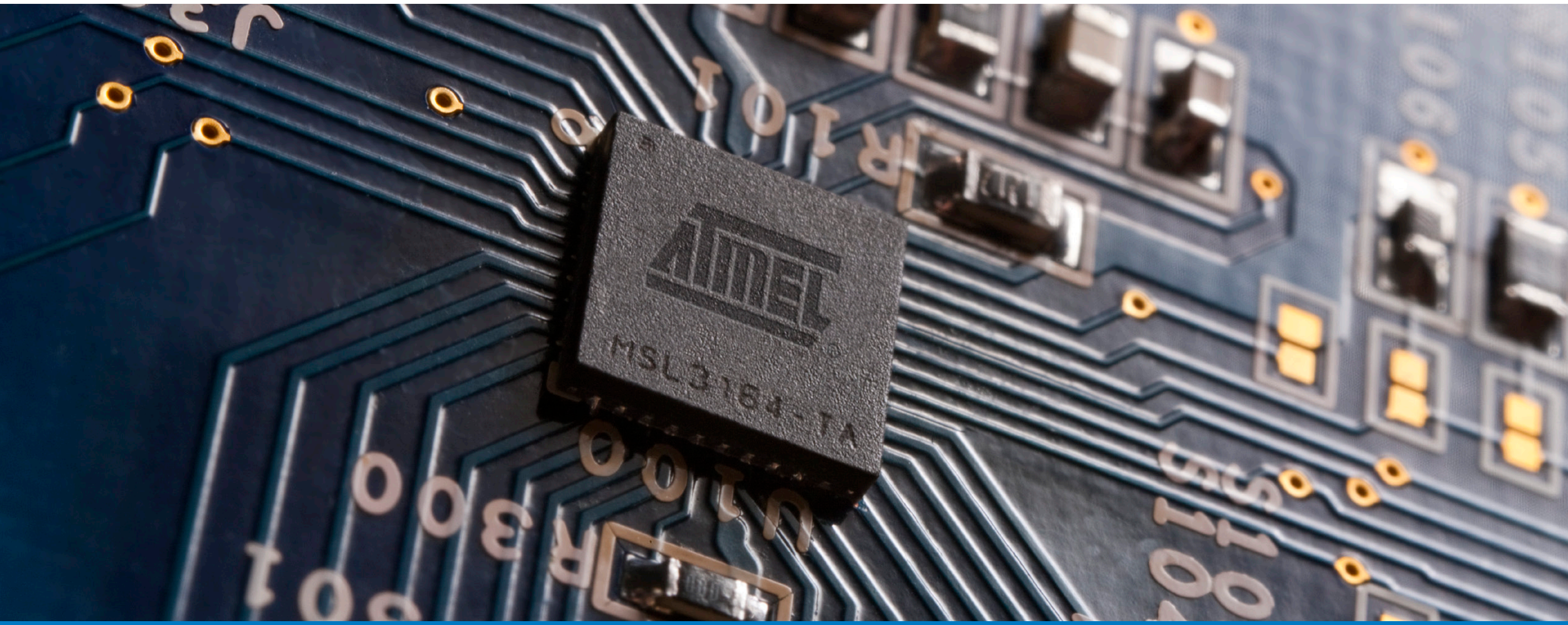


Atmel LED Drivers MSL3163 and MSL3164

16-string White & RGB LED Drivers with Adaptive Power Control, E^2PROM, and SPI/I^2C/SMBus Serial Interface

Datasheet Brief

Atmel LED Drivers-MSL3163 and MSL3164

16-string White & RGB LED Drivers with Adaptive Power Control, E^2PROM, and SPI/I^2C/SMBus Serial Interface

General Description

The Atmel LED Drivers-MSL3163 and MSL3164 compact, high-power LED string drivers use internal current control MOSFETs to sink up to 100mA per string, with current accuracy and matching better than 3%. The MSL3163/4 drive 16 parallel strings of ten white LEDs each, for a total of 160 white LEDs per device. Sixteen interconnected devices control up to 2560 white LEDs.

The MSL3163/4 adaptively controls the DC-DC converters that power the LED strings, using Atmel's Adaptive SourcePower technology. These Efficiency Optimizers minimize power use while maintaining LED current accuracy.

The MSL3164 features a 20 MHz SPI serial interface, and the MSL3163 offers a 1 MHz I^2C serial interface. Both interfaces support video frame-by-frame LED string intensity control for up to 16 interconnected devices to allow active area dimming. The devices include an advanced PWM engine that easily synchronizes to a video signal, and per-string phase adjustment to reduce unwanted LCD artifacts such as motion blur. Additionally, an on-chip E^2PROM allows the power-up defaults to be customized through the serial interface.

A unique combination of peak current control and pulse width management offer simple full screen brightness control, versatile area dimming and a consistent white point. One external resistor provides the global peak reference current for all LED strings, and global peak current fine-tuning is available through an 8-bit register. Global string drive pulse width is adjusted with an 8-bit global intensity register, and individual string pulse width is modulated with 12-bit registers.

The MSL3163/4 feature fault monitoring of open circuit, short circuit, loss of video sync and over temperature conditions, and provides a fault output to notify the system controller. Detailed fault status and control are available through the serial interface.

The MSL3163/4 are offered in a 6 x 6 x 0.75mm, 40-pin TQFN package and operate over the -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

Channel Signs

Architectural Lighting

Ordering Information

16-CHANNEL LED STRING DRIVERS		
PART	**INTERFACE**	**PACKAGE**
MSL3163BT	I^2C interface	40 pin, 6 x 6 x 0.75mm TQFN
MSL3164BT	SPI interface	40 pin, 6 x 6 x 0.75mm TQFN

