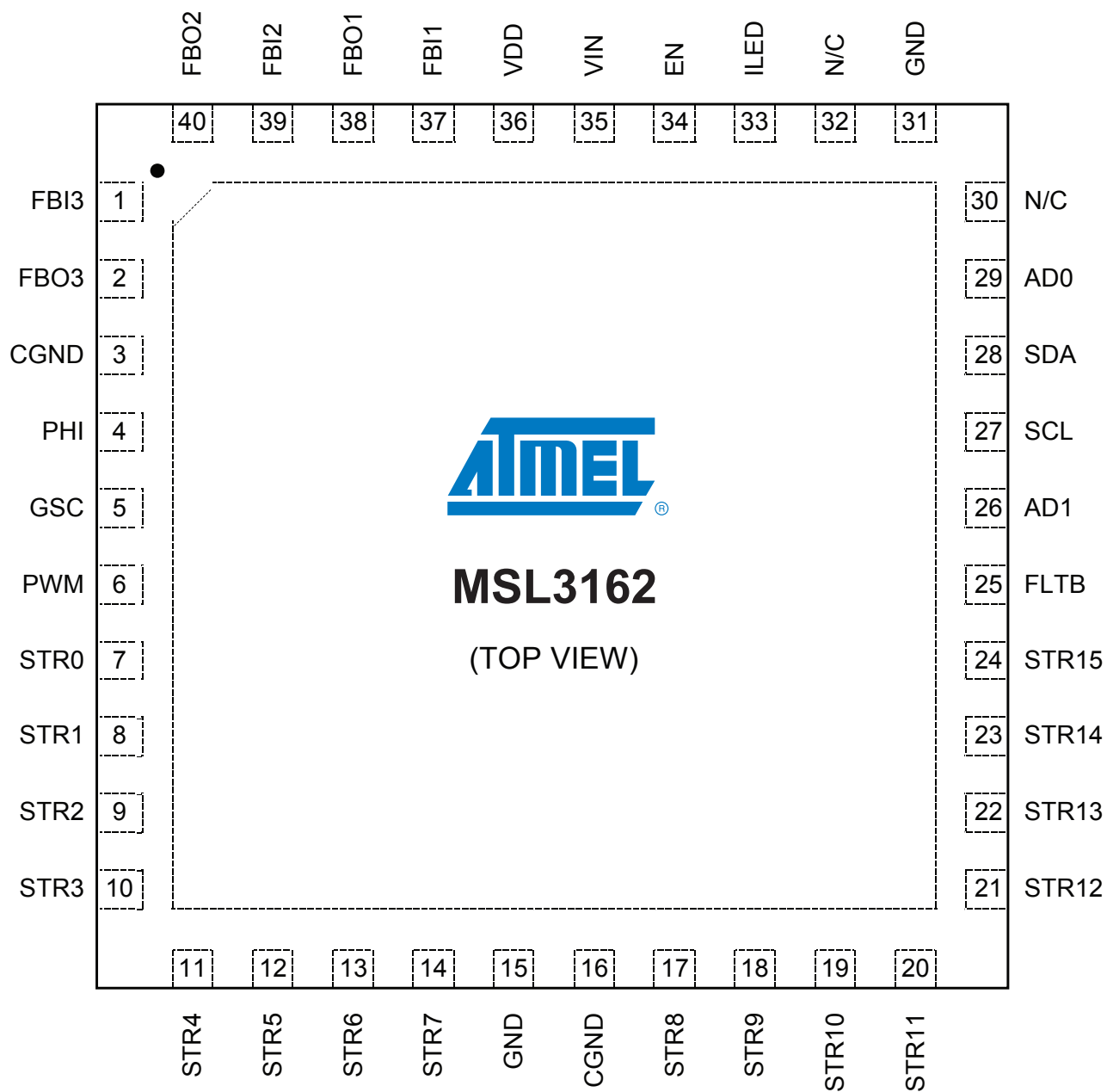


Figure 1. 40-pin, 6mm x 6mm x 0.75mm TQFN (0.5mm pin pitch) with Exposed Pad

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Package Pin-out

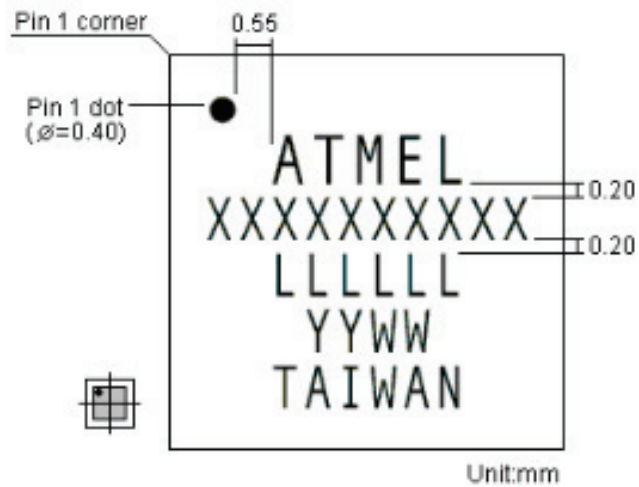


Figure 2. 40-pin TQFN Package Dimensions



Pin Descriptions

Table 3. Pin Descriptions

| PIN NAME | PIN NUMBER | PIN DESCRIPTION |
|------------------|-----------------|---|
| FBI1, FBI2, FBI3 | 37, 39, 1 | Efficiency Optimizer feedback inputs When using a common LED voltage over multiple MSL3162s, connect FBIs and FBOs in a chain, with the first FBI grounded and the last FBO controlling the external power source. For standalone operation, connect FBI to GND. |
| FBO1, FBO2, FBO3 | 38, 40, 2 | Efficiency Optimizer feedback outputs FBO controls the external regulator to dynamically adjust the LED voltage for optimal efficiency. When using a common LED voltage over multiple MSL3162s, connect FBIs and FBOs in a chain, with the first FBI grounded and the last FBO driving the feedback node of an external power source. |
| CGND | 3, 16 | Signal ground Connect all CGND and GND pins to system GND and to the exposed pad, EP, using short, wide traces as close to the MSL3162 as possible |
| GND | 15, 31 | Power ground Connect all GND and CGND pins to system GND and to the exposed pad, EP, using short, wide traces as close to the MSL3162 as possible |
| PHI | 4 | Phase synchronization input Drive PHI with an external signal from 40Hz to 10kHz to synchronize the MSL3162 PWM dimming to the signal at PHI. Connect PHI to GND if unused. |
| GSC | 5 | Gate shift clock input GSC sets the PWM dimming resolution. Drive GSC with the video signal gate shift clock up to 5MHz. Connect GSC to GND if unused. |
| PWM | 6 | PWM dimming input Drive PWM with a pulse-width modulated signal with a duty ratio ranging from 0% to 100% and frequency from 20Hz to 50kHz to control the brightness of all LED strings. |
| STR0 to STR15 | 7 - 14, 17 - 24 | STR0 to STR15 LED string current sink outputs Connect the cathode end of each series LED string to one of STR0 to STR15. Connect unused outputs to GND, and disable unused strings using the master control registers. |
| FLT B | 25 | Fault indication output (open drain, active low) FLT B sinks current to GND whenever the MSL3162 detects a fault. Once a fault is detected, FLT B remains low until the fault registers have been read. |
