Chipsmall Limited consists of a professional team with an average of over 10 year of expertise in the distribution of electronic components. Based in Hongkong, we have already established firm and mutual-benefit business relationships with customers from,Europe,America and south Asia,supplying obsolete and hard-to-find components to meet their specific needs.

With the principle of “Quality Parts,Customers Priority,Honest Operation,and Considerate Service”,our business mainly focus on the distribution of electronic components. Line cards we deal with include Microchip,ALPS,ROHM,Xilinx,Pulse,ON,Everlight and Freescale. Main products comprise IC,Modules,Potentiometer,IC Socket,Relay,Connector.Our parts cover such applications as commercial,industrial, and automotives areas.

We are looking forward to setting up business relationship with you and hope to provide you with the best service and solution. Let us make a better world for our industry!

Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

M09000-14

LED Driver and PMIC for DLP/LCOS Pico Projectors

Rev V2

Features

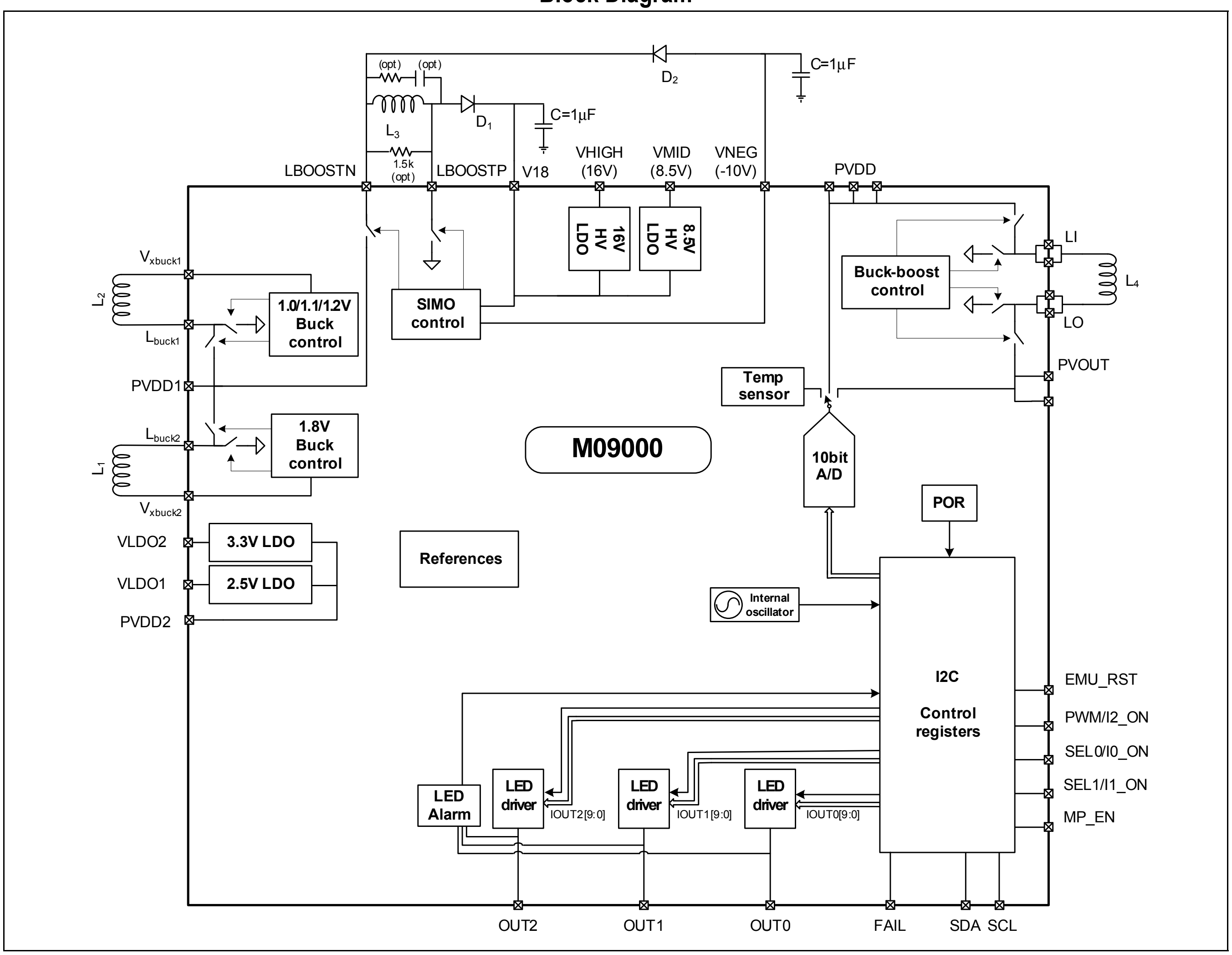
- Three programmable 1.2A common anode LED/laser drivers with integrated buck-boost converter and PWM current control
- 1.8 V and 1.0/1.1/1.2/1.8 V Buck converters capable of 300 mA current loads
- 2.5 V (30 mA) and 3.3 V (150 mA) LDO regulators
- Accurate DMD supply generators (+16 V/8.5 V and -10 V)
- Monitor and fault protection features
- I^2C interface

Applications

- Portable video projector systems

The M09000 is a highly integrated, high efficiency driver and power management IC designed for embedded DLP pico projectors. It provides three programmable LED/laser drivers with integrated buck-boost converter, power management functionalities, including high voltage generators for DMD. All of these functions are supported while operating from a single Li-Ion cell.

Block Diagram



Ordering Information

Part Number	Package	Case Operating Temperature
M09000-14	5x5 mm 40-pin QFN	-40 °C to +85 °C
* The letter “G” designator after the part number indicates that the device is RoHS compliant.		

Revision History

Revision	Level	Date	Description
V2	Release	July 2015	Updated registers.
D (V1)	Release	December 2012	Silicon updated to version -14. Changed typical LED Driver current accuracy in Table 1-3. Changed typical Undervoltage Lockout in Table 1-4. Changed ADC Offset Error, Slope Error and Full Scale in Table 1-5. Changed LDO operating voltage in Table 1-7 and Table 1-8. Changed Vih specification in Table 1-11.
C (V1P)	Preliminary	July 2012	Updated register section.
B (V2A)	Advance	March 2012	Changed the Operating Voltage from a minimum of 3.15 to 2.6 and a maximum of 4.3 to 5.25. This change is reflected in Table 1-2, Table 1-7, Table 1-8 and Table 1-9. Changed Pin 11 from GND to PVDDM (V_{DD} Supply). This is reflected in Figure 2-1 and Table 2-1.
A (V1A)	Advance	February 2012	Initial release.