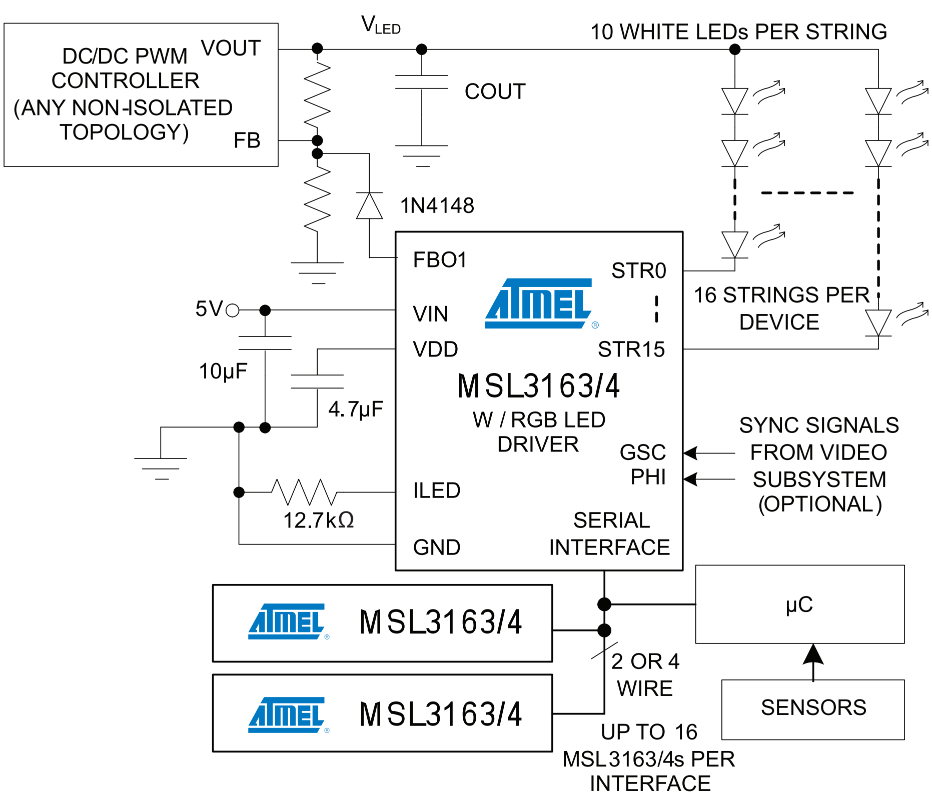
Atmel LED Drivers-MSL3163 and MSL3164

16-string White & RGB LED Drivers with Adaptive Power Control, E²PROM, and SPI/I²C/SMBus Serial Interface

Key Features

- 12-bit PWM String Dimming Operates at 240Hz
- Fast Serial Interfaces Support up to 16 Devices per Bus:
  - MSL3164 20 MHz SPI
  - MSL3163 1 MHz I²C
- 8-bit Adaptive Power Correction Maximizes Efficiency of up to Three String Power Supplies
- Drives 16 Parallel LED Strings of 10 White LEDs Each for up to 2560 White LEDs per Serial Bus
- Supports Adaptive, Real-time Area Dimming for Highest Dynamic Range LCD TVs and Monitors
- Programmable String Phase Reduces Motion Blur
- Global Intensity Control via Serial Interface
- 100mA Peak, 60mA Average LED String Current
- Single Resistor Sets Peak Current for all LED Strings
- ±3% Current Accuracy and Current Balance
- Video Frame (VSYNC) and Line (HSYNC) Sync Inputs
- Sync Loss Detectors Optionally Disable LED Strings
- Multiple MSL3163/4s Share String Power Supplies and Automatically Negotiate the Optimum Supply Voltage
- E²PROM Allows Customized Power-On Defaults
- Less Than 1µA LED String Off-Leakage Current
- String Open Circuit and LED Short Circuit Fault Detection
- Individual Fault Detection Enable for Each String
- Over-temperature Shutoff Protection
- Broadcast Write Simplifies Configuration
- -40°C To +85°C Operating Temperature Range

Application Circuit



Package Pin-out

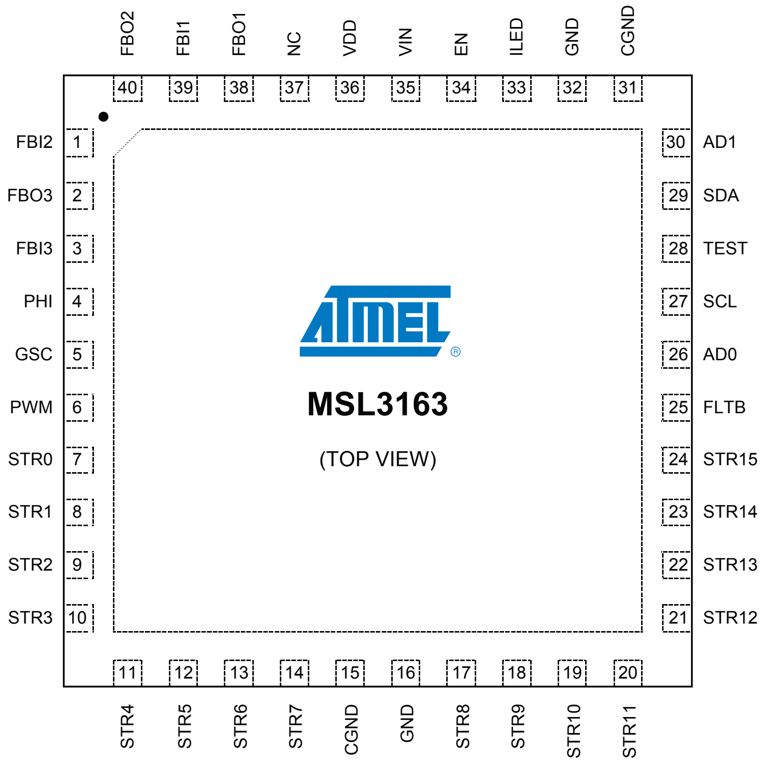


Figure 1. Atmel LED Driver-MSL3163 Pinout 40 Pin TQFN

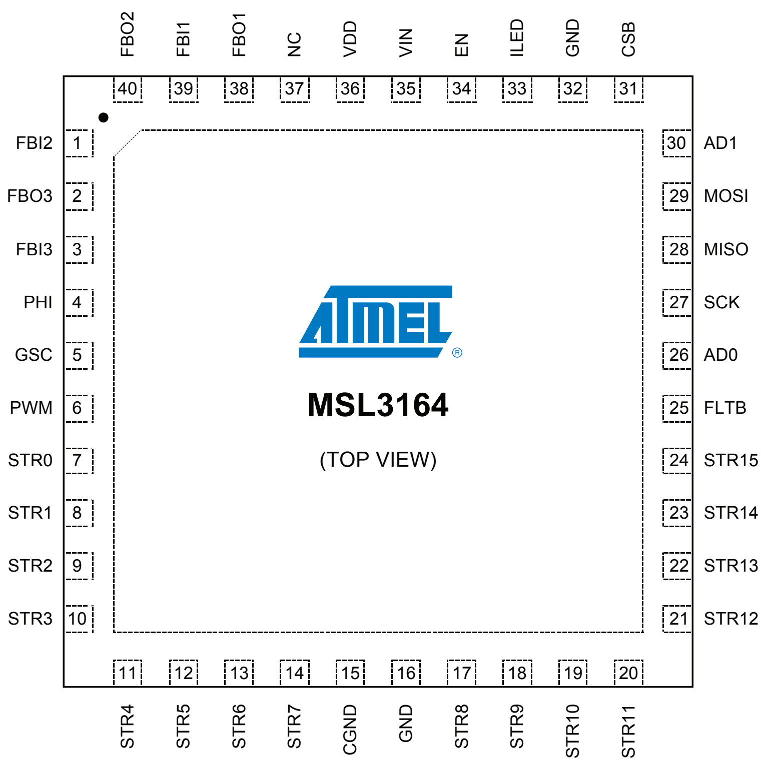
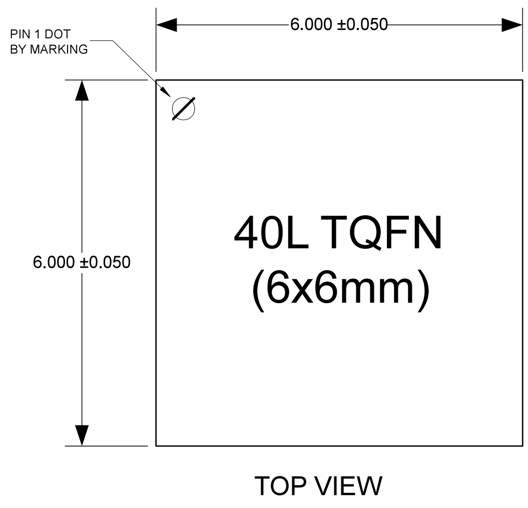