| AD1, AD0 | 26, 29 | I²C slave ID selection inputs AD0 and AD1 select the I ² C slave address used. Connect AD0 and AD1 to either GND, VDD, SCL, or SDA to select the slave ID. |
| SCL | 27 | I²C serial clock input SCL is the I ² C serial interface clock input. |
| SDA | 28 | I²C serial data I/O SDA is the I ² C serial interface data I/O |
| N/C | 30, 32 | Factory connection. Leave unconnected. |
| I LED | 33 | Maximum LED current control input Connect a resistor from I LED to GND to set the full-scale LED string current. A 34.8kΩ resistor to GND sets a 60mA sink current through each LED string. |
| EN | 34 | Enable input (active high) Drive EN high to turn on the MSL3162, and drive it low to turn it off. For automatic start-up, connect EN to VIN. |

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| PIN NAME | PIN NUMBER | PIN DESCRIPTION |
|----------|-------------|--|
| VIN | 35 | Supply voltage input Connect the 5V $\pm 10\%$ supply to VIN. Bypass VIN to GND with a 10 μ F or greater ceramic capacitor |
| VDD | 36 | 2.5V internal LDO regulator output VDD is the output of the internal regulator and powers internal logic. Bypass VDD to GND with a 1 μ F ceramic capacitor |
| EP | Exposed Pad | Power ground Connect the exposed pad, EP, to system GND and to the GND pins using short, wide traces |

Absolute Maximum Ratings

Voltage (With Respect to GND)

| | |
|-------------------------------|--------------------|
| VIN, EN..... | -0.3V to +6V |
| SDA, SCL, AD0, AD1, FLTB..... | -0.3V to +5.5V |
| PHI, GSC, PWM..... | -0.3V to VIN +0.3V |
| FBI1, FBI2, FBI3, ILED..... | -0.3V to VDD +0.3V |
| VDD, FBO1, FBO2, FBO3..... | -0.3V to +2.75V |
| STR0 to STR15..... | -0.3V to +40V |
| CGND..... | -0.05V to +0.05V |

Current (Into Pin)

| | |
|---------------------|---------------|
| VIN..... | 50mA |
| GND..... | 1700mA |
| STR0 to STR15..... | 105mA |
| All other pins..... | -20mA to 20mA |

Note 1. Pins 3, 15, 16, 31 and the exposed pad, EP, must all be connected to the system GND using short, wide traces

Note 2. Pins 30 and 32 must be left open circuit

Continuous Power Dissipation at 70°C

| | |
|---|--------|
| 40-pin, 6mm x 6mm QFN (see Note 8, Note 9)..... | 2963mW |
|---|--------|

Ambient Operating Temperature Range, T_A..... -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