Application Drawing

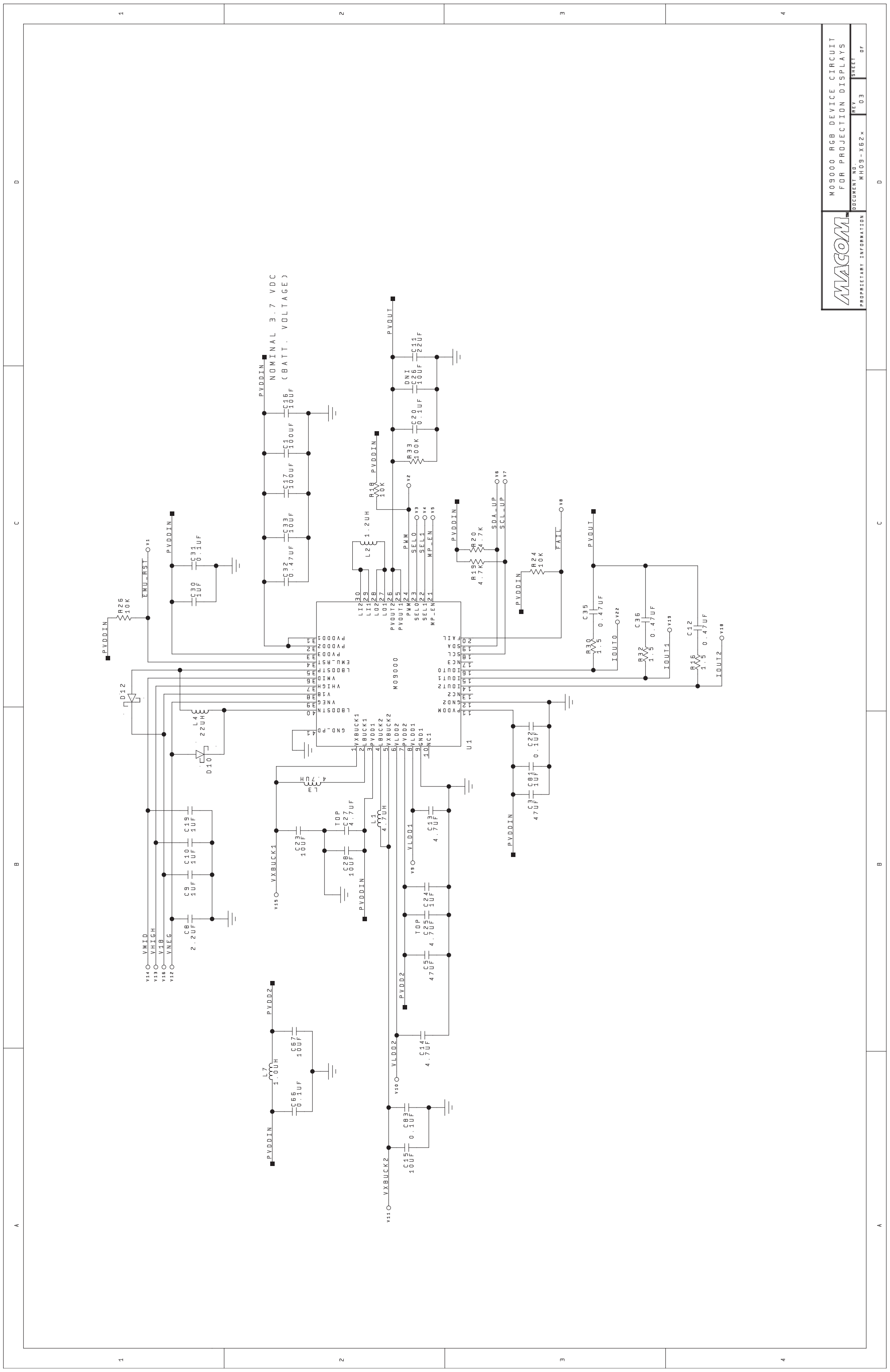


Table of Contents

1.0 Electrical Characteristics

1.1 Absolute Maximum Ratings

Table 1-1. Absolute Maximum Ratings

Symbol	Parameter	Notes	Minimum	Typical	Maximum	Units
PVDDX	3.7 V supplies	—	-0.4	—	+5.5	V
PVOUT	Buck-boost DC-DC converter output	—	-0.4	—	+5.5	V
IOUT0, IOUT1, IOUT2	Output pins for driving LED	—	-0.4	—	+5.5	V
LI, LO	External inductor pins for DC-DC converter	—	-0.4	—	+5.5	V
T_{JCTN}	Junction Temperature	1	- 40	—	+125	°C
T_{STG}	Storage Temperature	—	- 65	—	+150	°C
V18, VHIGH, VMID	Positive DMD outputs	—	-0.4	—	+19.8	V
VNEG	Negative DMD output	—	-12.0	—	+0.4	V
LBOOSTP	Positive side of inductor for DMD	—	-0.4	—	+19.8	V
LBOOSTN	Negative side of inductor for DMD	—	-12	—	+5.5	V
LBUCK1, LBUCK2	Inductor pins for buck converters 1 & 2	—	-0.4	—	+5.5	V
VXBUCK1	Output of buck converter 1	—	-0.4	—	+5.5	V
VXBUCK2	Output of buck converter 2	—	-0.4	—	+2.0	V
VLDO1, VLDO2	LDO regulator output 1 & 2	—	-0.4	—	+5.5	V
SCL, SDA	I^2C interface	—	-0.4	—	+5.0	V
FAIL, EMU_RST	Fault signal output and EMU reset pins	—	-0.4	—	+5.5	V
PWM, SEL0, SEL1	Strobe input and PWM input pins	—	-0.4	—	+5.5	V
MP_EN	Enable pin	—	-0.4	—	+5.5	V

NOTES:

1. θ_{JC} = 16.4 °C/W.

1.2 Operating Conditions

Typical values: Ta=25 °C, PVDD***X***=3.7 V.

Table 1-2. Operating Conditions

Parameter	Notes	Minimum	Typical	Maximum	Units
PVDDD, PVDD1, PVDDM	1	2.7	3.7	5.25	V
Disable current (EN=L)	—	—	1	25	µA
Active current (EN=H)	2	—	2	—	mA

NOTES:

1. All features will be functional down to 3.15 V.
2. No current drawn by high voltage supplies, buck regulators, LDOs or LEDs. Exclude power dissipation of I^2C.

1.3 LED Driver Characteristics

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-3. LED Driver Characteristics

Parameter	Notes	Minimum	Typical	Maximum	Units
Output current	1	—	—	1.2	A
Current accuracy	2	—	+/-3.6	—	%
Current step	3	—	1073	—	µA
Current turn-on time	4	—	30	40	µs
Current ripple	—	-2	—	2	%
Current overshoot	—	—	—	10	%
Driver impedance	5	—	100	—	mΩ
PWM input frequency	—	4.5	12.5	20	kHz
PWM resolution	—	—	—	8	bits
PWM time out	6	140	200	540	µs

NOTES:

1. At PVDDD=3.3 V. 1A for PVDDD=3.15 V. Limited by buck boost converter.
2. Part to part variation measured at room temperature @ 300 mA.
3. Scale DAC set to maximum scale (3Fh).
4. PVOUT transitioning from 2.5 V to 3.5 V, IOUT=1A, 10-90%. Limited by DC-DC converter slewing.
5. Iout=500 mA. Impedance can be lowered at the expense of accuracy.
6. Time out is 2Tck+40 µs.

1.4 Buck-Boost DC-DC Converter

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-4. Buck-Boost DC-DC Converter

Parameter	Notes	Minimum	Typical	Maximum	Units
Output voltage	1	2	—	4.6	V
Overvoltage protection	2	—	5.2	—	V
Input under voltage lock-out	—	—	3.14	—	V
Current limiter range	3	0.2	—	6.4	A
Current limiter accuracy	4	-25	—	+25	%
Soft start time	—	—	1	—	msec

NOTES:

1. PVDDD=3.15 V, Iout=1.2A. Output under voltage alarm set at 1.5 V.
2. Programmable 4.6 V, 4.8 V, 5.0 V (default), 5.2 V.
3. Programmable.
4. Valid in the range of 1 A to 6.4 A.