Figure 2. Atmel LED Driver-MSL3164 Pinout 40 Pin TQFN



		TQFN
A	MAX.	0.800
	NOM.	0.750
	MIN.	0.700

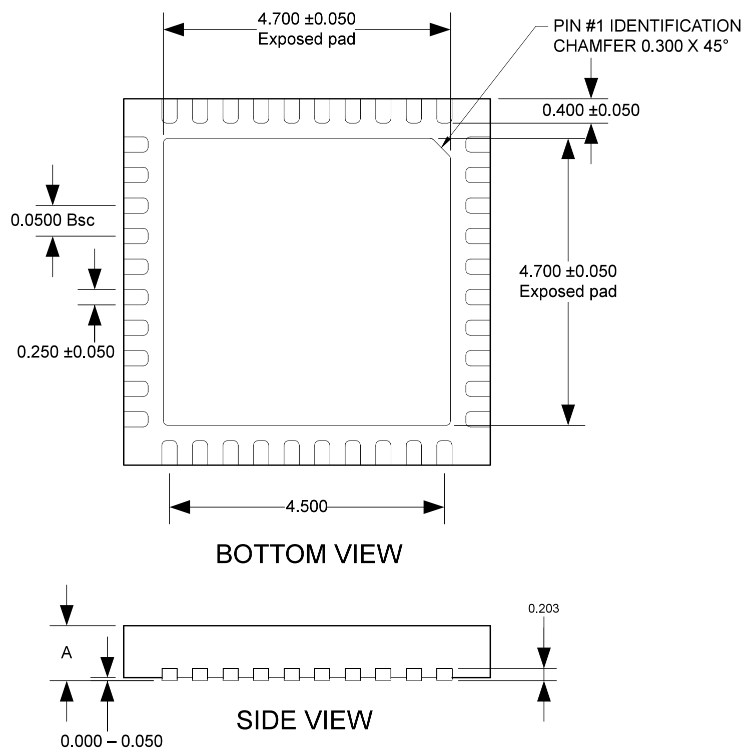


Figure 3. Package Dimensions: 40 Pin 6mm x 6mm x 0.75mm TQFN (0.5mm pin pitch) with exposed pad

Package Pin Description

Table 1. Pin Assignments

PIN	PIN NAME		PIN DESCRIPTION
	MSL3163	MSL3164	
1	FBI2	FBI2	**Efficiency Optimizer input 2** Connect FBI2 to FBO2 of the next device when chaining devices (Figure 7). If unused connect FBI2 to GND.
2	FBO3	FBO3	**Efficiency Optimizer output 3** Connect FBO3 to the third power supply's feedback node or to FBI3 of the previous device when chaining devices (Figure 7). If unused connect FBO3 to GND.
3	FBI3	FBI3	**Efficiency Optimizer input 3** Connect FBI3 to FBO3 of the next device when chaining devices (Figure 7). If unused connect FBI3 to GND.
4	PHI	PHI	**Phase synchronization input** Drive PHI with an external signal from 40Hz to 10kHz to synchronize the MSL3163/4 clock. PHI is typically the VSYNC signal input.
5	GSC	GSC	**Gate shift clock input** Drive GSC with the gate shift clock of the video signal, from 0 to 10MHz. GSC is typically the HSYNC signal input.
6	PWM	PWM	**PWM input** PWM allows direct external control of the brightness of all LED strings. The PWM input may also be used as a gate signal for the output of the PWM. Drive PWM with a pulse-width modulated signal with duty ratio ranging from 0% to 100% and frequency up to 5kHz.When not configured for use as an input PWM is high-impedance.
7 - 14, 17 - 24	STR0 thru STR15	STR0 thru STR15	**LED string current sink outputs** Connect the cathode of the n'th strings bottom LEDs to STRn. Connect unused STRn outputs to GND.
15	CGND	CGND	**Connect to ground** Connect CGND to GND and to EP with short, wide traces.
16, 32	GND	GND	**Signal ground** Connect all GNDs to system ground and to EP with short, wide traces.
25	FLTB	FLTB	**Fault indication output (active low)** Open drain output FLTB sinks current to GND whenever a fault condition is verified. Toggle EN low or read the fault registers to clear FLTB. Once cleared, FLTB reasserts if the fault conditions persist.
26,30	AD0, AD1	AD0, AD1	**Slave ID selection inputs** Connect AD1 and AD0 to GND through resistors to set the device address for the serial interface.
27	SCL	SCK	**MSL3163: I²C serial clock input** SCL is the clock input for the I²C serial interface. **MSL3164: SPI serial shift clock** SCK is the clock input for the SPI interface.
28	TEST	MISO	**MSL3163: factory test I/O** Factory test. Make no electrical connection to TEST. **MSL3164: Master input slave output** MISO is the SPI serial data output.
29	SDA	MOSI	**MSL3163: I²C serial data I/O** SDA is the data I/O for the I²C serial interface. **MSL3164: Master input slave output** MOSI is the SPI serial data input.
31	GND	CSB	**MSL3163: ground.** Connect GND to system ground and to EP with short, wide traces. **MSL3164: chip select (active low)** CSB is the chip select input for SPI transactions. CSB is active low.
33	ILED	ILED	**Maximum LED string current setting input** Connect a resistor from ILED to GND to set the full-scale LED string current for all strings using $I_{STRING} = 762 / R_{ILED}$. For example, connect a 12.7kΩ resistor to GND to set a 60mA maximum sink current through each LED string.
34	EN	EN	**Enable input (Active high)** Drive EN high to turn on the MSL3163/4, drive EN low to turn off the MSL3163/4. For automatic startup connect EN to VIN. When EN is low the entire device, including the serial interface, is turned off. Driving EN high initiates a boot load of the E²PROM data into the control registers, simulating a cold start-up.
35	VIN	VIN	**Supply voltage input** Connect a 5V supply to VIN. Bypass VIN to GND with a 10µF ceramic capacitor placed close to VIN.