(Circuit of Figure 4, $V_{IN} = 5V$, $V_{EN} = 5V$, default register settings of Table 5, $T_A = -40^{\circ}C$ to $+85^{\circ}C$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$)

| PARAMETER | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|--|---|--------------|------|--------------|-------------|
| DC ELECTRICAL CHARACTERISTICS | | | | | |
| VIN operating supply voltage | | 4.5 | 5 | 5.5 | V |
| VIN operating supply current | Run mode; all LED strings driven | | 7 | 20 | mA |
| VIN shutdown supply current | Sleep mode; SDA, SCL, AD0, AD1, PWM, PHI, GSC at GND or VDD | | 20 | 25 | μA |
| VDD regulation voltage | | 2.35 | 2.5 | 2.65 | V |
| Input high voltage SDA, SCL, AD0, AD1, PWM, PHI, GSC | | 0.7 x VDD | | | V |
| Input low voltage SDA, SCL, AD0, AD1, PWM, PHI, GSC | | | | 0.3 x VDD | V |
| Input high voltage EN | | 1.2 | | | V |
| Input low voltage EN | | | | 0.8 | V |
| Output low voltage SDA | Sinking 6mA | | | 0.4 | V |
| Output low voltage FLTB | Sinking 6mA | | | 0.6 | V |
| I _{LED} regulation voltage | I _{I_{LED}} = 10 μA | 340 | 355 | 370 | mV |
| FBI ₋ feedback input current | | 0 | | 140 | μA |
| FBO ₋ feedback output current | V _{FBO₋} = 0 to 1.8V | 0 | | 55 | μA |
| FBO ₋ feedback output current step size | FBI ₋ = GND; $T_A = +25^{\circ}C$ | 2.5 | 3 | 3.6 | μA |
| FBI ₋ input disable threshold | (Note 10) | | 140 | | mV |
| LED string sink current STR0 to STR15 | R _{I_{LED}} = 34.8k Ω \pm 0.1%; I _{STRn} = 0x20; V _{STRn} = 1V; $T_A = +25^{\circ}C$ | 28.5 | 30 | 31.5 | mA |
| | R _{I_{LED}} = 34.8k Ω \pm 0.1%; I _{STRn} = 0x3F; V _{STRn} = 1V; $T_A = +25^{\circ}C$ (Note 10) | | 58.9 | | mA |
| LED string sink current matching STR0 to STR15 | R _{I_{LED}} = 34.8k Ω \pm 0.1%; I _{STRn} = 0x20; V _{STRn} = 1V; | | | 3 | % |
| LED string sink current maximum STR0 to STR15 | R _{I_{LED}} = 20.5k Ω ; I _{STRn} = 0x3F (Note 8, Note 9, Note 10) | | 100 | | mA |
| Short circuit fault detection threshold | $T_A = +25^{\circ}C$ | 2.5 | 3.5 | 4.5 | V |
| Thermal cutoff temperature | (Note 10) | | 135 | | $^{\circ}C$ |
| Input leakage | | | | 10 | μA |

| PARAMETER | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|--------------------------------------|---|-----|-----|-------|------|
| AC ELECTRICAL CHARACTERISTICS | | | | | |
| OSC initial accuracy | OSCTRL = 0x04 (f _{OSC} = 20MHz); $T_A = 25^{\circ}C$ | 18 | 20 | 22 | MHz |
| PHI frequency | | 40 | | 10000 | Hz |

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| PARAMETER | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|----------------------------|----------------------|-----|-----|-------|------------|
| GSC frequency | | 0 | | 5 | MHz |
| High and low time PHI, GSC | | 40 | | | ns |
| PWM frequency | | 20 | | 50000 | Hz |
| PWM duty cycle | | 0.5 | | 100 | % |
| PHI DLL lock cycles | (Note 10) | | 4 | | PHI cycles |

| PARAMETER | SYMBOL | CONDITIONS AND NOTES | MIN | TYP | MAX | UNIT |
|--|----------------------|---|---------------------------|-----|------|------|
| I ² C SWITCHING CHARACTERISTICS | | | | | | |
| SCL clock frequency | 1/t _{SCL} | Bus timeout disabled (Note 2) | 0 | | 1000 | kHz |
| Bus timeout period | t _{TIMEOUT} | OSCTRL = 0x04 (f _{OSC} =20MHz); T _A =25°C | 27 | 30 | 33 | ms |
| | | OSCTRL = 0x00 to 0x07; f _{OSC} =16 to 23MHz | 600000 / f _{OSC} | | | |
| 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 setup time | t _{SU:STOP} | | 0.26 | | | μs |
| SDA data hold time | t _{HD:DAT} | | 5 | | | ns |
| SDA data valid acknowledge time | t _{VD:ACK} | (Note 3) | 0.05 | | 0.55 | μs |
| SDA data valid time | t _{VD:DAT} | (Note 4) | 0.05 | | 0.55 | μs |
| 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 5, Note 6) | | | 120 | ns |
| SDA, SCL rise time | t _R | | | | 120 | ns |
| SDA, SCL input suppression filter period | t _{SP} | (Note 7, Note 10) | | 50 | | ns |

Note 1. All parameters are tested at T_A=25°C unless otherwise noted. Specifications at temperature are guaranteed by design

Note 2. 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 feature for DC operation

Note 3. t_{VD:ACK} = SCL low to SDA (out) low acknowledge time

Note 4. t_{VD:DAT} = minimum SDA output data-valid time following SCL low transition