1.5 Monitor ADC Specifications

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-5. Monitor ADC Specifications

Parameter	Notes	Minimum	Typical	Maximum	Units
Resolution	—	—	—	10	bits
Full scale input	—	4.9	5.27	5.6	V
Step size	—	—	5.17	—	mV
Offset error	—	—	29	—	mV
Conversion rate	1	—	4	—	ksps

NOTES:

1. ADC is interleaved between temp sensor, VBAT and PVOUT in this order conversion initiated by SELX change: will require 750 µsec to complete all 3 conversion

1.6 DMD Power

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-6. DMD Power

Symbol	Parameter	Notes	Minimum	Typical	Maximum	Units
V_{HIGH}	DMD VHIGH voltage (pin 37)	—	15.68	16	16.32	V
I_{HIGH}	Allowable output current to maintain VHIGH regulation and ripple	—	—	—	4	mA
V_{MID}	DMD VMID voltage (pin 36), register 09h[3] = 0b	—	8.33	8.5	8.67	V
	DMD VMID voltage (pin 36), register 09h[3] = 1b	1		5		
I_{MID}	Allowable output current to maintain VMID regulation and ripple	—	—	—	3	mA
V_{NEG}	DMD VNEG voltage (pin 39)	—	-10.2	-10	-9.8	V
I_{NEG}	Allowable output current to maintain VNEG regulation and ripple	—	—	—	4	mA
IBAT	Typical current draw from battery	2	—	9.5	—	mA
T_1	EN=H → EMU_RST=H	3	100	120	240	msec
T_2	V_{MID}=H → V_{HIGH},V_{NEG} start	3	3.2	8	11	msec
T_3	V_{HIGH},V_{NEG} start turn-off → V_{MID} start turn-off	3	8	10	12	msec
T_4	V_{MID} start turn-off → EMU_RST=L	3	150	180	300	msec
Ripple	VHIGH, VMID, VNEG IOUT=4 mA,PVDD=3.7, COUT=1 μF	—	—	—	200	mV
Line regulation	V_{HIGH}, V_{MID}, V_{NEG}	—	—	—	20	mV/V
Load regulation	VHIGH, VMID, VNEG IOUT=0 → 4 mA,PVDD=3.7, COUT=1 μF	—	—	—	15	V/A

NOTES:
1. V_{HIGH} and V_{NEG} disabled at register 2Eh[0] =1b and 2Eh[2] =1b.
2. Current draw for a given load depends on external component selected (inductor ESR and diode leakage).
3. Programmable through registers 0x0Bh and 0x0Ch.

1.7 3.3 V LDO Regulator *(VLDO2)*

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 3.7 V to 5.25 V.

Table 1-7. 3.3 V LDO Regulator (VLDO2)

Parameter	Notes	Minimum	Typical	Maximum	Units
Operating voltage	—	3.7		5.25	V
Turn-on time	—	—	—	5	msec
LDO mode minimum operating voltage	1	—	3.4	3.6	V
Regulated voltage in LDO mode	1	3.25	3.3	3.36	V
High side switch resistance PVDD2 < 3.4 V	1	—	—	1	Ω
Current load	—	—		150	mA
Load regulation	—	—	10	30	mV
Line regulation	1	—	—	0.8	%

NOTES:
1. The maximum VLDO2 voltage will be limited by the battery voltage and the switch resistance.

1.8 2.5 V LDO Regulator *(VLDO1)*

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.8 V to 5.25 V.

Table 1-8. 2.5 V LDO Regulator (VLDO1)

Parameter	Notes	Minimum	Typical	Maximum	Units
Operating voltage	—	2.8	3.7	5.25	V
Turn-on time	—	—	—	5	msec
Output voltage	—	2.38	2.5	2.62	V
Current load	—	—		30	mA
Load regulation	—	—	10	30	mV
Line regulation	—	—	—	0.8	%

1.9 Buck Regulators (VXBUCK1/2)

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-9. Buck regulators (VXBUCK1/2)

Parameter	Notes	Minimum	Typical	Maximum	Units
Operating voltage	—	2.7	3.7	5.25	V
Turn-on time	—	—	—	5	msec
Output voltage ripple (1.2/1.8 V regulator)	—	—	2	—	%
Output voltage (1.2 V regulator)	—	1.14	1.2	1.26	V
Current load (1.2 V regulator)	—	—		300	mA
Output voltage (1.8 V regulator)	—	1.71	1.8	1.89	V
Current load (1.8 V regulator) [1]	—	—		300	mA

1.10 Internal Temperature Sensor

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-10. Internal Temperature Sensor

Parameter	Notes	Minimum	Typical	Maximum	Units
Range	—	—	-40 to 155	—	°C
Overtemperature alarm with default setting (register programmable at 0x18)	—	113	120	128	°C
Temperature step	—	—	0.45	—	°C
Absolute accuracy	1	—	+/-8	—	°C

NOTES:

1. After system calibration at room temperature (one point calibration).

1.11 CMOS Pin Characteristics

Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

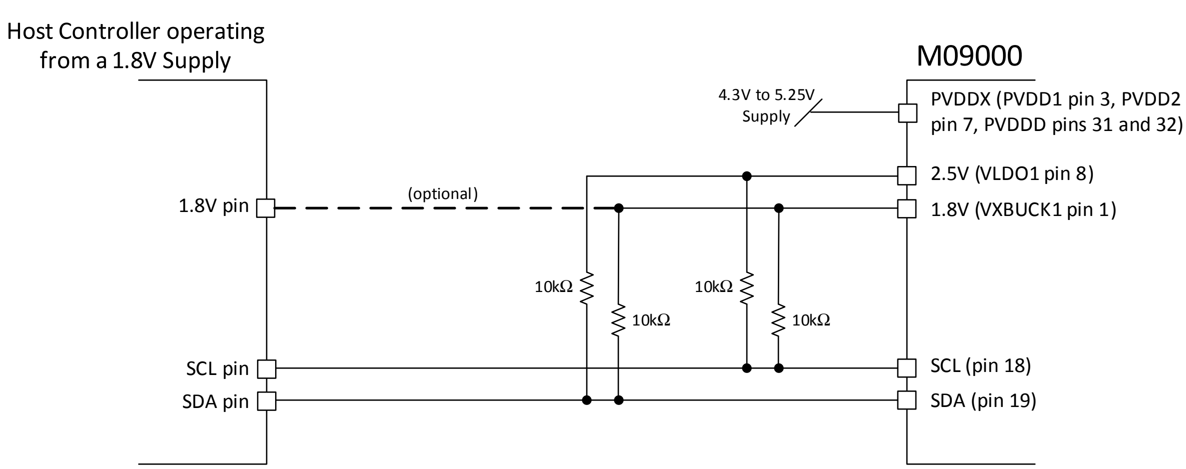
Table 1-11. CMOS Pins Characteristics

Symbol	Parameter	Notes	Minimum	Typical	Maximum	Units
V_{IH}	High level input voltage, pins SDA and SCL for PVDDX ≤ 4.3V	1	1.65	—	3.63	V
	High level input voltage, pins SDA and SCL for 4.3V < PVDDX ≤ 5.25V	1,2	1.83	—		
	High level input voltage, for input pins other than SDA and SCL and for PVDDX ≤ 4.3V	1	1.5	—		
	High level input voltage, for input pins other than SDA and SCL and for 4.3V < PVDDX ≤ 5.25V	1,2	1.61	—		
V_{IL}	Low level input voltage	—	0	—	0.4	V
V_{0L}	Low level output voltage	3	0	—	0.4	V
V_{0H}	High level output voltage	4	—	—	3.63	V

NOTES:

1. Digital pins are 3.3 V (+/-10%) tolerant if battery voltage is higher than 3.15 V.
2. See Figure 1-1 for recommended pull-up configuration for PVDDX >4.3V.
3. SDA/FAULT, Iout=3 mA
4. Open drain output.

