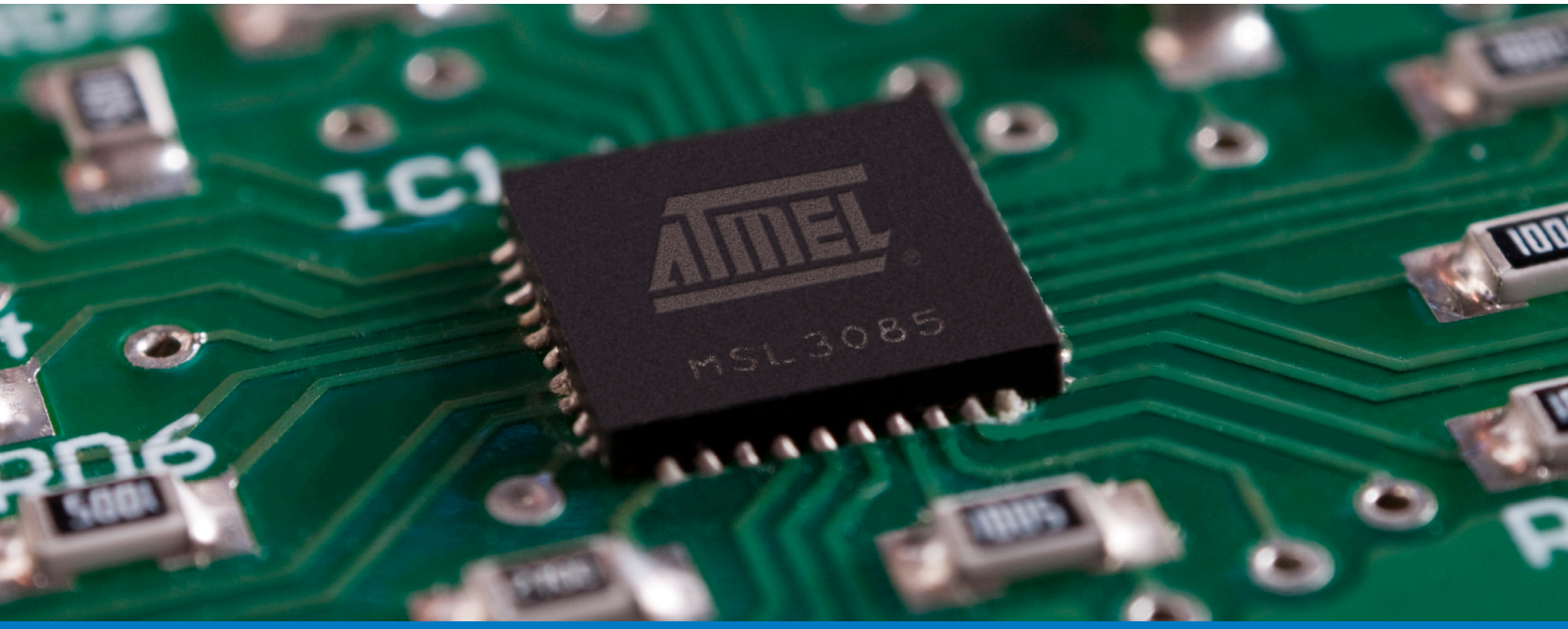


Atmel LED Driver-MSL3085

8-string White and RGB LED Driver with Adaptive Power Control, EEPROM, and I²C/SMBus Serial Interface

Datasheet Brief

Atmel LED Driver-MSL3085

8-string White and RGB LED Driver with Adaptive Power Control, EEPROM, and I²C/SMBus Serial Interface

General Description

The Atmel LED Driver-MSL3085 compact, high-power 8 LED strings controller uses external MOSFETs to sink up to 350mA per string, with current accuracy and matching better than ±1.5%. The MSL3085 drives eight parallel strings of LEDs, and offers fault detection and management of open and short circuit LEDs.

The MSL3085 features a 1MHz I²C serial interface. The interface supports video frame-by-frame LED string intensity control for up to eight interconnected devices, allowing active area dimming and phase shifted PWM timing for video displays. It includes an advanced PWM engine that synchronizes LED timing with the video signal for reduced motion blur and waterfall noise.

The MSL3085 adaptively controls the DC-DC converters that power the LED strings using patented Atmel Adaptive SourcePower™ technology. These fault monitored efficiency optimizers minimize power use while maintaining LED current accuracy, and allow up to eight interconnected devices to automatically negotiate the optimum power supply voltage.

A unique combination of peak current control and pulse width dimming management offers simple full-screen brightness control, versatile area dimming, and a consistent white point. LED string current is set for each string using a current sense (FET source) resistor. LED current is also digitally controlled for all eight LED strings. Global string drive pulse width is adjusted with an 8-bit global intensity register, and individual string pulse width is modulated with 12-bit control.

The MSL3085 monitors for string open circuit, LED short circuit, loss-of-sync and over temperature faults, and provides a hardware fault output to notify the MCU. Detailed fault status and control are available through the serial interface. Additionally, the MSL3085 includes an on-chip EEPROM that allows the power-up default register settings to be customized via the serial interface.

The MSL3085 is offered in a 6 x 6 x 0.75mm, 40-pin TQFN package, and operates 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