Note 5. A master device must internally provide an SDA hold time of at least 300ns to ensure an SCL low state

Note 6. The maximum SDA and SCL rise times are 300ns. The maximum SDA fall time is 250ns. This allows series protection resistors to be connected between SDA and SCL inputs and the SDA/SCL bus lines without exceeding the maximum allowable rise time

Note 7. MSL3162 includes input filters on SDA, SCL, AD0, and AD1 inputs that suppress noise less than 50ns

Note 8. Subject to thermal dissipation characteristics of the device

Note 9. When mounted according to JEDEC, JEP149, and JESD51-12 for a two-layer PCB, θ_{JA} = 18.6°C/W and θ_{JC} = 1.4°C/W

Note 10. Guaranteed by design and characterization. Not production tested

Block Diagram

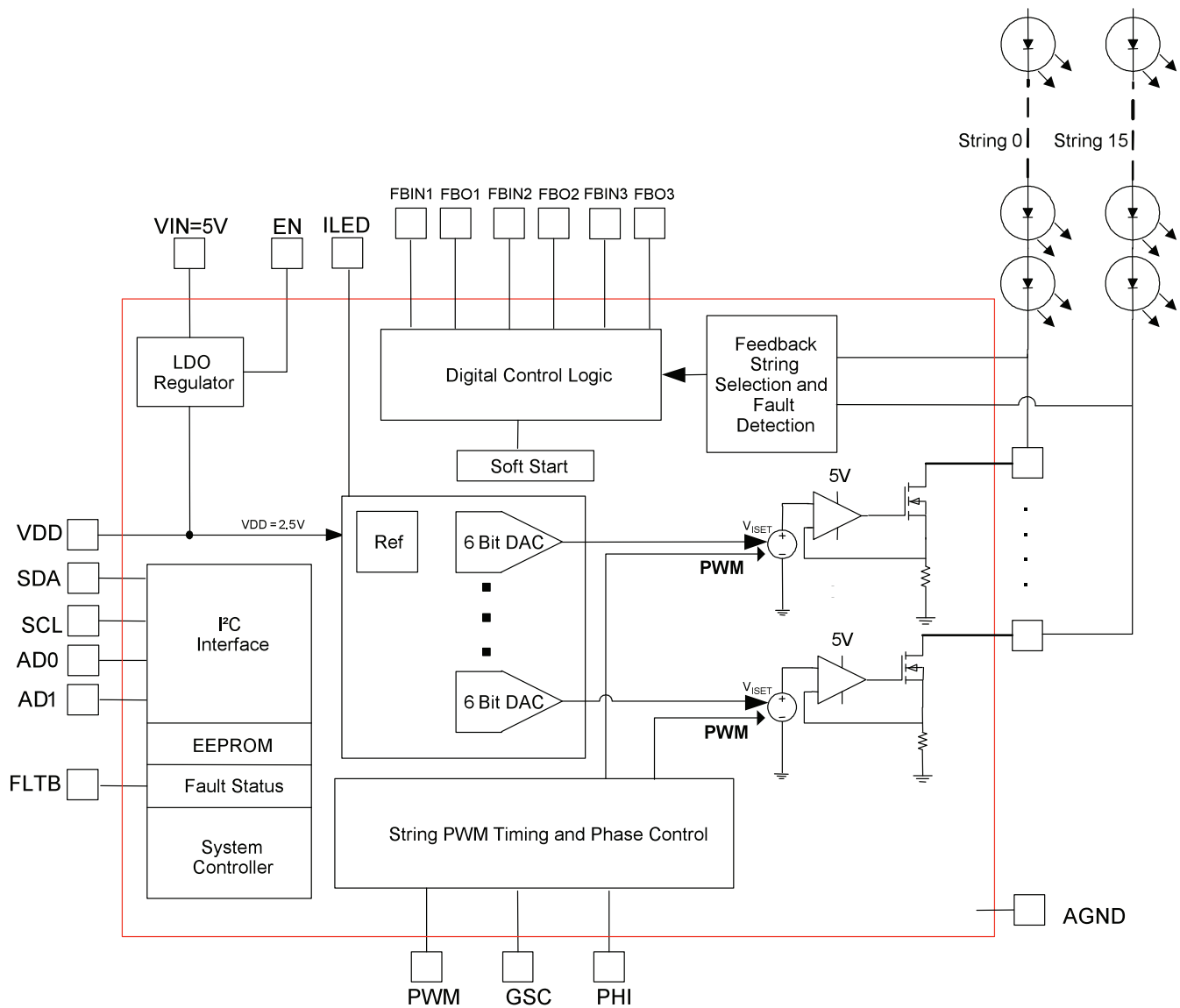


Figure 3. Atmel LED Driver-MSL3162 Block Diagram

16-string, RGB and White LED Drivers with Adaptive Power Control and 1MHz I²C/SMBus Serial Interface

Atmel LED Driver-MSL3162



Detailed Description

Internal Regulators and Enable Input

Built-in current control MOSFETs capable of withstanding up to 40V provide a compact solution. The Efficiency Optimizer circuit controls the LED voltage generated by an external DC-DC converter to minimize losses on the current control MOSFETs, improving efficiency and reducing driver power dissipation. The MSL3162 uses a high-speed, 1MHz I²C serial interface to control LED current, PWM dimming, and fault detection circuitry, making it an optimal solution for driving LED backlights for LCD panels. Onboard EEPROM allows default settings to be reconfigured for customization and settings to be saved at turn-off, eliminating the need to re-write settings at the next turn-on. The tiny, 6mm x 6mm QFN package enables a compact solution while maintaining high power dissipation.