PIN	PIN NAME		PIN DESCRIPTION
	MSL3163	MSL3164	
36	VDD	VDD	**2.5V internal LDO regulator output** VDD powers internal logic. Bypass VDD to GND with a 4.7µF ceramic capacitor placed close to VDD.
37	NC	NC	**No connect** Leave NC unconnected.
38	FBO1	FBO1	**Efficiency Optimizer output 1** Connect FBO1 to the first power supply's feedback node or to FBI1 of the previous device when chaining devices (Figure 7). If unused connect FBO1 to GND.
39	FBI1	FBI1	**Efficiency Optimizer input 1** Connect FBI1 to FBO1 of the next device when chaining devices (Figure 7). If unused connect FBI1 to GND.
40	FBO2	FBO2	**Efficiency Optimizer output 2** Connect FBO2 to the second power supply's feedback node or to FBI2 of the previous device when chaining devices (Figure 7). If unused connect FBO2 to GND.
EP	EP	EP	**Exposed pad, power ground** EP is the path that the string currents take to ground. EP also provides thermal relief for the die. Provide large traces from EP back to the string power supplies. Also connect EP to system ground, and to GND using short, wide traces.

Absolute Maximum Ratings

Voltage (With Respect to GND, CGND = EP = GND)

VIN, EN .... -0.3V to +6V

VDD .... -0.3V to +2.75V

MSL3163: SDA, SCL .... -0.3V to +6V

MSL3164: MISO, MOSI, CSB, SCK .... -0.3V to (VIN + 0.3V)

FLTB .... -0.3V to +6V

ILED, AD0, AD1 .... -0.3V to (VDD + 0.3V)

PHI, GSC, PWM, FBO1, FBO2, FBO3, FBI1, FBI2, FBI3 .... -0.3V to (VIN + 0.3V)

STR0 thru STR15 .... -0.3V to +40V

CGND .... -0.3V to +0.3V

Current (Into Pin)

VIN 50mA

EP .... -1700mA

STR0 thru STR15 .... 105mA

All other pins 20mA

Continuous Power Dissipation

40-Pin 6mm x 6mm QFN (derate 37mW/°C above T_A = +70°C) 2963mW

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	5.5	V
VIN Operating Supply Current	I_{VIN}	EN = VIN, SLEEP = 0, R_{ILED} = 12.7kΩ, PHI = 240Hz, GSC = 983.04kHz, POWERCTRL = 0x4F, ISTR = 0xFF, OSCCTRL = 0x04, GSCINTEN = 0, PHIINTEN = 0, STRnEN = 1; PWMn = 0x7FF		18	28	mA
		PWMn = 0xFFF		24	35	mA
VIN Shutdown Supply Current	I_{SHDN}	EN = GND, SDA, SCL, AD0, AD1, PWM, PHI and GSC = GND		10		µA
VIN Sleep Current	I_{SLEEP}	EN = 1, SLEEP = 1, SDA, SCL, AD0, AD1, PWM, PHI and GSC = GND or VDD		1.5		mA
VDD Regulation Voltage	VDD		2.4	2.5	2.6	V
Input High Voltage: SDA, SCL, PWM, PHI, GSC, MOSI, CSB	V_{IH}		0.7 x VDD			V
Input Low Voltage: SDA, SCL, PWM, PHI, GSC, MOSI, CSB	V_{IL}				0.3 x VDD	V
Input High Voltage: EN			1.22			V
Input Low Voltage: EN					0.8	V
Output High Voltage: PHI, GSC, MISO	V_{OH}	I_{SOURCE} = 5mA	VIN – 0.4			V
Output Low Voltage: PHI, GSC, SDA, MISO, FLTB	V_{OL}	I_{SINK} = 5mA			0.4	V
ILED Regulation Voltage		R_{ILED} = 12.7kΩ		350		mV
FBI Feedback Input Current			0		365	µA
FBO Feedback Output Current Range		V_{FBO} ≤ VIN – 0.5V	0		365	µA
FBO Feedback Output Current Step Size				1.1		µA
FBI Input Disable Threshold					50	mV
STR0 thru STR15 Sink Current		R_{ILED} = 12.7kΩ, ISTR = 0xFF, V_{STRn} = 1V	55	60	67	mA
STR0 thru STR15 Sink Current Maximum		R_{ILED} = 7.68kΩ, ISTR = 0xFF (Note 1)		100		mA
STR0 thru STR15 Current Load Regulation		R_{ILED} = 12.7kΩ; ISTR = 0xFF, FLDBKEN = 0, V_{STRn} = 1V to 5V		0.033		%/V
STR0 thru STR15 Current Matching		R_{ILED} = 12.7kΩ, ISTR = 0x7F, V_{STRn} = 1V	-5		5	%
STR0 thru STR15 Minimum Headroom	V_{STR}	R_{ILED} = 12.7kΩ; ISTR = 0xFF		0.5		V
STR0 thru STR15 Short Circuit Fault Detection Threshold	SC_{REF}			3.5		V
STR0 thru STR15 Current Slew Rate		Current rising (Note 2)		608		mA/µs
		Current falling (Note 2)		10868		mA/µs
Thermal Shutdown Temperature		(Note 2)		135		°C

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
AC ELECTRICAL CHARACTERISTICS						
OSC Frequency	f_{OSC}	OSCCTRL = 0x04	18.15	20.00	21.88	MHz
PHI Frequency	f_{PHI}		0.04		10	kHz
PHI Lock				4		PHI cycles
GSC Frequency	f_{GSC}		0		10	MHz
PWM Frequency	f_{PWM}				50	kHz
PWM Duty Cycle			0		100	%

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
I²C TIMING CHARACTERISTICS, MSL3163						
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 Setup Time	$t_{SU:STOP}$		0.26			µs
SDA Data Hold Time	$t_{HD:DAT}$		50			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
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 8)		50		ns

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
SPI TIMING CHARACTERISTICS, MSL3164						
SCK Frequency					20	MHz
CSB Falling Edge to SCK Rising Edge Setup Time	$t_{CSB:SCK(SU)}$		100			ns

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
SCK Falling Edge to CSB Rising Edge Setup Time	$t_{SCK:CSB(SU)}$		50			ns
MOSI to Falling Edge of SCK Setup Time	$t_{MOSI(SU)}$		16			ns
SCK Falling Edge to MOSI Setup Time	$t_{MOSI(HOLD)}$		20			ns
MOSI, CSB, SCK Signal Rise Time	$t_{R(SPI)}$			5.0		ns
MOSI, CSB, SCK Signal Fall Time	$t_{F(SPI)}$			5.0		ns
CSB Falling Edge to MISO Data Valid	$t_{CSB:MISO(DV)}$				50	ns
CSB Rising Edge to MISO High Impedance	$t_{CSB:MISO(HIZ)}$				50	ns
SCK Rising Edge to MISO Data Valid	t_{VALID}			25	80	ns

Note 1. Subject to thermal dissipation characteristics of the device

Note 2. Guaranteed by design, 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. $t_{VD:ACK}$ = SCL LOW to SDA (out) LOW acknowledge time.

Note 5. $t_{VD:DAT}$ = minimum SDA output data-valid time following SCL LOW transition.