Figure 1-1. I2C Pull-up for PVDDX from 4.3V to 5.25V



1.12 I²C Timing Specifications[1,2]

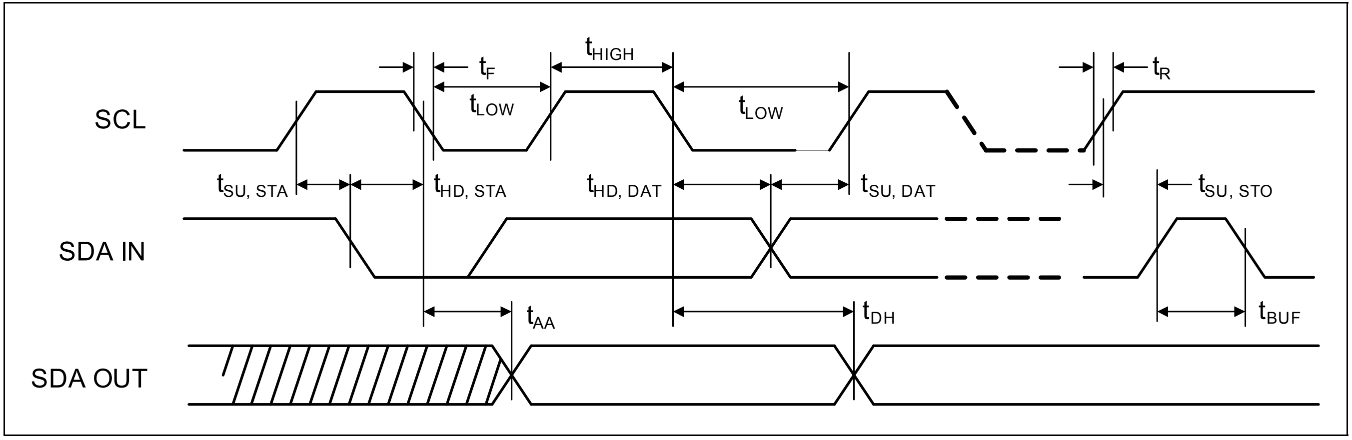
Typical values: Ta=25 °C, PVDD***X***=3.7 V.
Min and Max values: T_{CASE} = -40 °C to +85 °C, PVDDX = 2.7 V to 5.25 V.

Table 1-12. I²C Timing Specifications

Symbol	Parameter	Notes	Minimum	Typical	Maximum	Units
f_{SCL_MASTER}	Clock Frequency, SCL_M		—	—	400	kHz
t_{LOW}	Clock Pulse Width Low		160	—	—	ns
t_{HIGH}	Clock Pulse Width High		60	—	—	ns
t_{AA}	Clock Low to Data Out Valid		0	—	70	ns
$t_{HD,STA}$	Start Hold Time		160	—	—	ns
$t_{SU,STA}$	Start Set-up Time		160	—	—	ns
$t_{HD,DAT}$	Data In Hold Time		0	—	—	ns
$t_{SU,DAT}$	Data In Set-up Time		10	—	—	ns
$R_{PULL-UP}$	Outputs (SDA,FAULT) internal pull-up resistor value to PVDD2	2	—	250	—	kΩ
$t_{SU,STO}$	Stop Set-up Time		160	—	—	ns
t_{DH}	Data Out Hold Time		5	—	—	ns

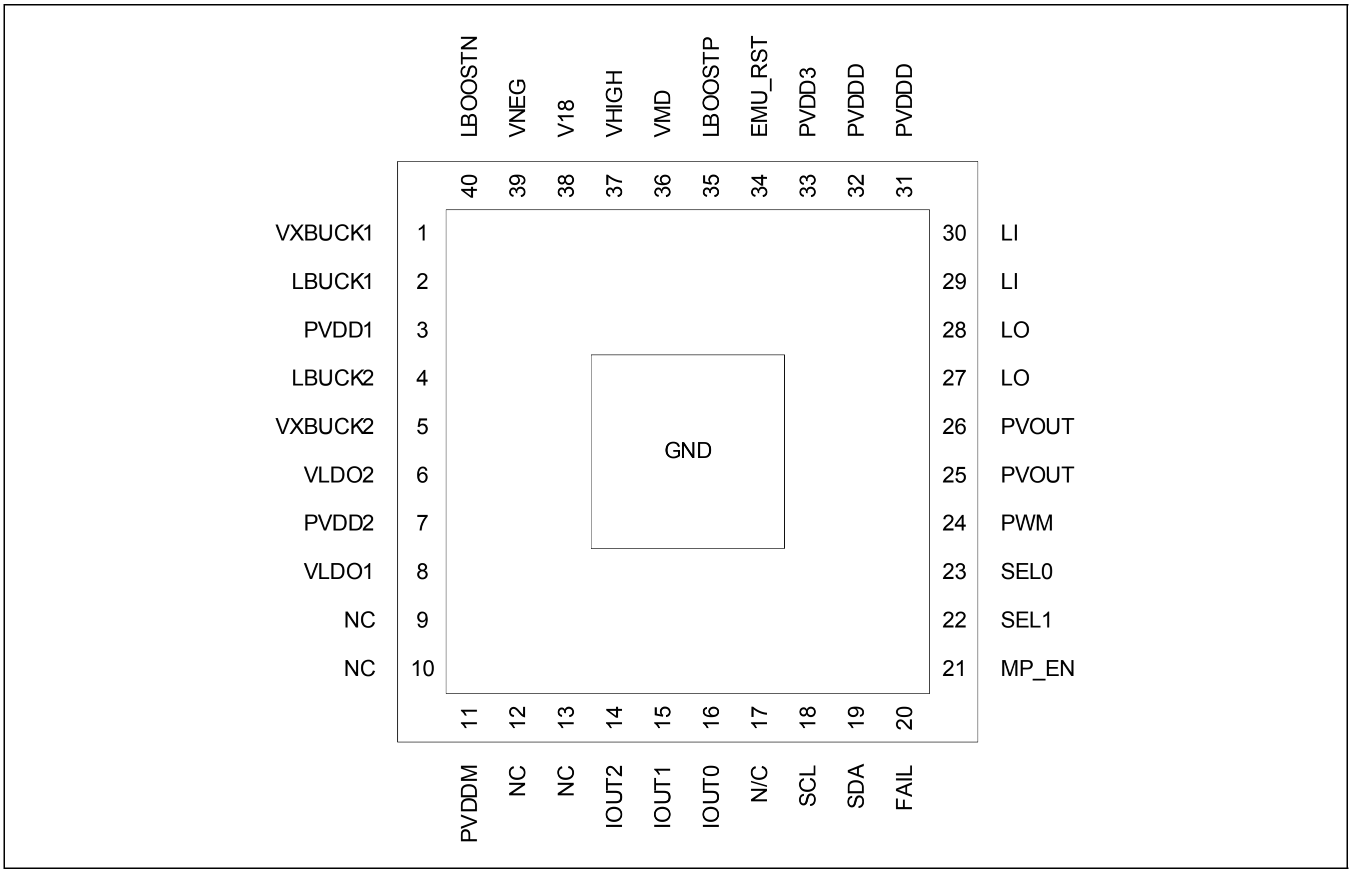
NOTES:
1. Guaranteed by design and characterization.
2. 4.7 kΩ should be added externally to the proper termination voltage for PVDDX < 4.3V. See Figure 1-2 for PVDDX ≥ 4.3V.