Internal Regulators and Enable Input

The MSL3162 includes an internal linear regulator that provides 2.5V supply voltage to power internal circuitry. Bypass VDD to GND with a 1μF or greater capacitor as close to the MSL3162 as possible.

The EN input turns the MSL3162 on and off. To turn on the MSL3162, drive EN high with a 5V logic level, and drive EN low to turn it off. When EN is low, the MSL3162 enters low-power mode, reducing input current to 20μA, and turns off the serial interface. For automatic start-up, connect EN to VIN, allowing the MSL3162 to start automatically when voltage is applied.

LED String Current Control

Each MSL3162 includes 16 current sink outputs, rated at 40V, each capable of sinking up to 100mA through a string of series connected LEDs. The internal Efficiency Optimizer circuit controls the LED voltage, minimizing power dissipated in the current sinks while maintaining high current-regulation accuracy. The MSL3162 power dissipation is limited to 2.1W. When using all 16 current sinks, maintain the total power dissipation within power dissipation limits.

Setting the Maximum LED String Current

The maximum I_{I_{LED}} current for the 16 LED strings STR0 to STR15 is set by external resistor R_{I_{LED}} from the ILED pin to GND and is determined by the equation:

$$I_{ILED} = \frac{2050}{R_{ILED}}$$

where I_{I_{LED}} is in mA and R_{I_{LED}} is in kΩ.

R_{I_{LED}}=34.8kΩ sets the full-scale LED current to 58.9mA. R_{I_{LED}}=20.5kΩ sets the full-scale LED current to 100mA, the maximum allowed. The currents for the 16 LED strings, STR0 to STR15, are reduced individually from full scale with 6-bit resolution using the LED string current control registers.

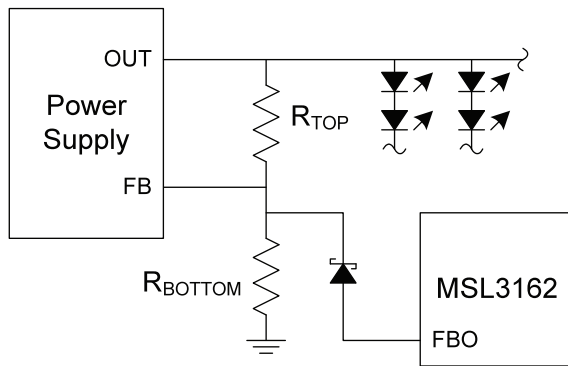
If I_{I_{LED}} for the 16 LED strings, STR0 to STR15, is chosen to be 30mA or lower (by selecting the value of external resistor R_{I_{LED}} to be greater than 68.3kΩ), then the values programmed into the LED string current control registers must be limited to the range 0x00 to 0x1F. The full range of 0x00 to 0x3F is only available if I_{I_{LED}} is set to be greater than 30mA by using an R_{I_{LED}} value of 68.3kΩ or lower.

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Efficiency Optimizer

The Efficiency Optimizer improves power efficiency by adjusting each external LED power supply output voltage to the minimum required by the connected LED strings. It does this by injecting a current from the FBO output into the external LED power source voltage divider (Figure 5), thus lowering the LED supply voltage. The power supply's feedback voltage (internal reference voltage) must be 1.4V or less, and the voltage setting feedback network divider must be accessible. Use a Schottky diode (CMPSH-3 or similar) as shown to protect the power source against reverse current flow into the FBO pin, should the power supply circuit be powered before the MSL3162.



**Figure 5. Atmel LED Driver-MSL3162
FBO_Connection to Power Supply Voltage Divider**

Connecting an LED String Power Supply to an Efficiency Optimizer

An LED string power supply uses a voltage divider (R_{TOP} and R_{BOTTOM} in Figure 6) to set its output voltage. The maximum output voltage is set by the voltage divider ratio and the power supply feedback regulation voltage per the equation:

$$V_{FB} = V_{OUT(MAX)} * \frac{R_{BOTTOM}}{R_{TOP} + R_{BOTTOM}} \quad \text{or} \quad V_{OUT(MAX)} = V_{FB} * \frac{R_{TOP} + R_{BOTTOM}}{R_{BOTTOM}}$$

$V_{OUT(MAX)}$ must exceed the maximum LED string voltage to ensure regulation, but ensure that $V_{OUT(MAX)}$ is always under the 40V maximum rating of the MSL3162's LED string outputs, STR0 to STR15.

The Efficiency Optimizer modifies the feedback network by injecting a current, I_{FBO} , in the range of 0 to 45μA from the FBO output into the measurement node, FB. The minimum power supply output voltage is determined by the equation:

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

where $I_{FBO(MAX)}$ is the 45μA maximum output current from the Efficiency Optimizer output.

