TMI9405 AM Mini-LED Local Dimming Backlight Driver with 4-channel Integrated Current Sink

FEATURES

- LED topology:
  - AM 4 constant current sink, each current sink can support 1~10 LEDs
- Operating voltage range:
  - VCC range: 3.0V to 5.5V
  - Interface pin compatible with: 3.3V/5.0V
  - LED supply voltage range: up to 40V
- Constant current sinks with high precision:
  - 0.3~80mA per channel sink when VCC>3V
  - Device-to-device error: ±1.5%
  - Knee voltage:600mV in 40mA
- PWM dimming options:
  - Global 8-bits maximum current (GC) setting from 0.3mA~80mA
- PWM dimming control:12 bits
- Ultra-low quiescent current:
  - 100µA in standby mode.
  - 1.5mA in normal mode @60mA
- Automatic Voltage range detection for V_{LED} Headroom voltage control.
- LED open (LOD)/ short (LSD) detection
- Over temperature detect and chip protection:
  - 120°C derating options
  - 150°C Shut down
- Programmable interface output ability for EMI
- Phase-shift PWM scheme.
- Two-wire interface compatible with common SPI, data transfer rate: 10MHz(max.)
- UART output for internal information readback.
- Interrupt output for system level ERROR information handle.
- ESD: 4000V HBM

GENERAL DESCRIPTION

The TMI9405 is a 4-channel, internal current sink, high precision, mini-LED backlighting driver for high dynamic range (HDR) LCD TVs, monitors and notebook displays. The device reports the voltage on the OUT pin to MCU to enable best system efficiency and thermal performance.

The TMI9405 integrates the ability to used digital dimming methods in one device. With an 8-bit global and 12-bit PWM digital dimming, the device improved contrast ratio in HDR displays. The current sinks can drive up to 40mA per channel and have very tightly controlled current accuracy.

A full array or protection circuits are integrated, including built-in LED open/short detection, over temperature protection and protection during both start-up and normal operation.

APPLICATIONS

- LCD local dimming backlight
- TV
- Monitor
- Notebook

TYPICAL APPILCATION
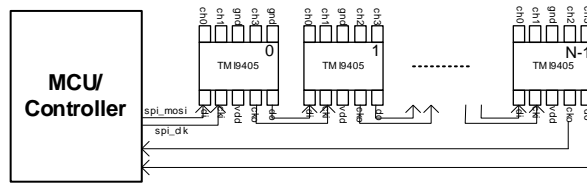
ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Min	Max	Unit
Voltage on Pins	VCC	3.0	5.5	V
	CKI/DI/CKO/DO	-0.3	5.5	V
	OUT0 to OUT3	-0.3	40	V
Storage Temperature Range	T_{STG}	-65	150	°C
Junction Temperature (Note 2)	T_J	-40	125	°C
Lead Temperature Soldering,10sec		-	260	°C

PIN CONFIGURATION

DI	1		10	OUT0
CKI	2		9	OUT1
VCC	3	TMI9405	8	GND
CKO	4		7	OUT2
DO	5		6	OUT3
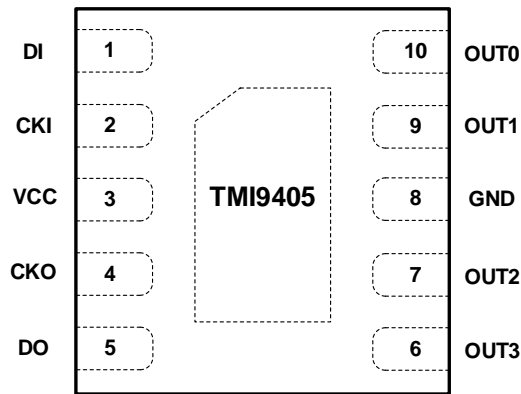
DFN2x2-10 (Top View)

Top Mark: T9JX/XX (T9J: Device Code, X/XX: Inside Code)

Part Number	Package	Top mark	Quantity/ Reel
TMI9405	DFN2x2-10	T9MX XX	3000

TMI9405 devices are Pb-free and RoHS compliant.