Channel Signs

Architectural Lighting

Ordering Information

EIGHT-CHANNEL LED STRING DRIVER		
PART	**INTERFACE**	**PACKAGE**
MSL3085BT	I²C	40-pin, 6 x 6 x 0.75mm TQFN

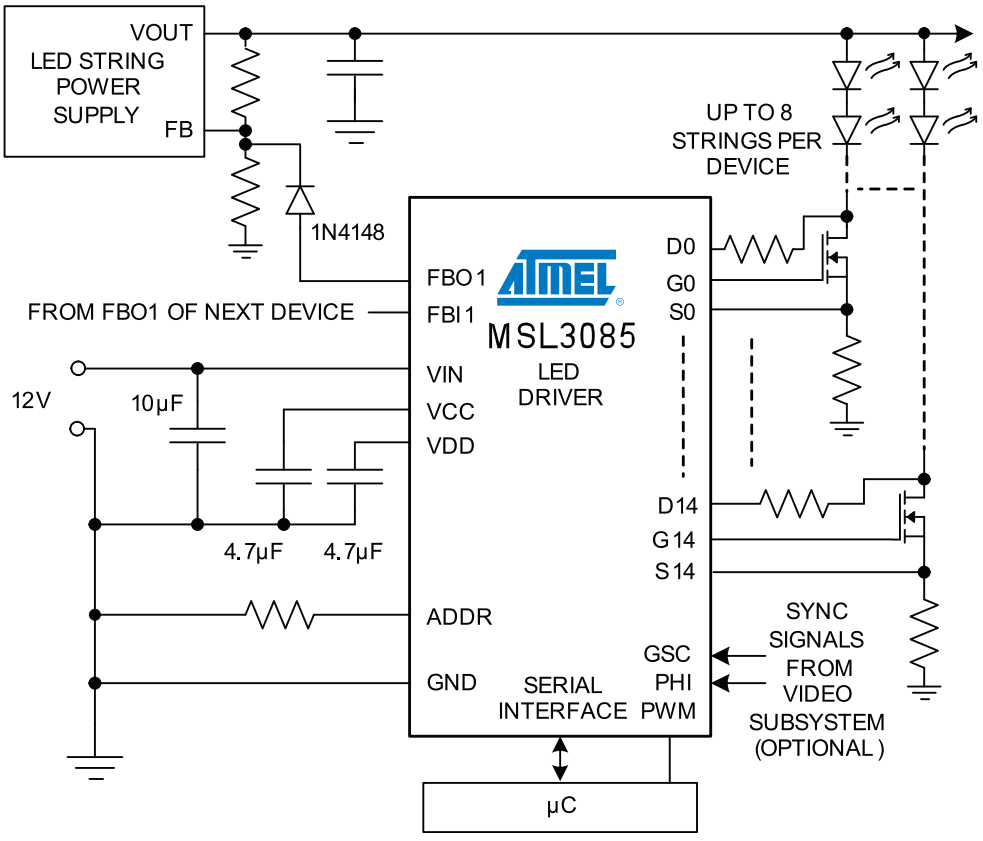
Atmel LED Driver-MSL3085

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Key Features

- 12-bit PWM String Dimming
- Fast, 1MHz I²C Serial Interface Supports up to Eight Devices per Bus
- 8-bit Adaptive Power Correction Maximizes Efficiency of up to Two String Power Supplies
- Multiple MSL3085s Share String Power Supplies and Automatically Negotiate the Optimum Supply Voltage
- External MOSFETs for high Voltage and/or Current
- Drives up to Eight Parallel LED Strings
- Supports Adaptive, Real-time Area Dimming for Highest Dynamic Range in LCD TVs and Monitors
- Programmable String Phase Reduces Motion Blur and Improves Efficiency
- Global Intensity Control via Serial Interface
- ±1.5% Current Accuracy and Current Balance
- Video Frame (VSYNC) and Line (HSYNC) Sync Inputs
- Sync Loss Detectors Optionally Disable LED Strings
- EEPROM Saves Power-on Default Settings
- LED Open Circuit and Short Circuit Fault Detection
- Individual Fault Detection Enable for Each String
- Over-temperature Shut-Off Protection
- Broadcast Write Simplifies Configuration
- -40°C To +105°C Operating Temperature Range

Application Circuit



Atmel LED Driver MSL3085 Overview

The MSL3085 controls eight strings of series-connected LEDs at up to 350mA per string. Eight MSL3085s can share a serial interface. The MSL3085 FET gate drive output is optimized for FETs requiring no more than 10nC of charge. The MSL3085 PWM engine generates the PWM signal that drives the strings, or optionally accepts an external PWM signal.

LED Power Supplies and Efficiency Optimizers

The MSL3085 features two efficiency optimizer outputs that dynamically adjust the LED string power supplies to their minimum voltage necessary to drive the LED strings, while assuring accurate LED current flow. One of the efficiency optimizers features an input that allows up to eight devices to be connected in a chain configuration. When implemented, the chain automatically negotiates, controls, and optimizes the string power supply for all LED strings driven by the chain.

The power supplies can use any topology, and are typically DC-DC boost converters. The efficiency optimizers rely on close matching of the LEDs connected to a string supply. The better the matching, the better the overall efficiency.

Timing, PWM, Intensity Controls and Synchronization

The PWM LED drive signals synchronize to video frame timing via the PHI input, and to pixel timing via the GSC input. Area LED dimming is supported for contrast and color gamut improvement. With area dimming, motion blur is reduced by setting each LED string's PWM phasing to synchronize string off times with the LCD update timing. The MSL3085 also includes internal PWM timing generation for standalone (non-video) LED lighting applications. Table 1 presents the available methods of LED intensity control.

Table 1. LED Intensity Controls

LED INTENSITY CONTROL	EFFECT	REGISTER	RESOLUTION
Global LED string current adjust	Reduces string current globally from maximum set by FET source resistors	ISTR (0x31)	8 bits
Global LED string PWM	Global PWM scaling	GINT (0x2F) and ALTGINT (0x30)	8 bits
Individual LED string PWM	PWM individual string control	PWMn (0x60 thru 0x7D) and ALTPWMn (0xA0 thru 0xBD)	12 bits
External resistor from FET source to ground	Sets maximum individual string current	-	-
External PWM input	Optionally controls all string PWM drives	-	-

Package Pin-out

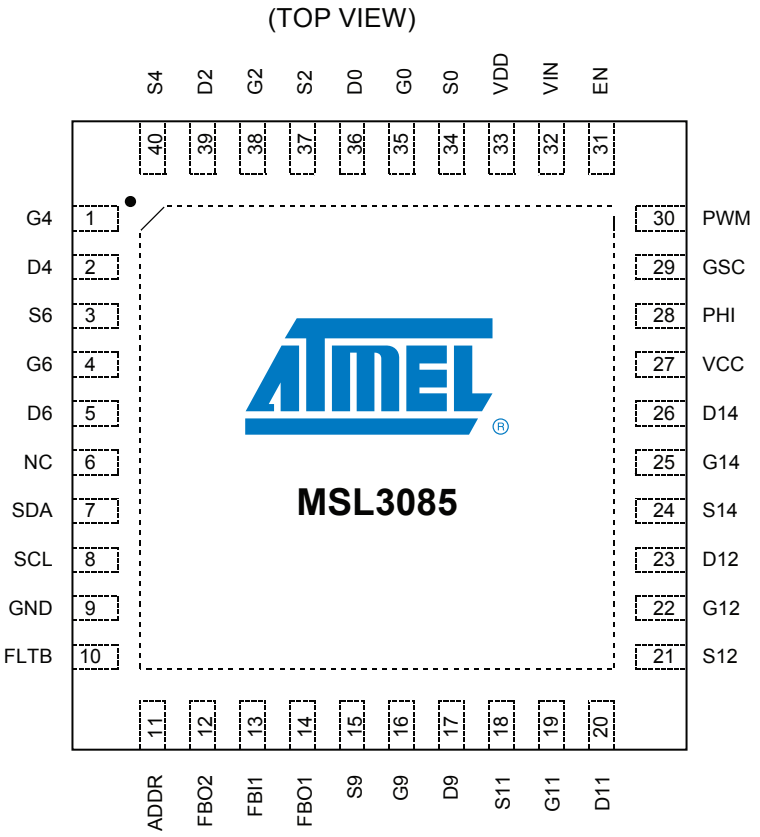


Figure 1. Atmel LED Driver-MSL3085 Pin-out, 40-pin TQFN.