From these equations, the equations to calculate the feedback resistors are:

$$R_{TOP} = V_{FB} * \frac{V_{MAX} - V_{MIN}}{I_{FBO(MAX)}} \quad \text{and} \quad R_{BOTTOM} = R_{TOP} * \frac{V_{FB}}{V_{OUT} - V_{FB}}$$



Using Multiple Atmel LED Driver-MSL3162s to Control a Single Power Supply

To use multiple MSL3162s to control a single power supply, connect the FBOx output of one MSL3162 to the FBx input of another MSL3162 to form a chain (Figure 6). The Efficiency Optimizer decides whether the current at the FBx input is less than what the FBOx output is programmed to. If the FBx current is less than the programmed current, the FBx current is transferred to the FBOx output. Otherwise, the programmed current is used at FBOx. The power supply output is, therefore, programmed to the minimum voltage required by all MSL3162s controlling it, and so all LED strings have sufficient voltage to maintain current regulation and power supply noise rejection.

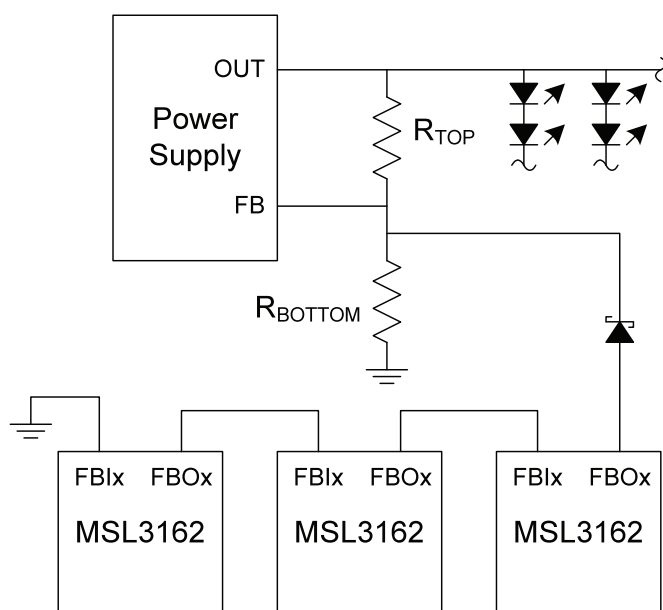


Figure 6. Cascade Multiple Atmel LED Driver-MSL3162s to Control a Common Power Supply

The accuracy of the FBOx output current can degrade through each link of the FBx/FBOx chain by as much as 2%. Therefore, the maximum output voltage correction current can drop by 2% per link. Calculate the worst-case FBOx current by the equation:

$$I_{FBOx (MAX / MIN)} = 45 \mu A * (0.98)^{N-1}$$

where $I_{FBOx (MAX / MIN)}$ is the worst-case (minimum) maximum FBOx output current, and N is the number of MSL3162 FBx/FBOx I/Os connected in series.

Take care in laying out the traces for the Efficiency Optimizer FBx/FBOx I/Os. If the FBx input is not used, connect it to GND as close to the MSL3162 as possible. When routing the FBx/FBOx signals across circuit boards, minimize the trace length as much as possible. Do not route the traces close to other traces with large variations in voltage or current because such traces may couple noise into the FBx/FBOx I/Os. If these traces must be routed near noisy signals, shield them from noise by use of ground planes or guard traces.

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16-string, RGB and White LED Drivers with Adaptive Power Control and 1MHz I²C/SMBus Serial Interface

Register Map Summary

The MSL3162 are controlled through an I²C interface through 82 registers (Table 4). Internal register addressing auto-increments through the register map. In some cases writing to unused register addresses can cause unintended behavior as shown in Table 4. It may be convenient to read or write to unused register address locations when accessing a block of registers sequentially which include unused registers. The power-up default values for all control registers are stored within on-chip user EEPROM, and any of these user EEPROM values may be changed by the user through the I²C interface.