Figure 1-2. I²C Timing Diagram



2.0 Pin Descriptions and Package Outline Drawings

Figure 2-1. M09000 Pinout Diagram



2.1 Pin Descriptions

Table 2-1. Pin Descriptions

Pin#	Name	Comment	Type	Description
1	VXBUCK1		A	VX buck converter 1 (1.0/1.1/1.2/1.8 V)
2	LBUCK1		A	Inductor for buck converter 1
3	PVDD1		P	Buck converters V_{DD}
4	LBUCK2		A	Inductor for buck converter 2
5	VXBUCK2		A	VX buck converter 2 (1.8 V)
6	VLDO2		P	LDO regulator output 2 (3.3 V)
7	PVDD2		P	Analog V_{DD}
8	VLDO1		P	LDO regulator output 1 (2.5 V)
9	NC		—	No connect
10	NC		—	No connect
11	PVDDM		P	Auxiliary supply
12	NC		—	No connect
13	NC		—	No connect
14	IOUT2		A	LED Current output 2. Add 100 kΩ to ground at this pin.
15	IOUT1		A	LED Current output 1. Add 100 kΩ to ground at this pin.
16	IOUT0		A	LED Current output 0. Add 100 kΩ to ground at this pin.
17	NC		I	Not connected
18	SCL	CMOS	I	I^2C clock
19	SDA	CMOS (PU)/Open collector	I/O	I^2C data
20	FAIL	Open collector (PU)	O	Fault signal (active low)
21	MP_EN	CMOS (PD)	I	Enable
22	SEL1	CMOS (PD)	I	Strobe input
23	SEL0	CMOS (PD)	I	Strobe input
24	PWM	CMOS (PD)	I	PWM input (for DLP systems)
25	PVOUT		P	DC-DC converter output (LEDs anode)
26	PVOUT		P	DC-DC converter output (LEDs anode)
27	LO		A	Inductor output (LED driver)
28	LO		A	Inductor output (LED driver)
29	LI		A	Inductor input (LED driver)
30	LI		A	Inductor input (LED driver)
31	PVDDD		P	Driver V_{DD} (3.2-4.2 V)

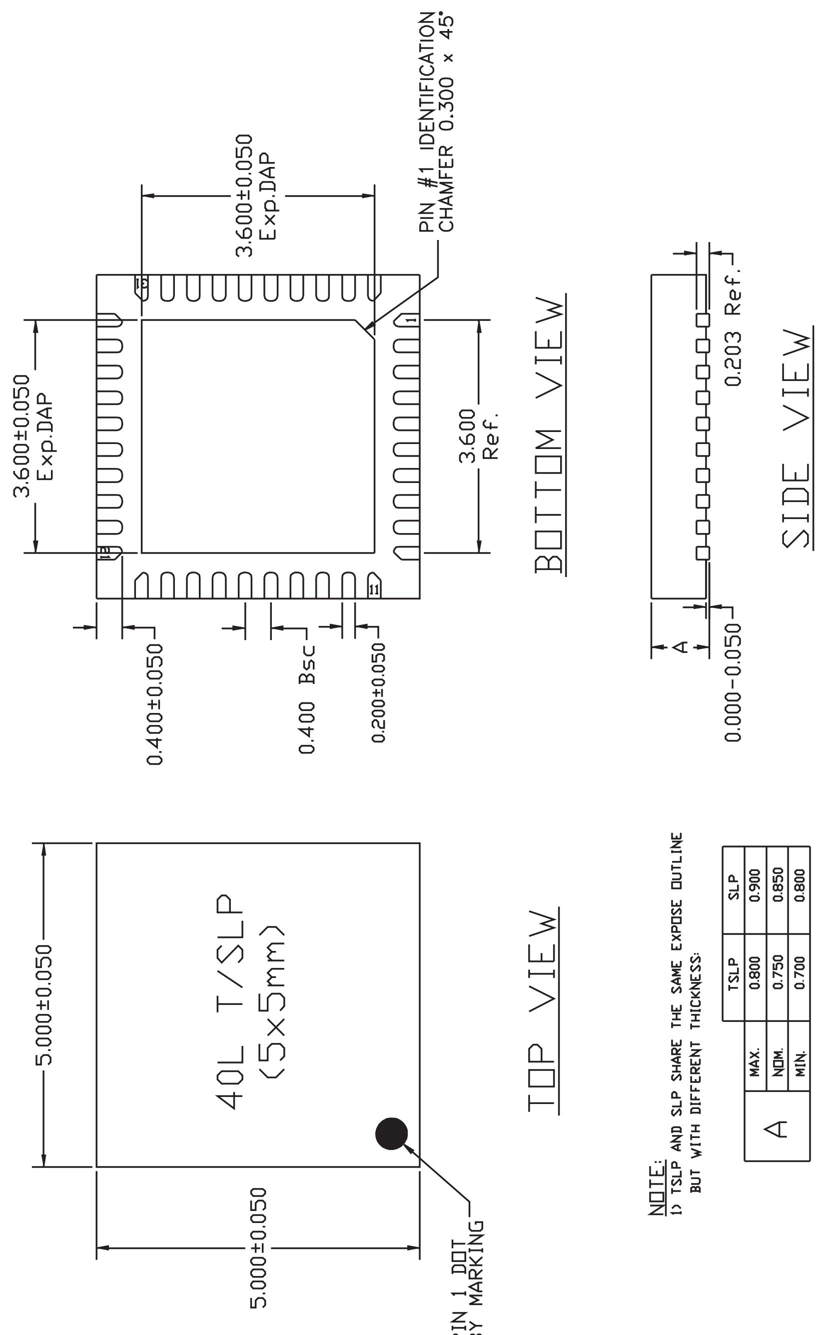
Table 2-1. Pin Descriptions

Pin#	Name	Comment	Type	Description
32	PVDDD		P	Driver V_{DD} (3.2-4.2 V)
33	PVDD3		P	Digital V_{DD}
34	EMU_RST	Open collector	O	EMU Reset (VHIGH,VMID,VNEG ready)
35	LBOOSTP		A	Positive side of inductor
36	VMID		A	+8.5 V output regulated voltage
37	VHIGH		A	+16 V output regulated voltage
38	V18		A	+18 V intermediate output voltage (from boost)
39	VNEG		A	-10 V output regulated voltage
40	LBOOSTN		A	Negative side of inductor

2.2 Package Information

The M09000 is packaged in a 5x5 mm 40pin QFN package with 0.4 mm pin pitch.

Figure 2-2. Package Information



A		TSLP	SLP
	MAX.	0.800	0.900
	NOM.	0.750	0.850
	MIN.	0.700	0.800

3.0 Functional Description

The M09000 is a highly integrated LED/laser driver and PMIC for projection display applications.

The driver portion consists of three 10-bit LED drivers and a buck-boost converter to generate the voltage necessary to bias the common anode voltage for the LEDs. The DC-DC converter can operate from a Li-Ion battery (2.7-4.3 V).

The part is capable of generating the DMD power supplies and includes 2 buck converters: 1.0/1.1/1.2/1.8 V programmable and 1.8 V, and 2 LDO regulators: 2.5 V and 3.3 V.