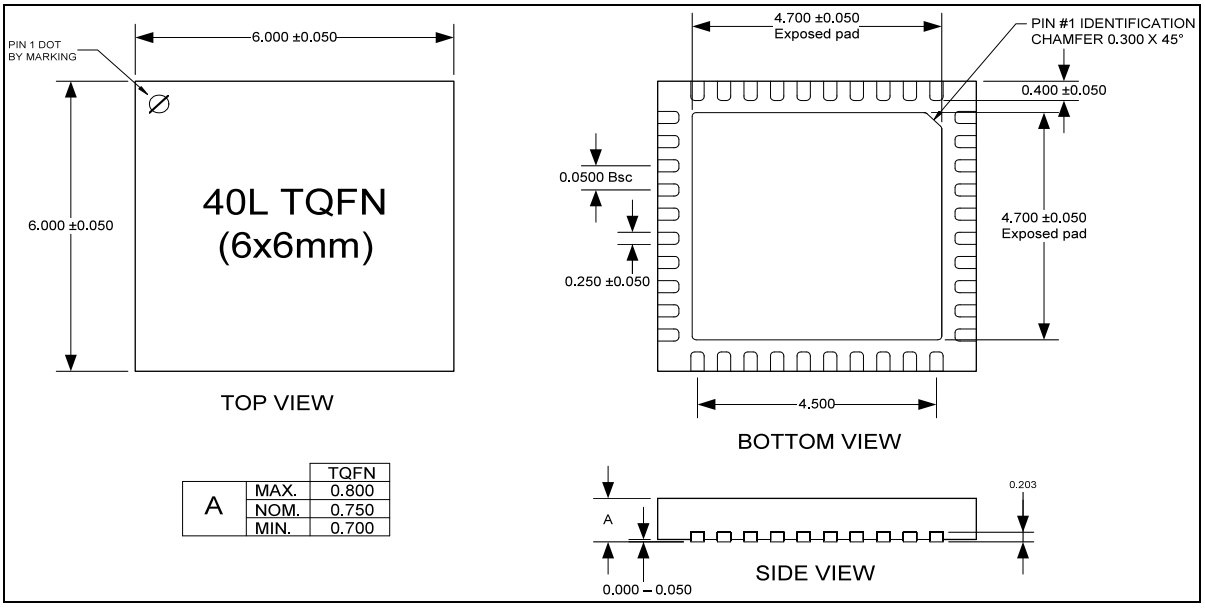


Figure 2. Package Dimensions: 40-pin, 6mm x 6mm x 0.75mm TQFN (0.5mm pin pitch) with Exposed Pad.

Pin Descriptions

NOTE: To ensure register compatibility with the 16-string device of the same family (Atmel LED Driver-MSL2161), pin names for gate, drain and source connections are not sequential.

PIN	PIN NAME	PIN DESCRIPTION
1	G4	**Gate output 4** Gate drive output for external MOSFET 4. Connect G4 to the gate of the external MOSFET driving LED string 4.
2	D4	**Drain sense input 4** Drain sense input for external MOSFET 4. Connect D4 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 4.
3	S6	**Source sense input 6** Source sense input for external MOSFET 6. Connect S6 to the source of the external MOSFET, and to the current sense resistor for LED string 6. The full-scale LED current is reached when 500mV is across the current sense resistor.
4	G6	**Gate output 6** Gate drive output for external MOSFET 6. Connect G6 to the gate of the external MOSFET driving LED string 6.
5	D6	**Drain sense input 6** Drain sense input for external MOSFET 6. Connect D6 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 6.
6	NC	**No connection** Make no connection to NC.
7	SDA	**I²C serial data I/O** SDA is the data I/O for the I²C serial interface.
8	SCL	**I²C serial clock input** SCL is the clock input for the I²C serial interface.
9	GND	**Ground** Connect GND to system ground and to EP with short, wide traces.
10	FLTB	**Fault indication output (active low)** Open drain output FLTB sinks current to GND whenever a fault is detected and verified. FLTB remains low until the fault registers are read, and reasserts if the fault persists.
11	ADDR	**Slave ID selection inputs** Connect ADDR to a resistor to GND to set the device address for the serial interface.
12	FBO2	**Efficiency Optimizer output 2** Connect FBO2 to the second power supply's feedback node. If unused, leave FBO2 unconnected.
13	FBI1	**Efficiency Optimizer input 1** Connect FBI1 to FBO1 of the next device, when chaining the Efficiency Optimizers Connect FBI1 to GND if unused.
14	FBO1	**Efficiency Optimizer output 1** Connect FBO1 to the first power supply's feedback node. If unused, leave FBO1 unconnected.
15	S9	**Source sense input 9** Source sense input for external MOSFET 9. Connect S9 to the source of the external MOSFET, and to the current sense resistor for LED string 9. The full-scale LED current is reached when 500mV is across the current sense resistor.
16	G9	**Gate output 9** Gate drive output for external MOSFET 9. Connect G9 to the gate of the external MOSFET driving LED string 9.
17	D9	**Drain sense input 9** Drain sense input for external MOSFET 9. Connect D9 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 9.
18	S11	**Source sense input 11** Source sense input for external MOSFET 11. Connect S11 to the source of the external MOSFET, and to the current sense resistor for LED string 11. The full-scale LED current is reached when 500mV is across the current sense resistor.
19	G11	**Gate output 11** Gate drive output for external MOSFET 11. Connect G11 to the gate of the external MOSFET driving LED string 11.
20	D11	**Drain sense input 11** Drain sense input for external MOSFET 11. Connect D11 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 11.