Table 4. Atmel LED Driver-MSL3162 Register Map

| REGISTER | ADDRESS | FUNCTION | REGISTER DATA | | | | | | | |
|-----------|---------|--|---------------|---------|--------------|----------|--------------|----------|--------------|--------|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| CONTROL0 | 0x00 | LED string enables | STR7EN | STR6EN | STR5EN | STR4EN | STR3EN | STR2EN | STR1EN | STR0EN |
| CONTROL1 | 0x01 | | STR15EN | STR14EN | STR13EN | STR12EN | STR11EN | STR10EN | STR9EN | STR8EN |
| POWERCTRL | 0x02 | Fault configuration | SLEEP | - | SCEN | OCEN | 0* | TOEN | FBEN | PHAEN |
| FLTSTATUS | 0x03 | Fault status, global | 0 | SCDET | OCDET | 0 | 0 | 0 | FBOICAL | FLTDET |
| FLTMASK0 | 0x04 | Fault enables, LED string monitoring | FLTEN7 | FLTEN6 | FLTEN5 | FLTEN4 | FLTEN3 | FLTEN2 | FLTEN1 | FLTEN0 |
| FLTMASK1 | 0x05 | | FLTEN15 | FLTEN14 | FLTEN13 | FLTEN12 | FLTEN11 | FLTEN10 | FLTEN9 | FLTEN8 |
| OCSTAT0 | 0x06 | Fault status, LED string open circuit | OC7 | OC6 | OC5 | OC4 | OC3 | OC2 | OC1 | OC0 |
| OCSTAT1 | 0x07 | | OC15 | OC14 | OC13 | OC12 | OC11 | OC10 | OC9 | OC8 |
| SCSTAT0 | 0x08 | Fault status, LED string short circuit | SC7 | SC6 | SC5 | SC4 | SC3 | SC2 | SC1 | SC0 |
| SCSTAT1 | 0x09 | | SC15 | SC14 | SC13 | SC12 | SC11 | SC10 | SC9 | SC8 |
| STRFB0 | 0x0A | LED string feed-back assignment to power supplies FBO1, FBO2, FBO3 | STRFB3[1:0] | | STRFB2[1:0] | | STRFB1[1:0] | | STRFB0[1:0] | |
| STRFB1 | 0x0B | | STRFB7[1:0] | | STRFB6[1:0] | | STRFB5[1:0] | | STRFB4[1:0] | |
| STRFB2 | 0x0C | | STRFB11[1:0] | | STRFB10[1:0] | | STRFB9[1:0] | | STRFB8[1:0] | |
| STRFB3 | 0x0D | | STRFB15[1:0] | | STRFB14[1:0] | | STRFB13[1:0] | | STRFB12[1:0] | |
| FBOCTRL0 | 0x10 | Efficiency Optimizer configuration | HLDSTEP[1:0] | | FBCLDLY[1:0] | | FBSDLY[1:0] | | FBCFDLY[1:0] | |
| FBOCTRL1 | 0x11 | | SCCDLY[1:0] | | - | - | ACALPWM | ACALFSTR | ACALEN | TRIDIS |
| FBODAC1 | 0x12 | Efficiency Optimizer DAC readback | DSTAT1 | 0 | 0 | 0 | FBODAC1[3:0] | | | |
| FBODAC2 | 0x13 | | DSTAT2 | 0 | 0 | 0 | FBODAC2[3:0] | | | |
| FBODAC3 | 0x14 | | DSTAT3 | 0 | 0 | 0 | FBODAC3[3:0] | | | |
| OSCCTRL | 0x18 | Oscillator frequency | - | - | - | - | - | OSC[2:0] | | |
| IGSCGEN | 0x1A | GSC clock generator internal | IGSCGEN[7:0] | | | | | | | |
| | 0x1B | | IGSCGEN[15:8] | | | | | | | |
| IPHIGEN | 0x1C | PHI clock generator internal | IPHIGEN[7:0] | | | | | | | |
| | 0x1D | | IPHIGEN[15:8] | | | | | | | |
| PWMCTRL0 | 0x20 | PWM and phase control configuration | HPSCREN | GINTEN | PHIPOL | OTPDIGEN | PHIMINEN | GSCMAXEN | FSNOZSK | 1* |
| PWMCTRL1 | 0x21 | | - | - | - | - | - | PWMMODE | INTPHI | INTGSC |
| SYSTEMP | 0x22 | System temperature | SYSTEMP[7:0] | | | | | | | |
| OTTEMP | 0x23 | Over-temp derating threshold | OTTEMP[7:0] | | | | | | | |
| OTSLOPE | 0x24 | Over-temp derating slope | OTSLOPE[7:0] | | | | | | | |



Table 4. Atmel LED Driver-MSL3162 Register Map

| REGISTER | ADDRESS | FUNCTION | REGISTER DATA | | | | | | | |
|--|---------|--|---------------|-------------|-------------|---------------|--------------|----|-------------|----|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| GSCMAX | 0x25 | Max osc. cycles per GSC pulse | GSCMAX[7:0] | | | | | | | |
| | 0x26 | | GSCMAX[15:8] | | | | | | | |
| PHIMIN | 0x27 | Min GSC pulses over PHI period | PHIMIN[7:0] | | | | | | | |
| | 0x28 | | - | - | - | - | PHIMIN[15:8] | | | |
| HPSCR | 0x29 | GSC divider | - | - | - | - | HPSCR[3:0] | | | |
| FRATE | 0x2A | PHI freq. multiplier | - | - | - | FRATE[4:0] | | | | |
| GINT | 0x2B | Global intensity | - | - | GINT[6:0] | | | | | |
| ISTR0 | 0x30 | LED string | - | - | ISTR0[5:0] | | | | | |
| to | | 6-bit individual analog current settings | - | - | to | | | | | |
| ISTR15 | 0x3F | | - | - | ISTR15[5:0] | | | | | |
| PHDLY0 | 0x40 | LED string 8-bit | PHDLY0[7:0] | | | | | | | |
| to | | individual PWM phase settings | to | | | | | | | |
| PHDLY15 | 0x4F | | PHDLY15[7:0] | | | | | | | |
| PWM0 | 0x50 | LED string 8-bit | PWM0[7:0] | | | | | | | |
| to | | individual PWM intensity settings | to | | | | | | | |
| PWM15 | 0x5F | | PWM15[7:0] | | | | | | | |
| Do not access address range 0x60 to 0x8F | | | | | | | | | | |
| E2ADDR | 0x90 | User EEPROM read/write access | - | E2ADDR[6:0] | | | | | | |
| E2CTRLSTA | 0x91 | | E2BUSY | BLDACT | E2ERR | SLVATCNT[1:0] | | | RWCTRL[1:0] | |

- Value written is stored and can be read back, but is not used internally.