Monitor functionality and safety features are integrated as well.

The M09000 can be controlled via the I^2C interface.

3.1 User Configurable Registers

The M09000 is controlled by 49 user configurable registers in address locations 0x00 through 0x2E and registers 0x3A and 0x3B. The registers are described in the last section of this data sheet.

At power-up all registers will be set to their default value and the M09000 outputs will be disabled. To make the M09000 outputs active the MP_EN pin must be pulled high and the registers in Chapter 3 below must have the appropriate values written to them through the I^2C port on the M09000.

Each time the MP_EN pin goes low the registers will be cleared and reset to their default value. When MP_EN is returned to a high state these registers must be rewritten before the M09000 will be reactivated.

It is not necessary to write all 48 registers. If the default setting of a register is acceptable then it does not need to be written.

Below is a basic register configuration to enable all the outputs.

Table 3-1. First Step Basic Register Configuration (all other registers may be left at their default value)

Name	Address	Recommended Setting	Description
SOFT_RESET	0X30h	00h	After power up and MP_EN=HI, then write AAh (self resetting)
INPUT_CNTL	0x0E	27h	Configure inputs and assign LED outputs
OUTPUT_CNTLx	0x10, 0x11, 0x12	34h	Recommended LED driver configuration.
IOUTx_LSB	0x13[5:0]	00xxxxxxb	Two least significant bits of output current setting
IOUTx_MSB	0x14, 0x15, 0x16	xxh	Eight most significant bits of output current setting.

Table 3-1. First Step Basic Register Configuration (all other registers may be left at their default value)

Name	Address	Recommended Setting	Description
HEADROOM_0, HEADROOM_1	0x19[3:0], 0x19[7:4], 0x1A[3:0]	0110b 1001b 1011b	Output headroom for 0 to 0.4A Output headroom for 0.4A to 0.8A Output headroom for 0.8A to 1.2A
BUCKBOOST_USR0	0x1B	3Ah	Buck-Boost disabled. Positive current limit set to 6.0A
BUCKBOOST_USR1	0x1C	98h	Recommended Buck-Boost converter configuration. Negative current limit set to 6.0A
BUCKBOOST_USR2	0x1D	5Fh	Recommended Buck-Boost converter configuration.
BUCKBOOST_USR3	0x1E	30h	Recommended Buck-Boost converter configuration.
BUCKBOOST_USR4	0x1F	F0h	Recommended Buck-Boost converter configuration.
HEADROOM_CTRL0	0x27h	10h	Recommended Buck-Boost converter control configuration.
HEADROOM_CTRL1	0x28h	17h	Recommended Buck-Boost converter control configuration.
TEMPSENS_CTRL0	0x29h	FFh	Recommended temperature sensor configuration.
DRV_CTRL	0x2Bh	C0h	Recommended Buck-Boost driver configuration
BUCKBOOST_STRT	0x2Ch	14h	Recommended Buck-Boost start-up configuration
BUCKBOOST_SPUP	0x2Dh	65h	Recommended Buck-Boost speed-up configuration

In LCOS applications the DMD supply may be used to generate 5V or some other voltage. In this case see Section 3.5.1 for the configuration of registers 06h, 09h and 2Eh.

After the basic configuration is complete the Buck-Boost supply and DMD supply may be enabled.

Table 3-2. Second Step Basic Register Configuration (all other registers may be left unchanged)

Name	Address	Recommended Setting	Description
DMD_RISE	0x0B	25h	Enable DMD Supply
BUCKBOOST_USR0	0x1B	3Bh	Enable Buck-Boost Supply
FAIL_CTRL	0x21	88h	Clear alarm status

3.2 LED Drivers

The current is provided to the RGB LED through three 1.2 A high accuracy 10-bit common anode drivers controlled by pin.SEL0 and pin.SEL1 according to the following table:

Table 3-3. RGB LED Current Settings

[SEL1,SEL0]	Status
[1,1]	Blue ON
[1,0]	Green ON
[0,1]	Red ON
[0,0]	OFF

The channel associated with each color can be controlled by register.**INPUT_CONT**[5:0]. If any of **INPUT_CONT** pairs of bit [1:0], [3:2] or [5:4] is 11b there is no decoding of the input signal and pin *SEL0*, *SEL1* and *PWM* control respectively channel *IOUT0*, *IOUT1* and *IOUT2*. In this mode of operation the PWM function is disabled. Please note that the PWM engine can also be shut down to save power by setting **INPUT_CONT**[7]=1b.

The current is controlled by programming registers.**IOUTx**.bit[9:0]. Each current step corresponds to 1.17 mA.

It is possible to store preferred value of current into the M09000 in case a particular part is mated with an optical engine. The default value of the bits setting the output current (register 0x13h through 0x16h) can be programmed in the internal OTP memory so the white balance point of an engine mated with the M09000 can be stores into the device. Please refer to the paragraph regarding the OTP memory in Section 3.12 for details on THE programming procedure.

The M09000 features a PWM to current amplitude modulation converter. The current at the output can scale proportionally to the duty cycle of the signal applied to pin.PWM. For example, if the duty cycle at the PWM input is 25% the current at the output will be reduced to 25% of the value programmed in the M09000.

The change in the amplitude of the output current as a response to a change in duty cycle of the PWM input is not instantaneous; the current during the subsequent sub-frame will be adjusted provided that the change in PWM duty cycles happens 2 clock cycles plus 40 µs before the change of sub-frame (toggling on pin.SEL0/pin.SEL1). This is defined as the time-out period.

The resolution of the PWM function is 8-bits: the M09000 is capable of resolving variations of 1/255 in the duty cycle of the PWM signal of frequency in the range of 5 kHz to 20 kHz. If PWM input is low continuously the output current will be forced to 1/255 of the full scale value.

To optimize power dissipation the headroom of each driver can be programmed using bits **HEADROOM_*x***. To achieve the specified accuracy the drivers require 10 mV of headroom for each 100 mA of current delivered to the LED down to a minimum of 50 mV. This corresponds to a driver impedance of 100 mΩ.

For example, if the maximum current required in the system is 700 mA the headroom that must be programmed is 70 mV (0110 binary code). If the maximum current required in the system is 350 mA the headroom that can be programmed is 40 mV (0011 binary code) but to achieve the specified accuracy 50 mV (0011 binary code) should be used.

Because of the driver architecture, the current overshoot in the M09000 is maintained well below 10%.

The driver will issue an alarm at the pin.FAIL in case of open or shorted LED and in case the LED cathode is shorted to ground.

3.3 Buck-boost Converter

The M09000 buck-boost converter controls the common anode voltage of the LED sub-assembly to guarantee optimal system efficiency.

The M09000 automatically adjusts the anode voltage of the LED to guarantee enough headroom for the LED and the driver to operate.

The typical current turn-on, limited by the DC-DC converter slewing is 30 μs with a transition of the LED anode voltage from 2.5 V to 3.5 V. This is very well representative of a red to green LED transition which is usually the slowest transition since the voltage difference between red and green LED is the highest.

The buck-boost converter is capable of delivering 1.2 A with a minimum battery voltage of 3.15 V (1 A at 2.7 V). The maximum buck-boost output voltage is 4.6 V.

The M09000 has a programmable undervoltage lockout at register.**ALARM_CTRL0**.bit[7:6] and overvoltage protection.

Moreover, a programmable current limiter (both positive and negative) allows the user to select the most appropriate inductor characteristic for the specific application by trading off inductor area with series resistance.