PIN	PIN NAME	PIN DESCRIPTION
21	S12	**Source sense input 12** Source sense input for external MOSFET 12. Connect S12 to the source of the external MOSFET, and to the current sense resistor for LED string 12. The full-scale LED current is reached when 500mV is across the current sense resistor.
22	G12	**Gate output 12** Gate drive output for external MOSFET 12. Connect G12 to the gate of the external MOSFET driving LED string 12.
23	D12	**Drain sense input 12** Drain sense input for external MOSFET 12. Connect D12 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 12.
24	S14	**Source sense input 14** Source sense input for external MOSFET 14. Connect S14 to the source of the external MOSFET, and to the current sense resistor for LED string 14. The full-scale LED current is reached when 500mV is across the current sense resistor.
25	G14	**Gate output 14** Gate drive output for external MOSFET 14. Connect G14 to the gate of the external MOSFET driving LED string 14.
26	D14	**Drain Sense Input 14** Drain sense input for external MOSFET 14. Connect D14 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 14.
27	VCC	**5V internal LDO regulator output** VCC powers the FBO outputs. Bypass VCC to GND with a 4.7µF ceramic capacitor placed close to VCC.
28	PHI	**Phase synchronization input** Drive PHI with an external signal of typically 100Hz to 480Hz to synchronize the MSL3085 LED PWM timing.
29	GSC	**Gate shift clock input** Drive GSC with the gate shift clock of the video signal.
30	PWM	**PWM input** PWM allows external control of the brightness of all LED strings. Drive PWM with a pulse-width-modulated signal with a duty cycle of 0% to 100% and a frequency up to 5kHz. When not configured as an input, PWM is high impedance.
31	EN	**Enable input (active high)** Drive EN high to turn on the MSL3085, and drive EN low to turn off the MSL3085. For automatic start-up, 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 EEPROM data into the control registers, simulating a cold start-up.
32	VIN	**Supply voltage input** Connect a 12V ±10% supply to VIN. Bypass VIN to GND with a 10µF ceramic capacitor placed close to VIN.
33	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.
34	S0	**LED string 0 external MOSFET source input** Source sense input for external MOSFET 0. Connect S0 to the source of the external MOSFET, and to the current sense resistor for LED string 0. The full-scale LED current is reached when 500mV is across the current sense resistor.
35	G0	**Gate output 0** Gate drive output for external MOSFET 0. Connect G0 to the gate of the external MOSFET driving LED string 0.
36	D0	**Drain sense input 0** Drain sense input for external MOSFET 0. Connect D0 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 0.
37	S2	**LED string 2 external MOSFET source input** Source sense input for external MOSFET 2. Connect S2 to the source of the external MOSFET, and to the current sense resistor for LED string 2. The full-scale LED current is reached when 500mV is across the current sense resistor.
38	G2	**Gate output 2** Gate drive output for external MOSFET 2. Connect G2 to the gate of the external MOSFET driving LED string 2.
39	D2	**Drain sense input 2** Drain sense input for external MOSFET 2. Connect D2 through a 10MΩ resistor to the drain of the external MOSFET driving LED string 2.
40	S4	**LED string 4 external MOSFET source input** Source sense input for external MOSFET 4. Connect S4 to the source of the external MOSFET, and to the current sense resistor for LED string 4. The full-scale LED current is reached when 500mV is across the current sense resistor.
EP	EP	**Exposed pad, power ground** Connect EP to system ground and to GND using short, wide traces. EP provides thermal relief for the die.

Absolute Maximum Ratings

Voltage (With Respect to GND)

VIN, EN, D0 thru D14, G0 thru G14 ..... -0.3V to +18V

VCC ..... -0.3V to +6V

VDD, ADDR, S0 thru S14 ..... -0.3V to +2.75V

FBO1, FBO2, FLTB ..... -0.3V to +5.5V

PHI, GSC, PWM ..... -0.3V to (VCC + 0.3V)

SDA, SCL ..... -0.3V to +5.5V

Current (Into Pin)

VIN 50mA

FBO1, FBO2 ..... +0µA to -800µA

G0 thru G14 ..... ±100mA

All other pins 20mA

Continuous Power Dissipation

40-Pin 6mm x 6mm QFN (derate 38mW/°C above T_A = +70°C) 2100mW

Ambient Operating Temperature range $T_A = T_{MIN}$ to T_{MAX} ..... -40°C to +105°C

Junction Temperature ..... +125°C

Storage Temperature range ..... -65°C to +125°C

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

Electrical Characteristics

Typical application circuit, V_{VIN} = 12V, $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted. Typical values are at V_{VIN} = 12V, T_A = +25°C

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
DC ELECTRICAL CHARACTERISTICS						
VIN operating supply voltage	VIN		10.8	12	13.2	V
VIN operating supply current	I_{VIN}	Normal operation, all LED strings driven		25	32.5	mA
VIN shutdown supply current	I_{SLEEP}	SLEEP = 1, SDA, SCL, ADDR, PWM, PHI and GSC at GND or VDD		500		µA
VCC regulation voltage	VCC	I_{VCC} = -1.0mA	4.5	5.0	5.5	V
VDD regulation voltage	VDD	I_{VDD} = -1.0mA	2.4	2.5	2.6	V
EN input high voltage			1.4			V

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
EN input low voltage					0.9	V
PWM, PHI, GSC input high voltage	V_{IH}		0.7 x VDD			V
PWM, PHI, GSC input low voltage	V_{IL}				0.3 x VDD	V
PHI, GSC output high voltage	V_{OH}	I_{SOURCE} = 5mA	VDD – 0.4			
PHI, GSC, FLTB output low voltage	V_{OL}	I_{SINK} = 6mA			0.4	V
FBO feedback output current		Compliance voltage 3.5V, minimum	0		360	µA
FBO feedback output current step size				1.2		µA
D0 thru D7 short circuit fault detection threshold				8		V
G0 thru G7 open circuit fault detection threshold				8		V
G0 thru G14 gate drive charge		(Note 2)			10	µC
S0 thru S7 regulation voltage			492	500	508	mV
S0 thru S7 voltage matching		ISTR = 0x7F	-1.5		1.5	%
Thermal shutdown temperature				TBD		°C

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
I²C LOGIC LEVELS						
SDA, SCL input high voltage			0.7 x VDD			V
SDA, SCL input low voltage					0.3 x VDD	V
SDA output low voltage		I_{SINK} = 6mA			0.4	V

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
AC ELECTRICAL CHARACTERISTICS						
OSC frequency	f_{OSC}	f_{OSC} = 20MHz, T_A = 25°C	19.4	20	20.6	MHz
PHI frequency	f_{PHI}		0.04		10	kHz
GSC frequency	f_{GSC}		0		10	MHz
PWM frequency	f_{PWM}				5	kHz
PWM duty cycle			0		100	%
PHI lock				4		PHI cycles

PARAMETER	SYMBOL	CONDITIONS AND NOTES	MIN	TYP	MAX	UNIT
I²C TIMING CHARACTERISTICS						
SCL clock frequency	$1/t_{SCL}$	Bus timeout disabled (Note 3)	0		1	MHz
Bus time-out period	$t_{timeout}$	f_{OSC} = 20MHz, T_A = 25°C	29	30	31	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 set-up 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
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

Note 1. Subject to thermal dissipation characteristics of the device.

Note 2. Guaranteed by design, and is not production tested.

Note 3. Minimum SCL clock frequency is limited by the bus time-out feature, which resets the serial bus interface if either SDA or SCL is held low for $t_{timeout}$. Disable bus time-out via the fault enable register 0x03[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 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 8. Input filters on SDA, SCL, and ADDR suppress noise less than 50ns.