Note 6. A master device must internally provide an SDA hold time of at least 300ns to ensure an SCL low state.

Note 7. The maximum SDA and SCL rise times is 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 8. MSL3163/4 includes input filters on SDA, SCL, AD0 and AD1 inputs that suppress noise less than 50ns.

Block Diagram

The block diagram for the Atmel LED Drivers-MSL3163/4 is shown in Figure 4.

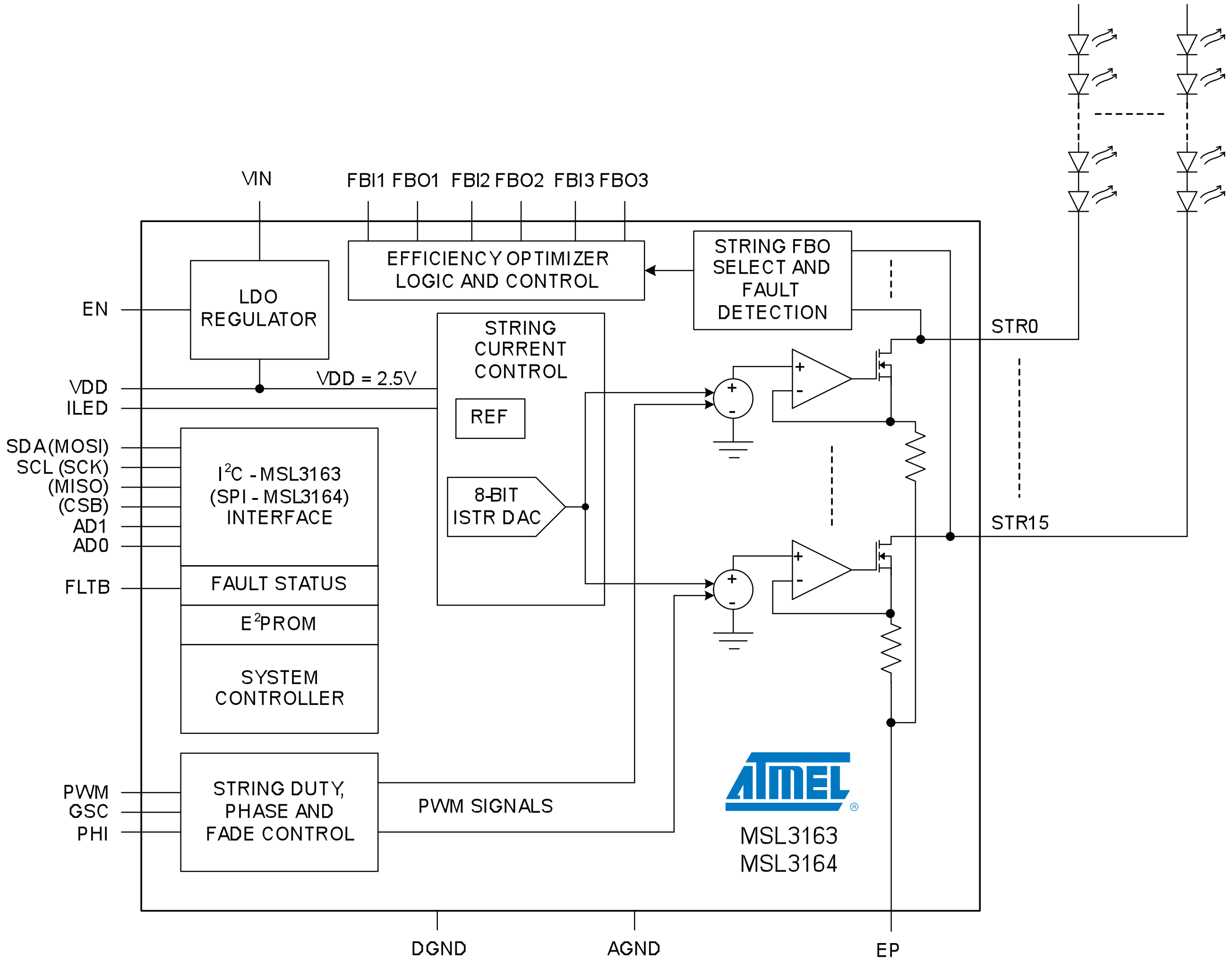


Figure 4. Atmel LED Drivers-MSL3163/4 Block Diagram

Typical Application Circuit

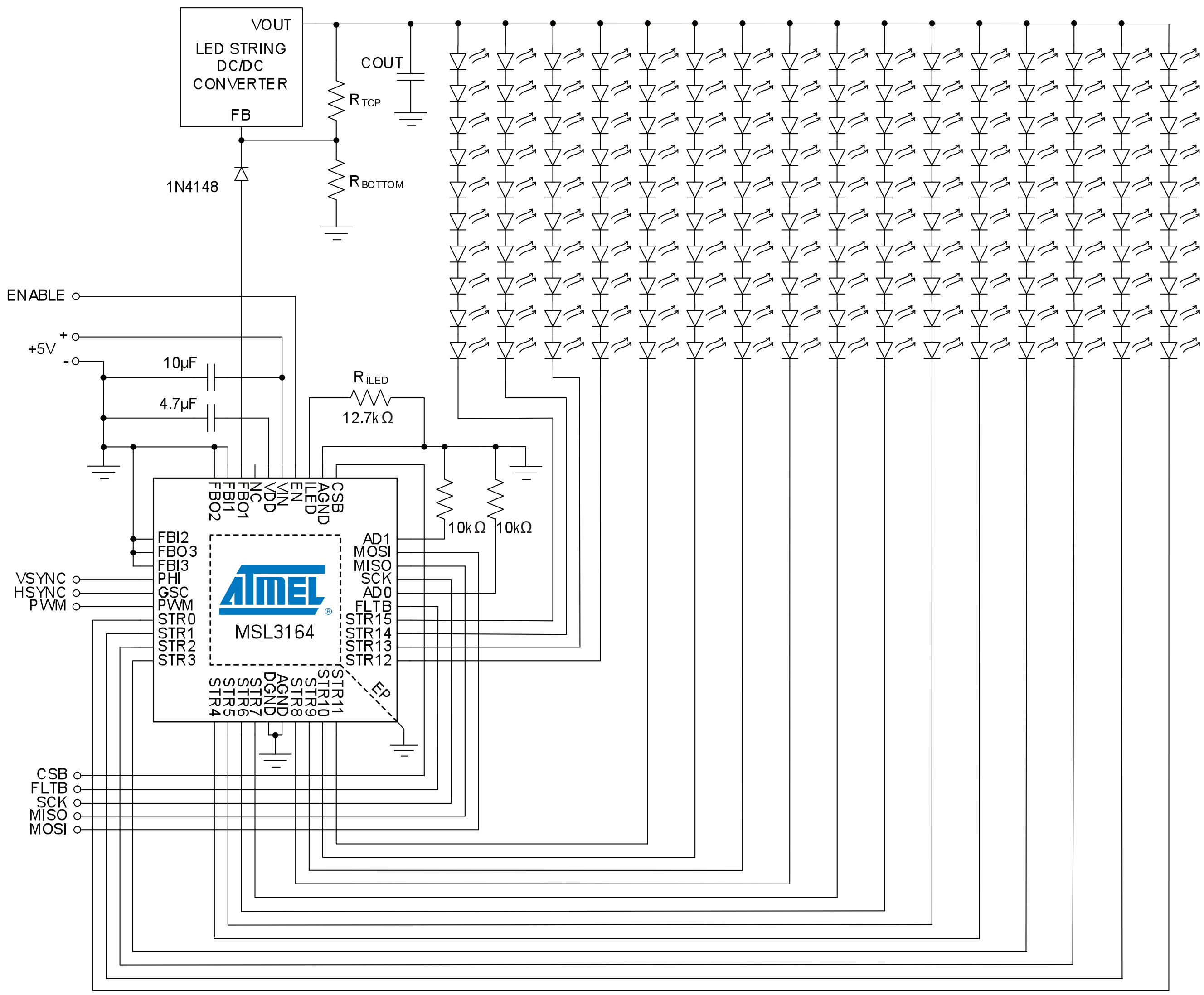


Figure 5. Atmel LED Driver-MSL3164 Driving 160 White LEDs in 16 Strings at 60mA Per String.

Detailed Description

The MSL3163 and MSL3164 are highly integrated, flexible multi-string LED drivers with power supply control to maximize system efficiency. The drivers easily connect to a video subsystem. Although optional, this offers a simple architecture for use in LCD TV backlight applications. Up to 16 drivers easily connect together to drive large numbers of LED strings in a system. The drivers provide multiple methods of controlling LED brightness, through both peak current control and through pulse width control of the string drive signals. Peak current control offers excellent color consistency, while pulse width control allows brightness management. An on-chip E²PROM holds all the default control register values. At power-up the data in the E²PROM automatically copy directly to the control registers, setting up the device for operation.

The devices interface to a µC via I²C (MSL3163) or SPI (MSL3164). The robust 1MHz I²C interface supports up to 16 devices on the bus. The 20MHz bus addressable SPI interface supports up to 16 devices per Chip Select line. While typically the LED drive PWM signal is internally generated, both drivers also accept an external direct-drive PWM signal and offer optional string drive phase spreading. With direct-drive PWM, a Pulse Width Modulated signal applied to the PWM input sets the PWM duty and the frequency of the LEDs drive signal. With phase spreading enabled, a progressive 1/16 PWM-frame time delay per string helps reduce both the transient load on the LED power supplies, and the power supply input capacitor size requirements.

The PWM frequency of the drivers is either synchronized to an external signal applied to PHI, or generated from the internal oscillator for stand-alone applications. Typically the VSYNC signal from the video system is used for the PHI input. The on-time of each string is individually programmed via the device registers, providing a peak resolution of 12-bits when using the on-chip PWM generator. The actual resolution of the PWM frequency depends upon on the ratio of