* These bits must remain set to the indicated state.

Table 5. Atmel LED Driver-MSL3162 Register Power-up Defaults

| REGISTER NAME AND ADDRESS | | | REGISTER DATA | | | | | | | |
|---------------------------|--------------------------------------|--|---------------|----|----|----|----|----|----|----|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x00 | CONTROL0 | LED strings STR0 to STR7 are disabled | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x01 | CONTROL1 | LED strings STR8 to STR15 are disabled | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x02 | POWERCTRL | Sleep mode | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| 0x04 | FLTMASK0 | Fault detection for LED strings STR0 to STR7 is disabled | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x05 | FLTMASK1 | Fault detection for LED strings STR8 to STR15 is disabled | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x0A to 0x0D | STRFB0 STRFB1 STRFB2 STRFB3 | LED strings STR0 to STR7 are not monitored by the voltage optimizers FBO1, FBO2, FBO3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x10 | FBOCTRL0 | Current sink error confirmation delay is 4μs FBO power supply correction delay is 2ms Efficiency Optimizer recalibration delay is 1s Efficiency Optimizer correction steps is 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x11 | FBOCTRL1 | Auto calibration is disabled | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x18 | OSCCTRL | f _{OSC} is 20MHz | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0x1A | IGSCGEN | f _{GSC} = f _{OSC} | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x1B | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x1C | IPHIGEN | f _{PHI} = f _{OSC} / 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x1D | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Atmel LED Driver-MSL3162

16-string, RGB and White LED Drivers with Adaptive Power Control and 1MHz I²C/SMBus Serial Interface

Table 5. Atmel LED Driver-MSL3162 Register Power-up Defaults

| REGISTER NAME AND ADDRESS | | POWER-UP CONDITION | REGISTER DATA | | | | | | | |
|---------------------------|-------------------|---|---------------|----|----|----|----|----|----|----|
| | | | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
| 0x20 | PWMCTRL0 | PWM is individually controlled by registers PWM0 to PWM15 GSC low- and high-frequency fault detection is disabled Over-temperature derating of LED strings is disabled PHI input falling edge synchronizes LED PWM Global intensity control uses GINT register GSC input is divided by value of GSC prescaler register | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x21 | PWMCTRL1 | External GSC signal at GSC input pin is used External PHI signal at PHI input pin is used PWM input pin is unused | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x22 | SYSTEMP | System temperature, SYSTEMP, is 0°C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x23 | OTTEMP | Temperature compensation threshold, OTCOMP, is 255°C | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x24 | OTSLOPE | Over-temperature derating slope, OTSLOPE, is 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x25 | GSCMAX | Maximum GSC pulse count is 65536 (0xFFFF) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x26 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0x27 | PHIMIN | Minimum PHI pulse count is 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x28 | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x29 | HPSCR | Internal GSC clock is GSC input pin frequency | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x2A | FRATE | PHI multiplier is 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0x2B | GINT | Global intensity PWM duty ratio $GINT = 16/64 = 25\%$ | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 0x30 to 0x3F | ISTR0 to ISTR15 | Individual LED string current $I_{LED} = 7/63$ times the full-scale current set by external resistor R_{ILED} | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0x40 to 0x4F | PHDLY0 to PHDLY15 | Individual LED string phase delay $t_{DLYx} = 0$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x50 to 0x5F | PWM0 to PWM15 | Individual LED string PWM duty ratio $D_{PWM} = 1/256 = 0.39\%$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x90 | E2ADDR | User EEPROM 7-bit address = 0x00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0x91 | E2CTRLSTA | User EEPROM read/write is disabled | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Atmel Corporation**

2325 Orchard Parkway
San Jose, CA 95131
USA

Tel: (+1) (408) 441-0311

Fax: (+1) (408) 487-2600

www.atmel.com

Atmel Asia Limited

Unit 01-5 & 16, 19F
BEA Tower, Millennium City 5
418 Kwun Tong Road
Kwun Tong, Kowloon
HONG KONG

Tel: (+852) 2245-6100

Fax: (+852) 2722-1369

Atmel Munich GmbH

Business Campus
Parking 4
D-85748 Garching b. Munich
GERMANY

Tel: (+49) 89-31970-0

Fax: (+49) 89-3194621

Atmel Japan

9F, Tonetsu Shinkawa Bldg.
1-24-8 Shinkawa
Chuo-ku, Tokyo 104-0033
JAPAN

Tel: (+81) (3) 3523-3551

Fax: (+81) (3) 3523-7581

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Тел: +7 (812) 336 43 04 (многоканальный)

Email: org@lifeelectronics.ru

www.lifeelectronics.ru