TMI9405

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PIN FUNCTIONS

Pin	Name	Function	Description
1	DI	I	Data input
2	CKI	I	Clock input
3	VCC	Power	Power Supply
4	CKO	O	Clock output
5	DO	O	Data output
6	OUT3	O	Constant-current output 3
7	OUT2	O	Constant-current output 2
8	GND	Ground	Ground
9	OUT1	O	Constant-current output 1
10	OUT0	O	Constant-current output 0

ESD RATING

Items	Description	Value	Unit
V_{ESD_HBM}	Human Body Model for all pins	±4000	V
V_{ESD_CDM}	Charge Device Model for all pins	±750	V

JEDEC specification JS-001

RECOMMENDED OPERATING CONDITIONS

Items	Description	Min	Max	Unit
Voltage Range	VIN	3.0	5.5	V
T_A	Ambient Temperature Range	-40	85	°C
T_J	Operating Junction Temperature Range	-40	125	°C

ELECTRICAL CHARACTERISTICS

(V$_{IN}$=5V, V$_{OUT}$=1.2V, T$_A$ = 25°C, unless otherwise noted.)

| Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Input Stage						
Input Voltage Range	V$_{CC}$		3.0		5.5	V
UVLO Restart	V$_{UVR}$	VCC rising			2.5	V
UVLO Shutdown	V$_{UVF}$	VCC falling	2.0	2.2		V
UVLO Hysteresis	V$_{UV\_HYS}$			0.2		V
Standby mode Current	I$_{STANDBY}$			100		µA
Shutdown Current	I$_{SHUTDOWN}$	VCC rising < V$_{UVR}$, VCC failing < V$_{UV}$			1	µA
Normal mode Current	I$_{NORMAL}$	IOUT=40mA		1.0		mA
Output Stage						
Constant current sink output range	I$_{CS}$	VCC>=3V, GC=FF, PWM=100%			80	mA
Leakage current (OUT0~OUT3)	I$_{LKG}$	PWM=0%, VLED=40V		0.01		µA
Device to device current error (I$_{ERR\_DD}$ =（I$_{AVE}$-I$_{SET}$）/ISET * 100%	I$_{ERR\_DD}$	All channels on, current set to 5mA	-1.5%		1.5%	
		All channels on, current set to 40mA	-1.5%		1.5%	
Device to device current error (I$_{ERR\_CC}$ =（I$_{AVE}$-I$_{SET}$）/ISET * 100%	I$_{ERR\_CC}$	All channels on, current set to 5mA	-1.5%		1.5%	
		All channels on, current set to 40mA	-1.5%		1.5%	
PWM frequency	F$_{PWM}$		0.96		30.72	kHz
Output saturation voltage	V$_{SAT}$	IOUT=40mA, VCC=3.3V		460		mV
		IOUT=20mA, VCC=3.3V		320		mV
Logic Interfaces						
High level input voltage, CKI, DI	V$_{LOGIC\_IH}$		0.7*V$_{CC}$			V
Low level input voltage, CKI, DI	V$_{LOGIC\_IL}$				0.3*V$_{CC}$	V
Input current CKI, DI	I$_{LOGIC\_I}$			1		µA
High level output voltage, CKI, DI	V$_{LOGIC\_OH}$		0.7*V$_{CC}$			V

ELECTRICAL CHARACTERISTICS

(V$_{IN}$=5V, V$_{OUT}$=1.2V, T$_A$ = 25°C, unless otherwise noted.)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Low level output voltage, CKI, DI	V$_{LOGIC\_OL}$				0.3*V$_{CC}$	V
Protection						
Threshold for channel open detection	V$_{LOD\_TH}$			0.15/0.2/ 0.25/0.3		V
Threshold for channel short detection	V$_{LSD\_TH}$			3/4/5/6/7 8/9/10		V
Thermal Shutdown	T$_{OTP\_150}$			150		°C
Derating Mode	T$_{OTP\_120}$			120		°C

TIMING REQUIREMENT

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
	F$_{CKI}$				10	MHz
CKI high time	T$_{W(H)}$			25		ns
CKI low time	T$_{W(L)}$			25		ns
Setup time	T$_{SU}$					ns
Hold time	T$_H$					ns
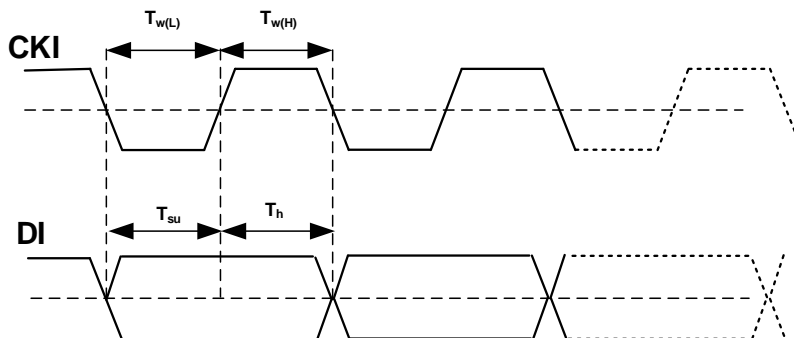
FUNCTION DESCRIPTION

Current Gain Control

The GC is used to set the maximum current IOUT_MAX for each current sink, this current is the maximum peak current for each LED dot. GC can be set with 8-bit(256)step form 0 mA to 80 mA. GC default value is 40 mA.