the GSC frequency (typically provided by a systems HSYNC signal, but can be internally generated) to the PHI frequency, because the on-time of a string is programmed as a 12-bit count of the number of GSC clock cycles. This count can be further scaled by an 8-bit Global intensity value, when enabled. The GSC clock is also used to precisely set each string's phase delay so that it is synchronized relative to the video frame.

The Efficiency Optimizers control a wide range of different architectures of external DC/DC and AC/DC converters. Multiple drivers in a system communicate with each other in real time to select an optimized operating voltage for the LEDs. This allows design of the power supply for the worst case Forward Voltage (V_f) of the LEDs without worrying about excessive power dissipation issues. During the start-up sequence the MSL3163/4 automatically reduce the power supply voltage to the minimum voltage required to keep the LEDs in current regulation. The devices can be configured to periodically perform this optimization to compensate for changes of the LED's forward voltage, and to assure continued optimum power savings.

Internal Regulators and Enable Input

The MSL3163/4 includes an internal linear regulator that operates from the 5V nominal input supply, VIN, and provides an internal 2.5V supply, VDD, to power the low-voltage internal circuitry. Bypass VDD (pin 36) to GND with a 4.7µF capacitor. Bypass VIN (pin 35) to GND with a 10µF capacitor.

The MSL3163/4 enable input, EN, enables the device. Drive EN low to enter low power operation, which lowers quiescent current draw to less than 20µA. With EN low the serial interface is ignored. Drive EN high to turn on the device. When EN is driven high the contents of the E²PROM are boot-loaded into the control registers, simulating a cold start-up.

Setting the LED String Current with R_{ILED} and ISTR

The MSL3163/4 features 16 current sink outputs, rated at 40V, each designed to sink up to 100mA peak. Limit average current to 60mA if the PCB copper around the MSL3163/4 is the only heat sink employed. The maximum string current, I_{ILED}, for all 16 LED string inputs is set by a single external resistor, R_{ILED}, placed from ILED to GND, whose value is determined using:

$$R_{ILED} = \frac{762}{I_{ILED}} .$$

For example, a full-scale LED current of 60mA returns R_{ILED} = 12.7kΩ. The current for all LED strings is reduced from its full-scale value with 8-bit resolution using ISTR, the String Current Control register 0x0F.

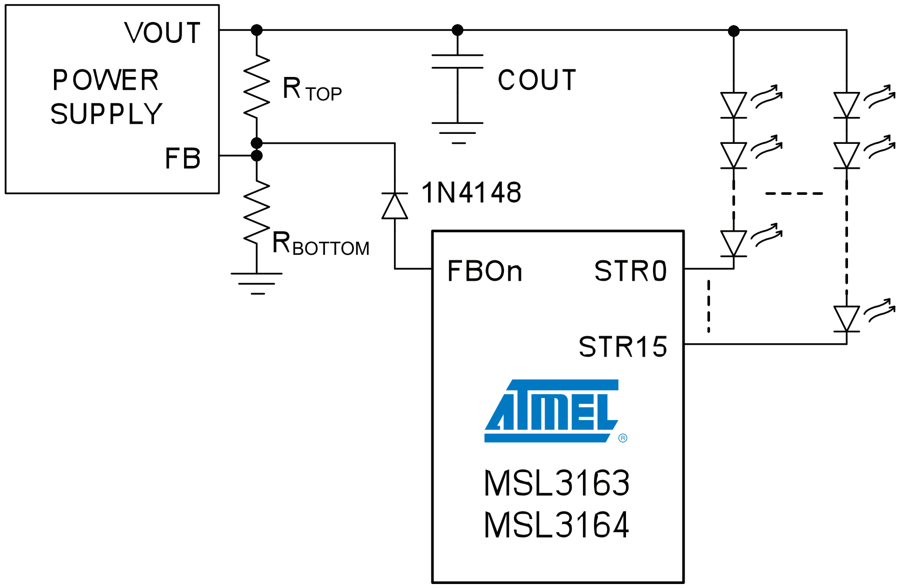


Figure 6. FBOn Connects to the Power Supply Voltage Divider Through a Diode

Connecting the Efficiency Optimizer to an LED String Power Supply and Selecting Resistors