The current limiters can be programmed through register.**BUCKBOOST_USR0**.bit[5:1] and register.**BUCKBOOST_USR1**.bit[4:0].

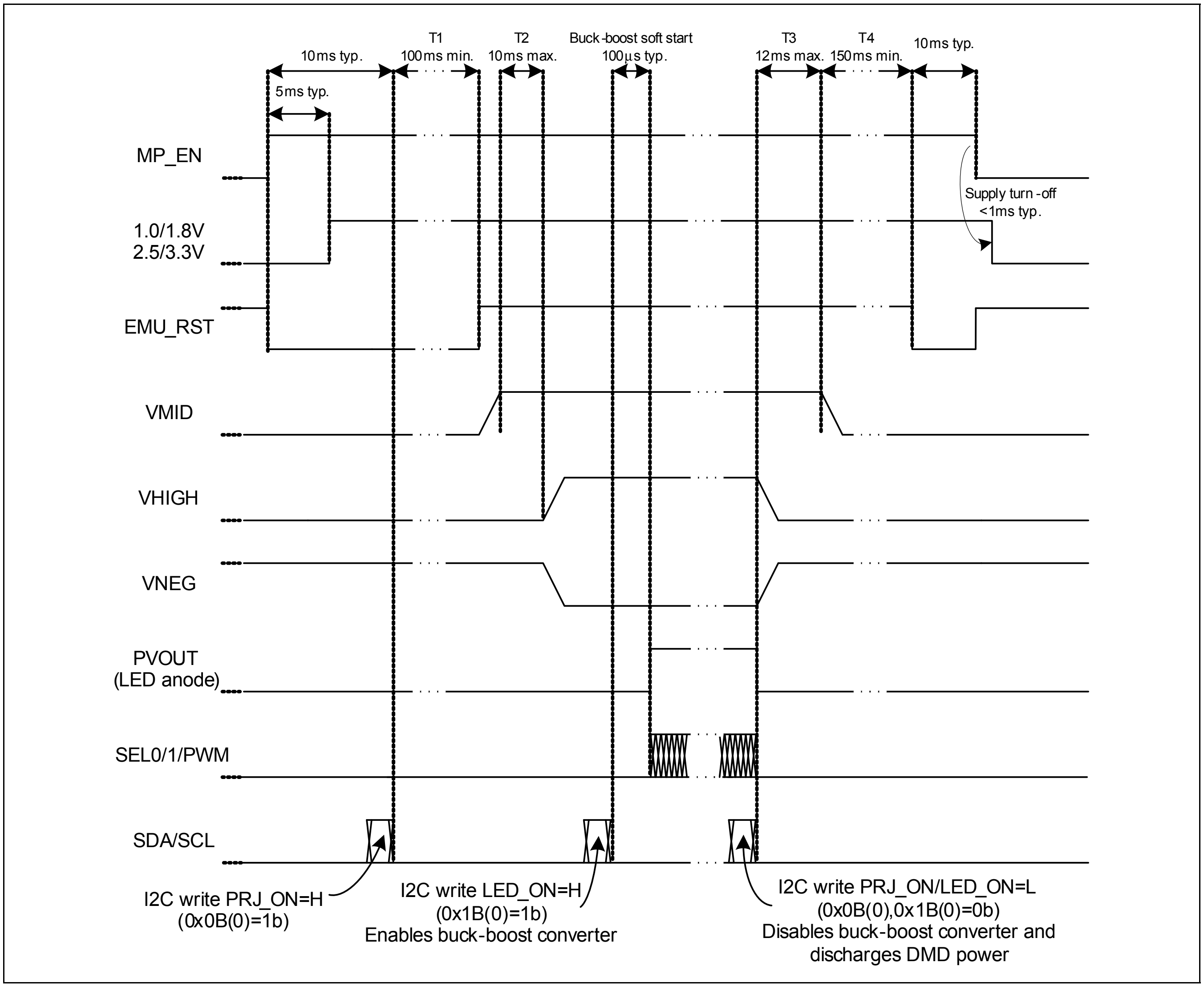
3.4 PMIC Functions

The M09000 generates all the necessary supplies from a single battery.

The power management portion includes DMD power generators, two buck converters which can generate 1.8 V and 1.0/1.1/1.2/1.8 V (programmable through BUCKV10_USR2[1:0]) and 2 LDO generators delivering 2.5 V and 3.3 V.

The following timing diagram details the power up sequence:

Figure 3-1. Power Up Sequence



It should be noticed that pin.MP_EN is capable of accepting 3.3 V as well as 1.8 V level signals provided that the battery voltage (PVDD2) is between 2.7 V and 5.25V.

The battery voltage is supplied to the power management blocks as illustrated in the block diagram on the front page of this document: PVDD1 power supplies current to the 2-buck converter and the DMD supplies generator while PVDD2 supplies the 2 LDO regulators. This allows for better noise isolation between the different supplies when appropriate decoupling is provided (1 µF+10nF) for each one of them and a star connection to the battery is used from a board layout perspective.

LED_ON command enables the buck-boost converter. The SEL0/1 pins are locked out (i.e. will not be able to turn on the driver) unless LED_ON command is issued. The SEL0/1 pins will be able to control the drivers after the buck-boost soft-start: typically 100 µs.

3.5 DMD Supply

The M09000 generates the high voltage DLP supplies according to the timing diagram in the previous paragraph and to the following table.

Table 3-4. DMD Supply Voltages

Supply Name	Voltage	Maximum Current Load
VHIGH	16 V+/-2%	4 mA
VMID	8.5 V+/-2%	4 mA
VNEG	-10+/-2%	4 mA

As illustrated in the block diagram, the M09000 requires only one external inductor and 2 Schottky diodes. Standard decoupling practices should be used at the input.