8-bits Global current register		Current
Binary	Decimal	mA
00000000	0	0
00000001	1	0.314
00000010	2	0.627
…		
10000000(default)	128	40.157
…		
11111110	254	79.686
11111111	255	80

PWM Dimming

There are several methods to control the PWM duty cycle of each LED dot
- 12-bit PWM
- Spectrum PWM
- 4 Individual PWM Phase
- Precise PWM on/off slew rate control
- 3 Bit programmable slew rate control for EMI reduction

VOUT Voltage Detection

TMI9405 has rich voltage threshold reference for LED node voltage detection. After the detection, each device generates the detection result and transmit through the two-wire interface. The last device can summarize all the results and transmit through interface to the external Controller/MCU. The controller/MCU can receive the result one frame one time and choose the strategy the adjust the DC/DC and save the system power.
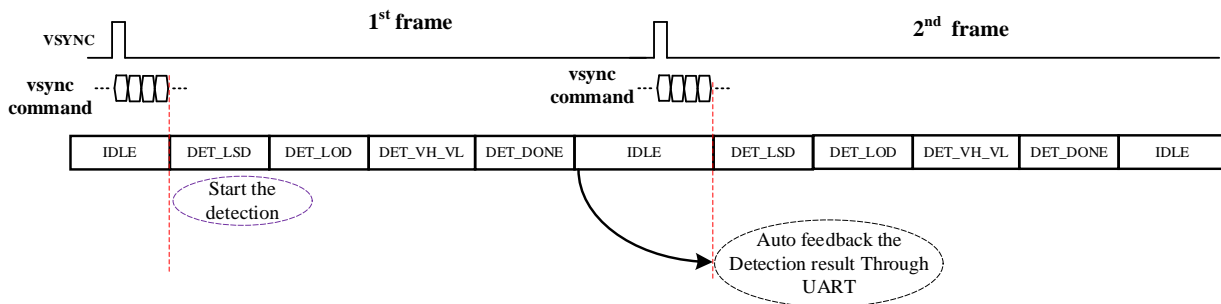
Detection flow

Four reference voltage is using for VOUT voltage detect: V_{LSD_REFV}, V_{VH_REFV}, V_{VL_REFV}, V_{LOD_REFV}. For each channel, there are four status: LSD_FLAG, VH_FLAG, VL_FLAG, LOD_FLAG, the VOUT condition is as below table show, the recommend action for DC/DC of each status is also list in this table.

VOUT condition	LOD_FLAG	LSD_FLAG	VH_FLAG	VL_FLAG	Recommend Action
>V_{LSD_REFV}	1	1	0	0	keep
>V_{VH_REFV} & <V_{LSD_REFV}	0	0	1	0	decrease
<V_{VL_REFV} & >V_{LOD_REFV}	0	0	0	1	increase
<V_{LOD_REFV}	1	1	0	0	keep

PROTECTIONS AND DIAGNOSTICS

Thermal shutdown detection

TMI9405 implement a thermal shut down mechanism to protect device from damage due to the overheating. When the junction temperature rises to 150°C in normal mode, the device switches into shutdown mode. TMI9405 device will go back to normal mode when the junction temperature of the device decreases to 130°C.

TMI9405 also implement a thermal derating mechanism, when the junction temperature rises to 120°C in normal mode, by setting register bit DR, TMI9405 can decreasing the GC by 1/8GC, 1/4GC or 1/2GC. The TMI9405 device will go back to normal mode when the junction temperature of the device decreases to 100°C.