The MSL3163/4 are designed to control LED string power supplies that use a voltage divider (R_{TOP} and R_{BOTTOM} in Figure 6) to set output voltage, and whose regulation feedback voltage is not more than 3.5V. The Efficiency Optimizer improves power efficiency by injecting a current of between 0µA and 255µA into the voltage divider of the external power supply, dynamically adjusting the power supply's output to the minimum voltage required by the LED strings. To select the resistors first determine $V_{OUT(MIN)}$ and $V_{OUT(MAX)}$, the minimum and maximum string supply voltage limits, using:

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

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 10). For example, if the LED data are $V_{f(MIN)}$ = 3.5V and $V_{f(MAX)}$ = 3.8V, and ten LEDs are used in a string, then the total minimum and maximum voltage drops across the LEDs are 35V and 38V. Adding an allowance of 0.5V of 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 the string drivers STR1 thru STR15. Then determine R_{TOP} using:

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

where $I_{FBOn(MAX)}$ is the 255µA maximum output current of the Efficiency Optimizer outputs FBOn (if cascading multiple MSL3163/4s determine $I_{FBOn(MAX)}$ as shown in the next section). 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 FBOn and the supply's feedback node to protect the MSL3163/4 against current flow into FBOn.

Using Multiple Atmel LED Drivers-MSL3163/4s to Control a Common Power Supply

Cascade multiple MSL3163/4 devices into a chain configuration, with the FBIn of one device connected to the FBOn of the next (Figure 7). Connect the first FBOn to the power supply feedback resistor node through a diode, and the unused FBIn inputs (and any unused FBOn outputs) to GND as close to the MSL3163/4 as possible. Assign all strings powered by a common supply to the proper FBOn output using String Set registers (STRnSET) 0x20 thru 0x3F. The chained devices work together to ensure that the system operates at optimum efficiency. Note that the accuracy of the feedback chain may degrade through each link of the FBIn/FBOn chain by as much as 2%. Determine the potential worst case maximum FBOn current $I_{FBOn(MAX/MIN)}$ using:

$$I_{FBOn(MAX/MIN)} = 255\mu A * (0.98)^{N-1} ,$$

where N is the number of MSL3163/4s connected in series. Use this result in the above R_{TOP} resistor equation for the term $I_{FBOn(MAX)}$ instead of using 255µA.

Take care in laying out the traces for the Efficiency Optimizer connections. Minimize the FBIn/FBOn trace lengths as much as possible. Do not route the signals close to traces with large variations in voltage or current, because noise may couple into FBIn. If these traces must be routed near noisy signals, shield them from noise by using ground planes or guard traces.

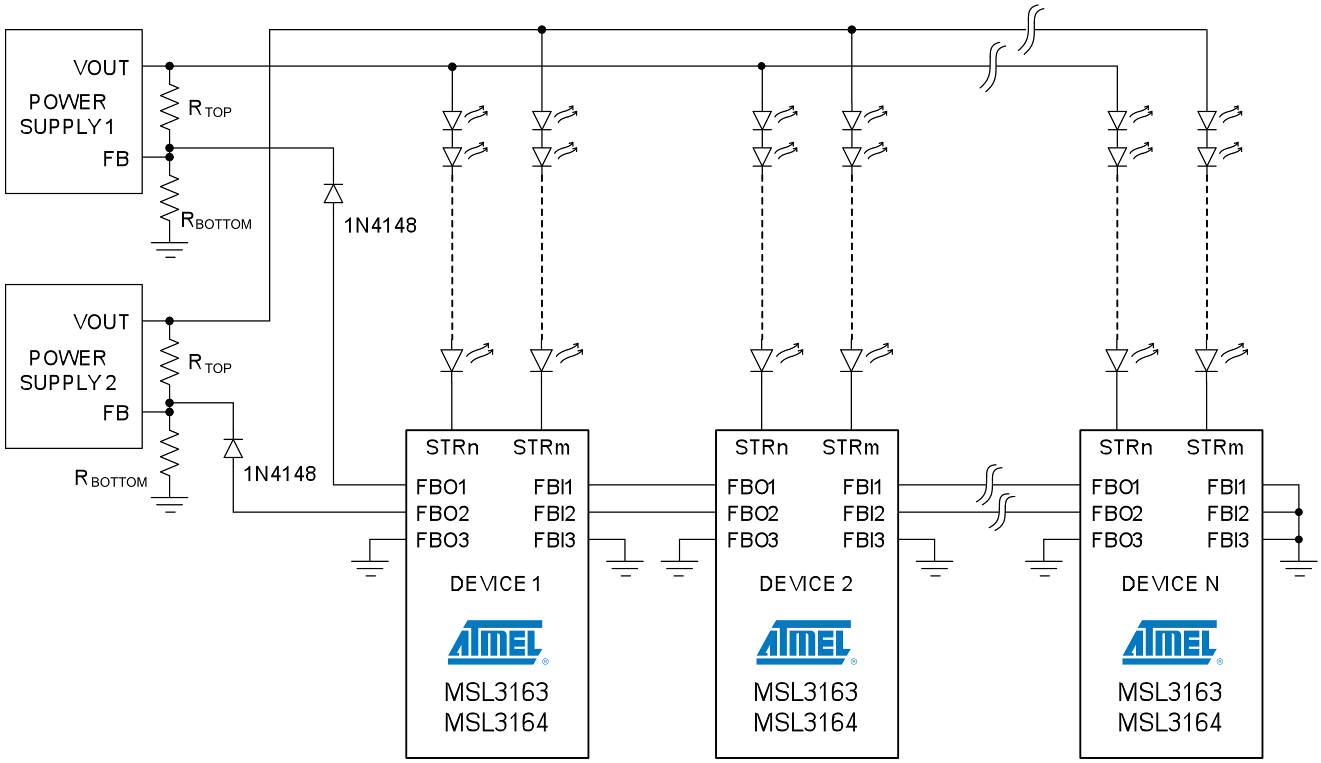


Figure 7. Example of Cascading Multiple Devices to Optimize Common Power Supplies

Direct PWM Control of the LED Strings

An external PWM signal applied to the PWM input allows direct PWM control over the strings when bits PWMEN and PWMDIRECT are set in PWM Control register 0x1E. This configuration bypasses PHI and GSC, but allows automatic LED string phase delay using bit D2 of register 0x1E.

The PWM input can also be configured as a gate for the output of the PWM engine using the PWM Global Enable bit D3 of the PWM Control register 0x1E.