Typical Application Circuit

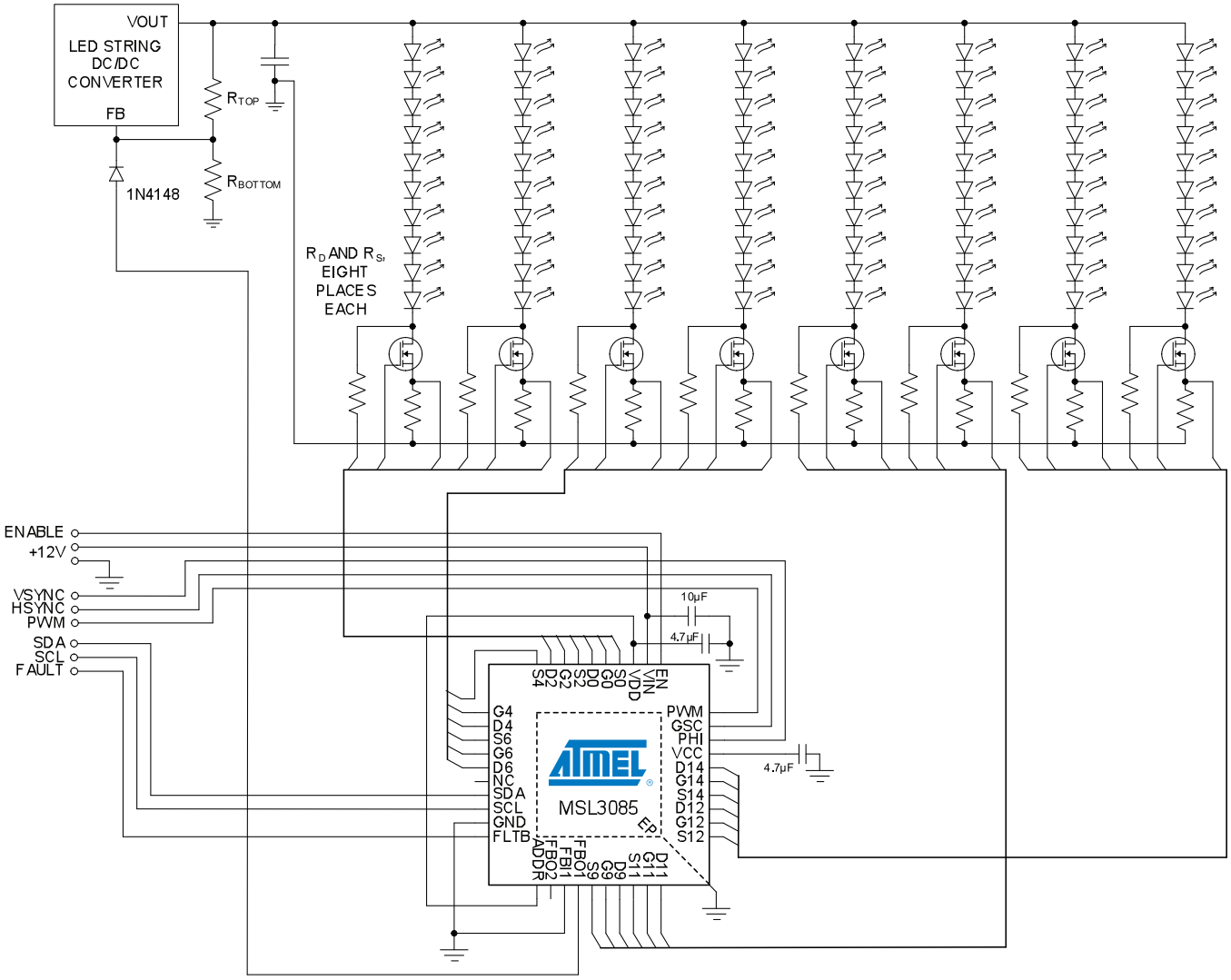


Figure 3. Atmel LED Driver-MSL3085 Driving 80 White LEDs in Eight Strings.

Detailed Description

The MSL3085 is a highly integrated, flexible, multi-string LED driver that uses external MOSFETs to allow high LED string currents, and includes power supply control to maximize efficiency. The driver optionally connects to a video subsystem to offer a simple architecture for use in LCD TV backlight applications. Up to eight devices easily connect together to drive a large number of LED strings in a system. The drivers provide multiple methods of controlling LED brightness through both peak current control and 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 EEPROM holds all the default control register values. At power-up, the data in the EEPROM is automatically copied directly to the control registers, setting up the device for operation. The factory programmed EEPROM values are changeable through the serial interface if a different power-up condition is desired.

The device interfaces to an MCU via the I^2C interface. The robust, 1MHz I^2C interface supports up to eight devices on the bus. While typically the LED drive PWM signal is internally generated, the device also accepts an external direct PWM drive signal applied to the PWM input that sets the PWM duty cycle and the frequency of the LED drive signals. The MSL3085 also allows phase spreading of the LED drive signals, which helps reduce both the transient load on the LED power supplies and the power supply input capacitor size requirements.

The MSL3085 is an eight string version of the MSL2161, squeezed into a smaller package, with two efficiency optimizer (EO) outputs and one EO input. (The MSL2161 offers 16 string drives, three EO outputs, and three EO inputs.) This offers the advantage of small size, but to ensure register compatibility with the MSL2161, pin names of the FET drive outputs are not sequential. The FET drive outputs are named 0, 2, 4, 6, 9, 11, 12, and 14 (not 0 through 7). All control registers also follow this naming convention. Additionally, this has a small impact on the automatic phase-shift feature, whose sequential phase shifts for outputs 9 and 12 are spaced at $1/16^{th}$ the PWM frame, while the others are spaced at $1/8^{th}$ the PWM frame.

The PWM frequency of the drivers is easily synchronized to an external video signal applied to PHI, synchronized to the internal oscillator for standalone applications, or set directly by a signal at the PWM input. Typically, the VSYNC signal from the video system is used as the PHI input. A frequency multiplier (1x to 32x) processes this signal for use by the PWM engine. 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 on the ratio of the GSC frequency (typically provided by a system's 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 register, when enabled. The GSC clock is also used to precisely set each string's phase delay so that it is synchronized to its physical position relative to the video frame.

The efficiency optimizers control a wide range of different external DC-DC and AC/DC converter architectures. Multiple drivers in a system communicate in real time among themselves 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 concern about excessive power dissipation issues. During the start-up sequence, the MSL3085 automatically reduces the power supply voltage to the minimum voltage required to keep the LEDs in current regulation. The devices are configured to periodically perform this optimization to compensate for changes in LED forward voltage, and to assure continued optimum power savings.

Internal Regulators and Enable Input

The MSL3085 includes two internal linear regulators that provide VCC (5V) and VDD (2.5V) for internal circuitry. VIN (12V nominal) supplies the VCC and VDD regulators. Bypass VIN to GND with a 10µF capacitor close to the device. Bypass VCC to GND with a 4.7µF capacitor close to the device. Bypass VDD to GND with a 4.7µF capacitor close to the device.

The MSL3085 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, the efficiency optimizer is disabled, and all strings are turned off. Drive EN high to turn on the device. When EN is driven high, the contents of the EEPROM are boot loaded into the control registers, simulating a cold start-up, and all bits in the fault registers are cleared to 0.

Setting the Maximum LED String Current With a Source Resistor

The maximum string current, I_{LED}, for each string is set by a resistor, R_S, connected to ground from the source terminal of the external string drive MOSFET. The feedback threshold is 500mV. Determine the resistor value using:

$$R_S = \frac{0.5}{I_{LED}}$$, where I_{LED} is in amperes and R_S is in ohms.