LED open detection (LOD)

TMI9405 include LED open detection (LOD) for the fault cause by any opened output channel if the voltage is detected lower than open threshold VLOD_REF.V The LOD fault result can be masked by register LOD_DET_EN and LOD channel can be turned off automatically by register LODRM_EN

LED short detection (LSD)

TMI9405 include LED open detection (LSD) for the fault cause by any opened output channel if the voltage is detected lower than open threshold VLSD_REF. The LSD fault result can be masked by register LSD_DET_EN and LSD channel can be turned off automatically by register LSDRM_EN

UART and Interrupt

TMI9405 devices to configured interface output from CKO/DO to INT/UART. When error occurs, the INT will pull up and error result can be read by UART.
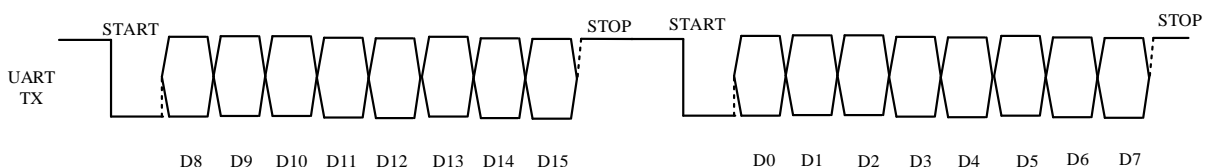
DEVICE FUNCTION MODE
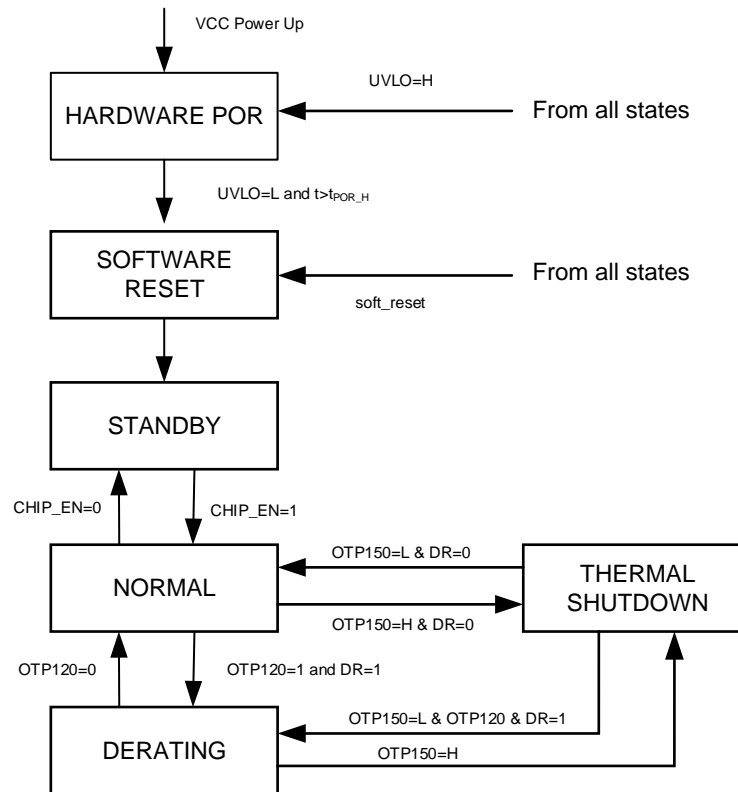
HARDWARE POR: the device enters into SHUTDOWM mode from all state on VCC power up.
HA

SOFTWARE RESET: the device enters into SOFTWARE RESET mode when VCC rise higher than VUVR with time $t>t_{POR\_H}$. In this mode, all registers are reset, entry can also be from any state when write RESET, or UVLO is LOW.

STANDBY: The device enters the STANDBY mode when CHIP_EN is 0. In this mode, device enters into low power mode, but the interface is still active and all the registers is retained.

NORMAL: the device enters the NORMAL mode when CHIP_EN with the $t>t_{CHIP\_EN}$.

THERMAL SHUTDOWN: The device enters the THERMALSHUTDOWN mode when the junction temperature exceeds 150°C. If the junction temperature decreases below 130°C, the device returns to the NORMAL state.