Register Map and the E²PROM

Register Map Summary

Control the MSL3163/4 using the 96 registers in the range 0x00 thru 0x5F (Table 2). It may be convenient, and it is allowed, to read and write to unused bits in this range when accessing registers, but always write zeros. Reads from unused bits always return zeros. Three additional registers, 0x90, 0x91 and 0x93 allow access to the E²PROM and provide Efficiency Optimizer status. The power-up default values for all control registers are stored within the on-chip E²PROM, and any of these E²PROM values may be changed through the serial interface.

Table 2. Atmel LED Drivers-MSL3163/4 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
0x02	POWERCTRL	Fault configuration	SLEEP	I²CTOEN	PHIMINFEN	GSCMAXFEN	STRSCFEN	STROCFEN	FBOOCEN	FBOEN
0x03	FLTSTATUS	Fault status, global	-	-	PHIMINFLT	GSCMAXFLT	STRSCDET	STROCDET	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]		FBSDLY[1:0]		FBCFDLY[1:0]	
0x0B	FBOCTRL1		SCCDLY[1:0]		DECRSTEP[1:0]		INITPWM	ACAL100	ACALEN	ICHKDIS
0x0C	FBODAC1	Efficiency Optimizer DAC readback	FBODAC1[7:0]							
0x0D	FBODAC2		FBODAC2[7:0]							
0x0E	FBODAC3		FBODAC3[7:0]							
0x0F	ISTR	8-bit global string current	ISTR[7:0]							
0x10	OSCCTRL	Oscillator frequency	-	-	-	-	-	OSCTRL[2:0]		
0x11	GSCCTRL	GSC processing control	GSCCHK-SEL	-	-	-	GSCMAXEN	GSCPOL	GSCPHI-SYNCEN	GSCINTEN
0x12	GSCGEN	Internal 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	PHIPOL	PHIINTEN
0x19	PHIGEN	Internal PHI clock generator	PHIGEN[7:0]							
0x1A			PHIGEN[15:8]							

Table 2. Atmel LED Drivers-MSL3163/4 Register Map

ADDRESS AND REGISTER NAME		FUNCTION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x1B		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	PHA-DLYEN	PWM-DIRECT	PWMEN
0x1F	GINT	Global PWM scaling	GINT[7:0]							
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	E²PROM read/ write access	-	E2ADDR[6:0]						
0x91	E2CTRLSTA		E2BUSY	BLDACT	E2ERR	-	-	RWCTRL[2:0]		
0x93	FBOSTATUS	FBO status	FBOOPEN[3:1]			FBOACTIVE[3:1]			FBOCAL	FBOINITCAL

Register Power-Up Defaults

Register power-up default values are shown in Table 3

Table 3. Atmel LED Drivers-MSL3163/4 Register Power-Up Defaults

REGISTER NAME AND ADDRESS		POWER-UP CONDITION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x00	CONTROL0	LED strings STR0 thru STR7 enabled	1	1	1	1	1	1	1	1
0x01	CONTROL1	LED strings STR8 thru STR15 enabled	1	1	1	1	1	1	1	1
0x02	POWERCTRL	Efficiency Optimizer outputs enabled FBO open circuit detection enabled String open circuit detection enabled LED short circuit detection enabled GSC maximum fault detection disabled PHI minimum fault detection disabled I²C bus timeout detection enabled Device awake	0	1	0	0	1	1	1	1
0x08	FLTMASK0	Fault detection enabled on all strings	1	1	1	1	1	1	1	1
0x09	FLTMASK1		1	1	1	1	1	1	1	1
0x0A	FBOCTRL0	Current sink error confirmation delay = 4µS FBO power supply correction delay = 2ms Efficiency Optimizer recalibration delay = 1s Efficiency Optimizer correction steps = 6	0	0	0	0	0	0	0	0
0x0B	FBOCTRL1	Current sink error detection not disabled Auto recalibration enabled PWM settings used during auto recalibration PWM duty cycle = 100% during initial calibration Efficiency Optimizer operates using 1µA steps LED short circuit confirmation delay = 4µs	0	0	0	1	0	0	1	0
0x0F	ISTR	Strings current set to 50% of R_{ILED} setting	0	1	1	1	1	1	1	1
0x10	OSCCTRL	f_{OSC} = 20MHz	0	0	0	0	0	1	0	0
0x11	GSCCTRL	GSC synchronized to the falling edge of the external signal	0	0	0	0	0	0	0	0
0x12	GSCGEN	Although disabled, Internal GSC frequency = 20MHz / (19 + 1) = 1MHz	0	0	0	1	0	0	1	1
0x13			0	0	0	0	0	0	0	0
0x14	GSCMUL	GSC multiplied by 4	0	0	0	0	0	0	1	1
0x15	GSCDIV	GSC not divided	0	0	0	0	0	0	0	0
0x16	GSCMAX	Although disabled, GSC max count is set to 19 clock cycles	0	0	0	1	0	0	1	1
0x17			0	0	0	0	0	0	0	0
0x18	PHICTRL	PHI synchronized to the falling edge of the external signal	0	0	0	0	0	0	0	0
0x19	PHIGEN	Although disabled, Internal PHI frequency = 20MHz / (8 * (10416 + 1)) = 240Hz	1	0	1	1	0	0	0	0
0x1A			0	0	1	0	1	0	0	0
0x1C	PHIMIN	No PHI minimum	0	0	0	0	0	0	0	0
0x1D			0	0	0	0	0	0	0	0

REGISTER NAME AND ADDRESS		POWER-UP CONDITION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x1E	PWMCTRL	PWM Operation enabled Internal PWM engine determines t_{ON} and t_{OFF} Phase delay enabled PWM input not esed as gate for PWM engine output String on-times allowed to extend beyond PWM frame GINT ignored String current fold-back enabled	1	0	0	1	0	1	0	1
0x1F	GINT	Although Disabled, Global Intensity is set to (127) / 256 = 49.6%	0	1	1	1	1	1	1	1
0x20	STR0SET	All Strings set to 0 Phase Delay Strings Efficiency Optimizer assignments are: FBO1: Strings 0,4,8,12 FBO2: Strings 1,2,5,6,9,10,13,14 FBO3: Strings 3, 7, 11, 15	0	0	0	0	0	0	0	0
0x21			0*	1*	0	0	0	0	0	0
↓	↓		↓							
0x3E	STR15SET		0	0	0	0	0	0	0	0
0x3F			1*	1*	0	0	0	0	0	0
0x40	PWM0	All Strings Have PWM Value = 512 GSC Cycles	0	0	0	0	0	0	0	0
0x41			0	0	0	0	0	0	1	0
↓	↓		↓							
0x5E	PWM15		0	0	0	0	0	0	0	0
0x5F			0	0	0	0	0	0	1	0
0x90	E2ADDR	E^{2}PROM 7-bit address = 0x00	0	0	0	0	0	0	0	0
0x91	E2CTRLSTA	E^{2}PROM read/write disabled	0	0	0	0	0	0	0	0
0x93	FBOSTATUS	Feed Back Output Status	0	0	0	0	0	0	0	0

*** These bits set the FBOn string assignments.**

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