For example, a full-scale LED current of 100mA returns R_S = 5Ω. The current for all LED strings is reduced from the full-scale value with 8-bit resolution using ISTR, the string current control register 0x31.

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

The MSL3085 is designed to control an external LED string power supply that uses a voltage divider (R_{TOP} and R_{BOTTOM} in Figure 4) 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 0 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 minimum and maximum forward voltage drops at the peak current set by R_S. 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 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. 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. 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 MSL3085 against current flow into FBOn. Assign all strings powered by a common supply to the proper FBO output using string set registers 0x40 - 0x5D.

Once configured, determine the change in power supply output voltage in response to a change in FBOn output current using:

$$\Delta V_{OUT} = \Delta I_{FBO} * R_{TOP}$$

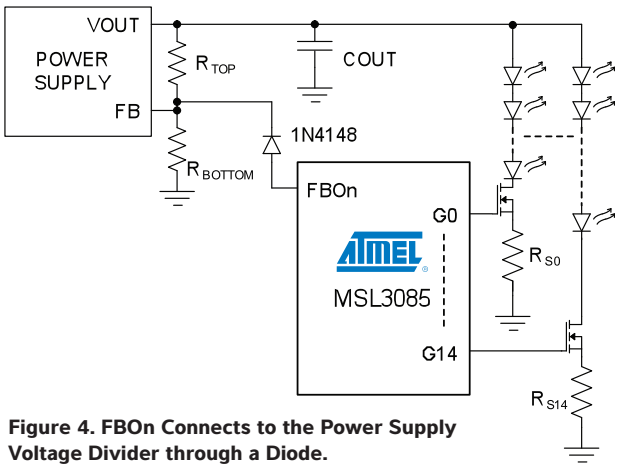


Figure 4. FBOn Connects to the Power Supply Voltage Divider through a Diode.

Using Multiple Atmel LED Driver-MSL3085s to Control a Common Power Supply

Cascade multiple MSL3085 devices into a chain configuration (Figure 5), with the FBI1 of one device connected to the FBO1 of the next. Connect the first FBO1 to the power supply feedback resistor node through a diode, and the unused FBI1 input to ground as close to the MSL3085 as possible. Assure that all strings powered by the common supply are assigned to FBO1 using string set registers (STRnSET) 0x20 - 0x3D (FBO1 is the power-up default setting for all strings). The chained devices work together to ensure that the system operates at optimum efficiency. Note that the accuracy of the feedback chain can degrade through each link of the FBI1/FBO1 chain by as much as 2%. Determine the potential worst case maximum FBO1 current, $I_{FBOn(MAX/MIN)}$, using:

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

where N is the number of MSL3085s 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 FBI1/FBO1 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 FBI1. If these traces must be routed near noisy signals, shield them from noise by using ground planes or guard traces.

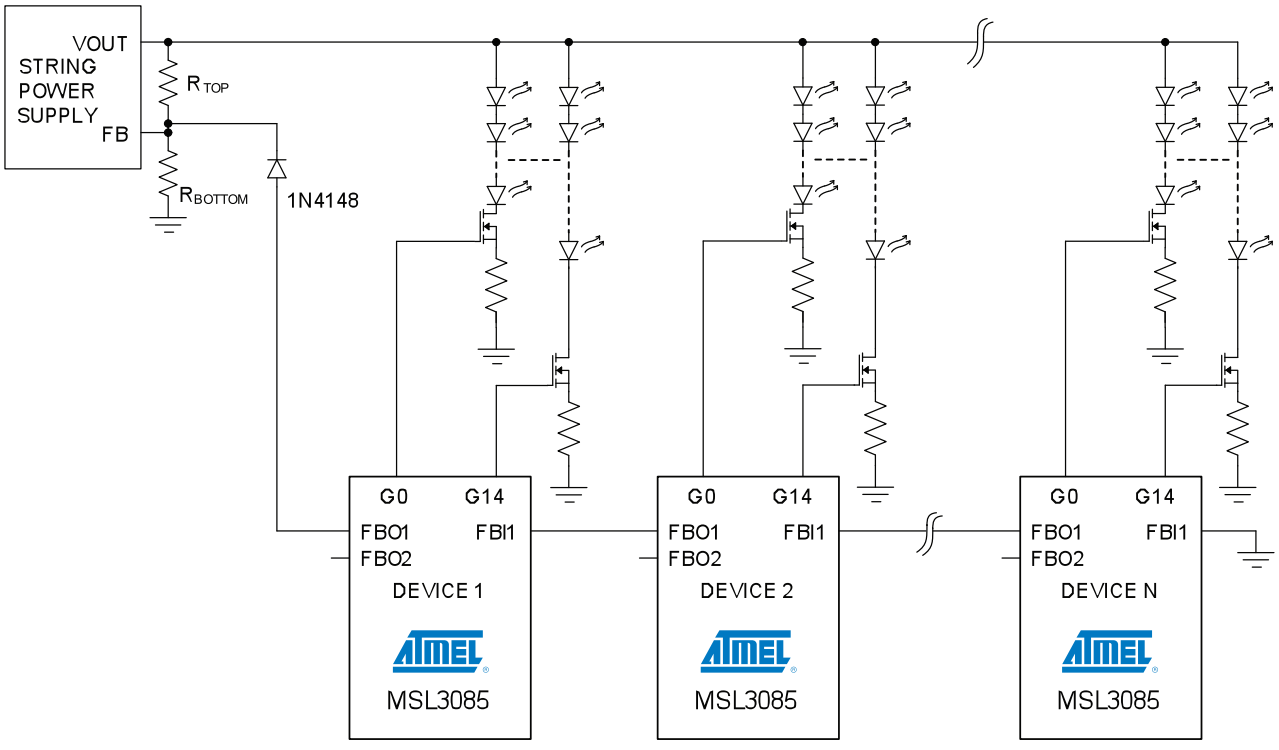


Figure 5. Example of Cascading Multiple Devices to Optimize a Common String Power Supply.

Direct PWM Control of the LED Strings

An external PWM signal applied to the PWM input allows direct PWM control over the strings when PWMEN and PWMDIRECT (bits D0 and D1 in PWM control register 0x2D) are set to 1. This configuration bypasses PHI and GSC, but allows LED string phase delay via the phase delay enable bit, PHADLYEN (bit D0 of register 0x2E). With phase delay enabled, a progressive delay based on the period of the PWM frame is calculated and applied successively to each string drive signal. The delay is typically 1/8th the PWM frame, but outputs 9 and 12 have sequential delays of 3/16th and 1/16th of the PWM frame, respectively.

The PWM input can also be configured as a gate for the output of the PWM engine using PWM global enable (bit D2 of the PWM control register 0x2D).