DERATING: The device enters DERATING mode when Junction temperature exceed 120°C and DR function is enabled. If the Junction temperature decreases below 100°C, the device returns to the NORMAL state.
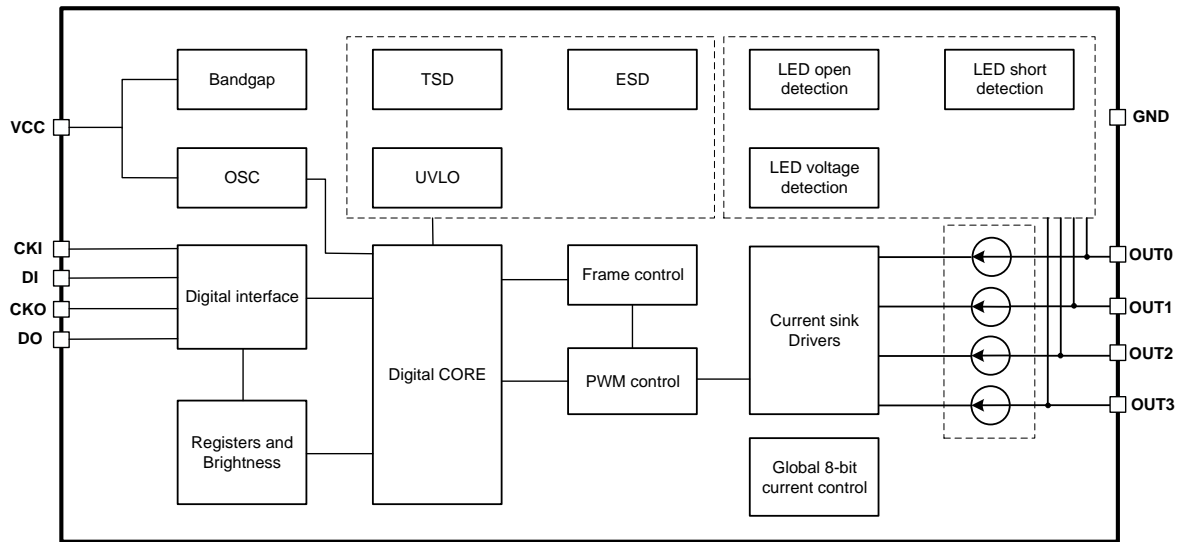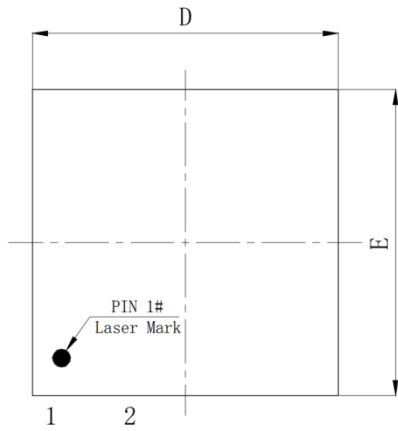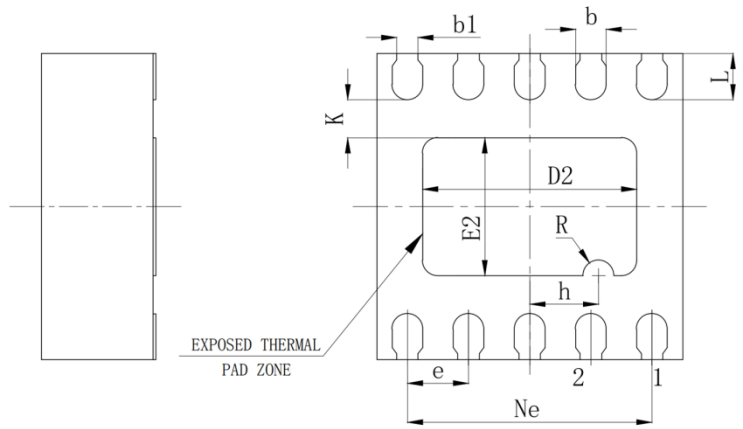
FUNCTIONAL BLOCK DIAGRAM
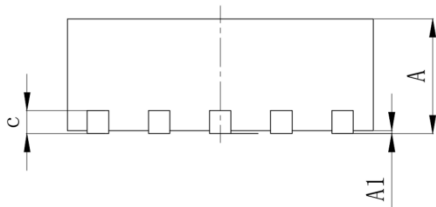

Figure 1. TMI9405 Block Diagram

PACKAGE INFORMATION

DFN2x2-10

TOP VIEW

SIDE VIEW

BOTTOM VIEW

Unit: mm

Symbol	Dimensions In Millimeters			Symbol	Dimensions In Millimeters		
	Min	Nom	Max		Min	Nom	Max
A	0.70	0.75	0.80	E2	0.60	0.70	0.80
A1	0	0.02	0.05	e	0.40BSC		
b	0.15	0.20	0.25	Ne	1.60 BSC		
b1	0.18 REF			L	0.35	0.40	0.45
c	0.203 REF			K	0.25 REF		
D	1.90	2.00	2.10	h	0.55 BSC		
D2	1.50	1.60	1.70	R	0.10 REF		
E	1.90	2.00	2.10				

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