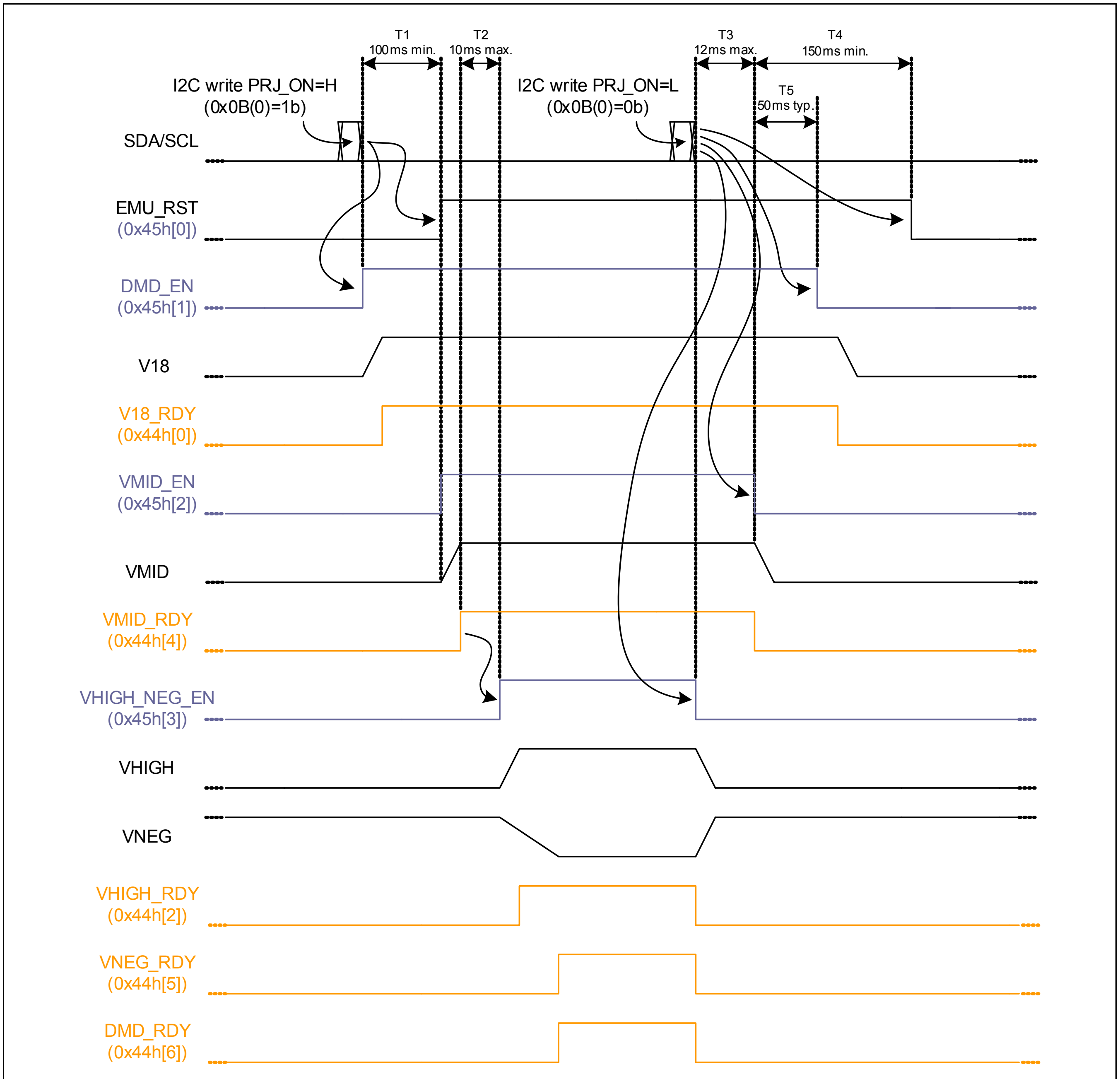
To ensure small ripple at the VHIGH, VMID and VNEG, a 2.2 µF output capacitor is suggested for each one of them.

The digital engine is in charge of the timing of the enabling of the various DMD generators for the V18, VHIGH, VMID and VNEG as illustrated in Figure 3-2. The black signals are pins, the purple signals are outputs to the digital block, while the orange signals are input to the digital block.

The timing delay of the various signals are illustrated in Figure 3-2.

Since the VMID voltage must be enabled when the VHIGH is present, VHIGH_EN should be gated by VMID_RDY in such a way that if the VMID voltage drops (and VMID_RDY goes low) the VHIGH_EN also goes low.

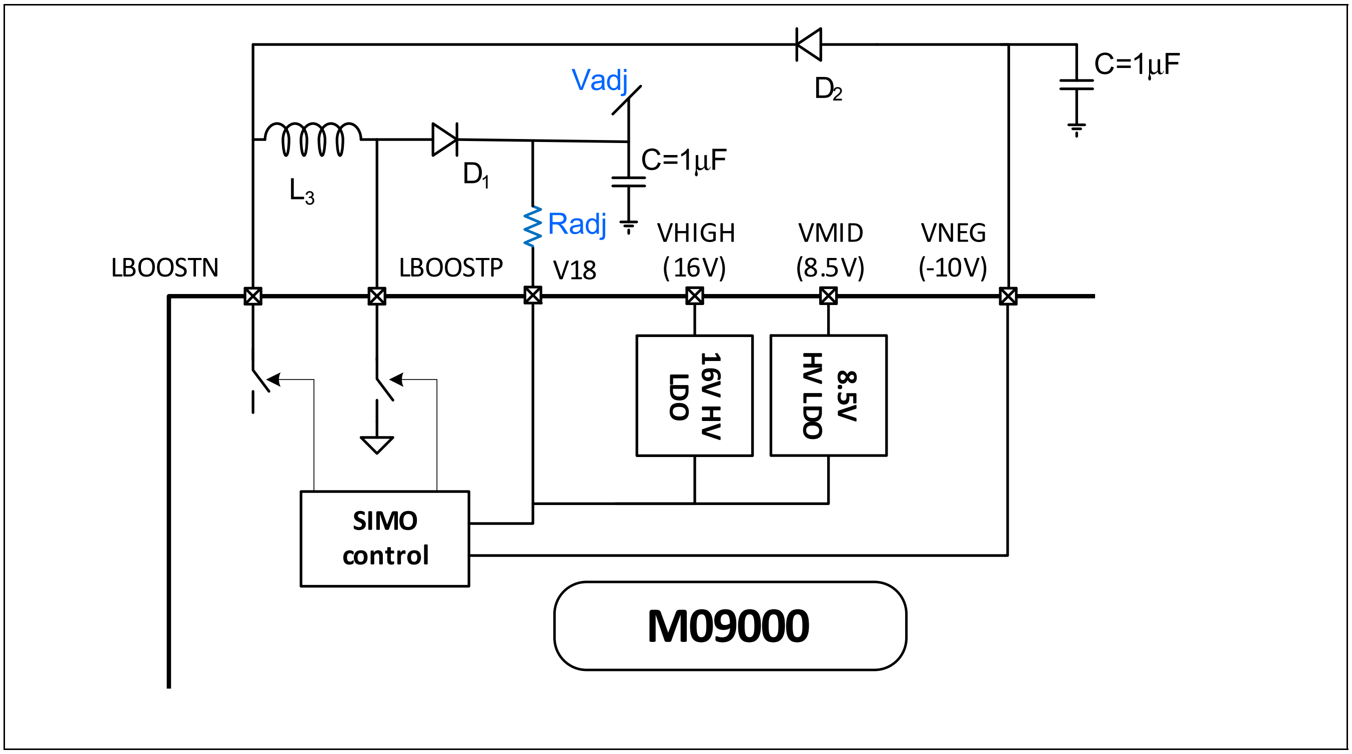
Figure 3-2. Digital Engine Timing Diagram



3.5.1 LCOS Applications - Other Uses for the DMD Supply

The boost converter of the DMD generator can be used to generate a 5 V supply or other voltage by setting 06h[7]=1b. In this case, all the other DMD voltage generators (VNEG, and the 2 LDO generating VMID and VHIGH) should be shut off setting 2Eh[2:0]=111b in order to save power. There will be an approximate 20% part to part variation in the output voltage using this method. An adjustment resistor should be added as shown in Figure 3-3.

Figure 3-3. Creating an Adjustable Output Voltage with the Boost Converter



Alternatively an accurate 5 V can be generated by the VMID LDO selecting 09h[3]=1b. In this configuration the VHIGH and VNEG generator should be disabled with registers 2Eh[2]=1b and 2Eh[0]=1b. This configuration will be inefficient since the 5 V at VMID will be derived from an LDO supplied by the boosted voltage of 18 V.

3.6 Low Dropout Regulators

The M09000 features 2 low dropout regulators. These provide accurate voltage by regulating the battery voltage down to the desired level.

The 2.5 V regulator will work as a regulator for battery voltages > 3.15 V.

3.7 Buck Regulators

Two high efficiency step-down DC-DC converters are also available. These provide accurate voltage by regulating the battery voltage down to the desired level.

Output voltage ripple is maintained within 2% of output voltage and typical turn-on time (soft start) of 5 msec.