Register Map and the EEPROM

Register Map Summary

Control the MSL3085 using the registers in the range 0x00 - 0xBD (Table 2). Two additional registers, 0xC0 and 0xC1, allow access to, and programming of, the EEPROM. 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

Table 2. Atmel LED Driver-MSL3085 Register Map

ADDRESS AND REGISTER NAME		FUNCTION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x00	STRINGEN0	LED string enables	-	STR6EN	-	STR4EN	-	STR2EN	-	STR0EN
0x01	STRINGEN1		-	STR14EN	-	STR12EN	STR11EN	-	STR9EN	-
0x02	CONFIG	Configuration	SLEEP	-	-	-	FLDBKEN	STRSCDLY[2:0]		
0x03	FLTEN	Fault enable	-	-	I²CTOEN	PHIMAXFEN	GSCMAXFEN	STRSCFEN	STROCFEN	FBOOCFEN
0x04	STRFLTEN0	String fault enable	-	FEN6	-	FEN4	-	FEN2	-	FEN0
0x05	STRFLTEN1		-	FEN14	-	FEN12	FEN11	-	FEN9	-
0x06	FLTSTATUS*	Fault status	FLTBDRV	-	-	PHIMAXFLT	GSCMAXFLT	STRSCFLT	STROCFLT	FBOOCFLT
0x07	OCSTAT0*	String open circuit fault status	-	OC6	-	OC4	-	OC2	-	OC0
0x08	OCSTAT1*		-	OC14	-	OC12	OC11	-	OC9	-
0x09	SCSTAT0*	String short circuit fault status	-	SC6	-	SC4	-	SC2	-	SC0
0x0A	SCSTAT1*		-	SC14	-	SC12	SC11	-	SC9	-
0x0B - 0x0E		UNUSED								
0x0F	OSCFREQ	Oscillator frequency	-	-	-	-	-	OSCFREQ[2:0]		
0x10	FBOCTRL0	Efficiency Optimizer control	HDRMSTEP[1:0]		RECALDLY[1:0]		SETTLE[1:0]		IERRCONF[1:0]	
0x11	FBOCTRL1		INCRSTEP[1:0]		DECRSTEP[1:0]		INITPWM	ACAL100	ACALEN	ICHKDIS
0x12	FBOCTRL2		-	-	-	-	-	FBO2OCEN	FBO1OCEN	FBOEN
0x13	FBODAC1*	Efficiency Optimizer DAC readback	FBODAC1[7:0]							
0x14	FBODAC2*		FBODAC2[7:0]							
0x15		UNUSED								
0x16	FBOSTAT*	Efficiency Optimizer status	-	FBO2OC	FBO1OC	-	FBO2ACT	FBO1ACT	FBOCAL	FBOINITCAL

Table 2. Atmel LED Driver-MSL3085 Register Map

ADDRESS AND REGISTER NAME		FUNCTION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x17	- 0x1F		UNUSED							
0x20	GSCCTRL	GSC processing control	GSCCHK-SEL	-	-	-	GSCMAXEN	GSCPOL	GSCPHI-SYNCEN	GSCINTEN
0x21	GSCCNTR	Internal clock counter for GSC	GSCCNTR[7:0]							
0x22			GSCCNTR[15:8]							
0x23	GSCMUL	GSC multiplier	-	-	-	GSCMUL[4:0]				
0x24	GSCDIV	GSC divider	GSCDIV[7:0]							
0x25	GSCMAX	Max oscillator cycles between GSC pulses	GSCMAX[7:0]							
0x26			GSCMAX[15:8]							
0x27	PHICTRL	PHI processing control	PHICHK SEL	-	-	-	-	PHIMAXEN	PHIPOL	PHIINTEN
0x28	PHICNTR	Internal clock counter for PHI	PHICNTR[7:0]							
0x29			PHICNTR[15:8]							
0x2A	PHIMUL	PHI multiplier	-	-	-	PHIMUL[4:0]				
0x2B	PHIMAX	Max GSC cycles between PHI pulses	PHIMAX[7:0]							
0x2C			PHIMAX[15:8]							
0x2D	PWMCTRL0	PWM control	GINT+1EN	GINTEN	ALTEN	OVRFLOZEN	OVRFLOEN	PWM GLBLEN	PWMDIRECT	PWMEN
0x2E	PWMCTRL1		-	-	-	-	EXTALTEN	PHOVR FLOZEN	PHOVR FLOEN	PHADLYEN
0x2F	GINT	Global PWM scaling	GINT[7:0]							
0x30	ALTGINT	Alternate global PWM scaling	ALTGINT[7:0]							
0x31	ISTR	8-bit global string current scaling	ISTR[7:0]							
0x32	PWMSTATUS*	PWM and counter status	PHIMAXERRCNT[2:0]			PHIMAX1FLT	PHISIGFLT	GSCSIGFLT	PHICNTRFLT	GINT-MULERR
0x33	PHIPCNTR*	PHI pulse counter and status	PHICNTR-MAX	-	-	PHIMULCNTR[0:4]				
0x34	GSCPCNTR*	GSC pulse counter	GSCPULSECNTR[7:0]							
0x35			-	-	-	GSCPULSECNTR[12:8]				
0x36 - 0x3F			UNUSED							

ADDRESS AND REGISTER NAME		FUNCTION	REGISTER DATA							
			D7	D6	D5	D4	D3	D2	D1	D0
0x40	STR0SET	Phase delay and EO assignment for string 0	PHDLY0[7:0]							
0x41			FBOSET0[1:0]		-	-	PHDLY[11:8]			
↓	↓	↓								
0x5C	STR14SET	Phase delay and EO assignment for string 14	PHDLY14[7:0]							
0x5D			FBOSET14[1:0]		-	-	PHDLY[11:8]			
0x5E and 0x5F			UNUSED							
0x60	PWM0	PWM setting for string 0	PWM0[7:0]							
0x61			-	-	-	-	PWM0[11:8]			
↓	↓	↓								
0x7C	PWM14	PWM setting for string 14	PWM14[7:0]							
0x7D			-	-	-	-	PWM14[11:8]			
0x7E and 0x7F			UNUSED							
0x80	ALTSTR0SET	Alternate phase delay for string 0	ALTPHDLY0[7:0]							
0x81			-	-	-	-	ALTPHDLY[11:8]			
↓	↓									
0x9C	ALTSTR14SET	Alternate phase delay for string 14	ALTPHDLY14[7:0]							
0x9D			-	-	-	-	ALTPHDLY[11:8]			
0x9E and 0x9F			UNUSED							
0xA0	ALTPWM0	Alternate PWM setting for string 0	ALTPWM0[7:0]							
0xA1			-	-	-	-	ALTPWM0[11:8]			
↓	↓									
0xBC	ALTPWM14	Alternate PWM setting for string 14	ALTPWM14[7:0]							
0xBD			-	-	-	-	ALTPWM14[11:8]			
0xBE and 0xBF			UNUSED							
0xC0	E2ADDR	EEPROM read/write access	-	E2ADDR[6:0]						
0xC1	E2CTRLSTA		E2BUSY	BLDACT	E2ERR	-	-	RWCTRL[2:0]		

Register Power-up Defaults

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

Table 3. Atmel LED Driver-MSL3085 Register Power-up Defaults

REGISTER NAME AND ADDRESS		POWER-UP CONDITION REGISTERS INITIALIZED FROM EEPROM	REGISTER DATA								
			D7	D6	D5	D4	D3	D2	D1	D0	HEX
0x00	STRINGEN0	LED strings 0, 2, 4, 6, 9, 11, 12, and 14 enabled	0	1	0	1	0	1	0	1	55
0x01	STRINGEN1		0	1	0	1	1	0	1	0	5A
0x02	CONFIG	String short circuit confirmation delay = 256µs String current fold-back enabled Device awake	0	0	0	0	1	1	0	1	0D
0x03	FLTEN	FBO open circuit fault detect globally enabled String open circuit fault detect globally enabled LED short circuit fault detect globally enabled GSC max fault detect globally disabled PHI max fault detect globally disabled I^2C timeout enabled	0	0	1	0	0	1	1	1	27
0x04	STRFLTEN0	Fault detection individually enabled For all strings (0, 2, 4, 6, 9, 11, 12, and 14)	0	1	0	1	0	1	0	1	55
0x05	STRFLTEN1		0	1	0	1	1	0	1	0	5A
0x0F	OSCFREQ	f_{osc} = 20MHz	0	0	0	0	0	1	0	0	04
0x10	FBOCTRL0	Current sink error confirmation delay = 2µs FBO power supply correction delay = 4ms Efficiency Optimizer auto-recalibration delay = 1s	0	1	0	0	1	0	0	1	49
0x11	FBOCTRL1	Efficiency Optimizer headroom steps = 3 MOSFET current sink error detection enabled Efficiency Optimizer auto-recalibration enabled	0	0	0	1	1	0	1	0	1A
0x12	FBOCTRL2	PWM settings used during auto-recalibration PWM settings used during initial calibration Efficiency Optimizer correction step size = 1 LSB (1µA) Efficiency Optimizer initial calibration step size = 1 LSB (1µA) FBO outputs globally enabled FBO1 open circuit detection enabled FBO2 open circuit detection disabled	0	0	0	0	0	0	1	1	03
0x20	GSCCTRL	External signal at GSC is selected for input to the PWM engine GSC not internally synchronized to PHI PWM drive synchronized to falling edge of external GSC signal GSC maximum count fault detect is disabled although disabled, GSC max fault monitors f_{pGSC}	0	0	0	0	0	0	0	0	00
0x21	GSCCNTR	Although disabled, internal GSC Frequency f_{GGEN} = 20MHz / (80 + 1) = 246kHz	0	1	0	1	0	0	0	0	50
0x22			0	0	0	0	0	0	0	0	00
0x23	GSCMUL	GSC multiplexer output is multiplied by 4 (register setting + 1)	0	0	0	0	0	0	1	1	03
0x24	GSCDIV	GSC multiplier output is divided by 1 (register setting + 1)	0	0	0	0	0	0	0	0	00
0x25	GSCMAX	Although disabled, GSC max count is set to 174 clock cycles	1	0	1	0	1	1	1	0	AE
0x26			0	0	0	0	0	0	0	0	00
0x27	PHICTRL	External signal at PHI selected for input to PWM engine PWM engine is synchronized to the falling edge of PHI PHI maximum count fault detect is disabled Although disabled, PHI max count monitors f_{pPHI}	0	0	0	0	0	0	0	0	00

REGISTER NAME AND ADDRESS		POWER-UP CONDITION REGISTERS INITIALIZED FROM EEPROM	REGISTER DATA								
			D7	D6	D5	D4	D3	D2	D1	D0	HEX
0x28	PHICNTR	Although disabled, internal PHI Frequency f_{PGEN} = 20MHz / (8 * (10416 + 1)) = 240Hz	1	0	1	1	0	0	0	0	B0
0x29			0	0	1	0	1	0	0	0	28
0x2A	PHIMUL	PHI multiplier = 1 (register setting + 1)	0	0	0	0	0	0	0	0	00
0x2B	PHIMAX	Although disabled, PHI maximum count = 4148	0	0	1	1	0	1	0	0	34
0x2C			0	0	0	1	0	0	0	0	10
0x2D	PWMCTRL0	PWM operation enabled Individual LED string drive pulse widths internally determined PWM input does not gate the output of the PWM engine	1	0	0	1	1	0	0	1	99
0x2E	PWMCTRL1	String on times allowed to extend beyond end of PWM frame String on times allowed to extend into frame zero Alternate timing not used Global intensity (GINT) disabled Although disabled, (GINT + 1) is provided to the PWM engine String drive phasing enabled Delayed string turn on beginning after PWM frame allowed Delayed turn on occurring in frame zero allowed Alternate timing not selected by PWM input state	0	0	0	0	0	1	1	1	07
0x2F	GINT	Global intensity set to (127 + 1) / 255 = 50.2%	0	1	1	1	1	1	1	1	7F
0x30	ALTGINT	Alternate global intensity set to (95 + 1) / 255 = 37.6%	0	1	0	1	1	1	1	1	5F
0x31	ISTR	Strings current set at 50% of R_S setting	0	1	1	1	1	1	1	1	7F
0x40	STR0SET	All strings phase delay = zero All strings assigned to FBO1	0	0	0	0	0	0	0	0	00
0x41			0	1	0	0	0	0	0	0	40
↓	↓		↓								
0x5C	STR14SET		0	0	0	0	0	0	0	0	00
0x5D			0	1	0	0	0	0	0	0	40
0x60	PWM0	All strings have PWM value = 512 GSC cycles	0	0	0	0	0	0	0	0	00
0x61			0	0	0	0	0	0	1	0	02
↓	↓		↓								
0x7C	PWM14		0	0	0	0	0	0	0	0	00
0x7D			0	0	0	0	0	0	1	0	02
0x80	ALTSTR0SET	All strings alternate phase delay = zero	0	0	0	0	0	0	0	0	00
0x81			0	0	0	0	0	0	0	0	00
↓	↓		↓								
0x9C	ALTSTR14SET		0	0	0	0	0	0	0	0	00
0x9D			0	0	0	0	0	0	0	0	00
0xA0	ALTPWM0	All strings set with alternate PWM value = 512 GSC cycles	0	0	0	0	0	0	0	0	00
0xA1			0	0	0	0	0	0	1	0	02
↓	↓		↓								
0xBC	ALTPWM14		0	0	0	0	0	0	0	0	00
0xBD			0	0	0	0	0	0	1	0	02
REGISTERS WITH FIXED INITIAL VALUES											
0xC0	E2ADDR	EEPROM 7-bit address = 0x00	0	0	0	0	0	0	0	0	00
0xC1	E2CTRLSTA	EEPROM read/write disabled	0	0	0	0	0	0	0	0	00

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