DM631

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16-CHANNEL CONSTANT CURRENT LED DRIVER

WITH PROGRAMMABLE PWM OUTPUTS

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DM631

16-CHANNEL CONSTANT CURRENT LED DRIVER WITH PROGRAMMABLE PWM OUTPUTS

General Description

DM631 is a 16-channel constant current sink LED driver. Each channel has adjustable 12-bits (4096 steps) grayscale PWM control current outputs. It incorporates shift registers, data latches, constant current circuitry with current value set by an external resistor, selectable oscillator source for PWM function, and built-in LED open detection circuit to detect error status. It is specifically designed for LED display or lighting applications.

Features

- Constant-current outputs: 5mA to 90mA adjustable by one external resistor
- 12-bit PWM control current outputs for each channel
- Maximum output voltage: 17V
- Maximum clock frequency: 25MHz
- Selectable internal/external PWM reference clock
- PWM free-running capability (refresh rate (~4.4KHz) with internal oscillator (~ 18 MHz))
- Build-in real-time LED open detection
- Package and pin assignment (except QFN32) compatible to pure LED drivers series (ST2221C, DM134/5/6, DM13C)
- Power supply voltage: 3.3V to 5.5V

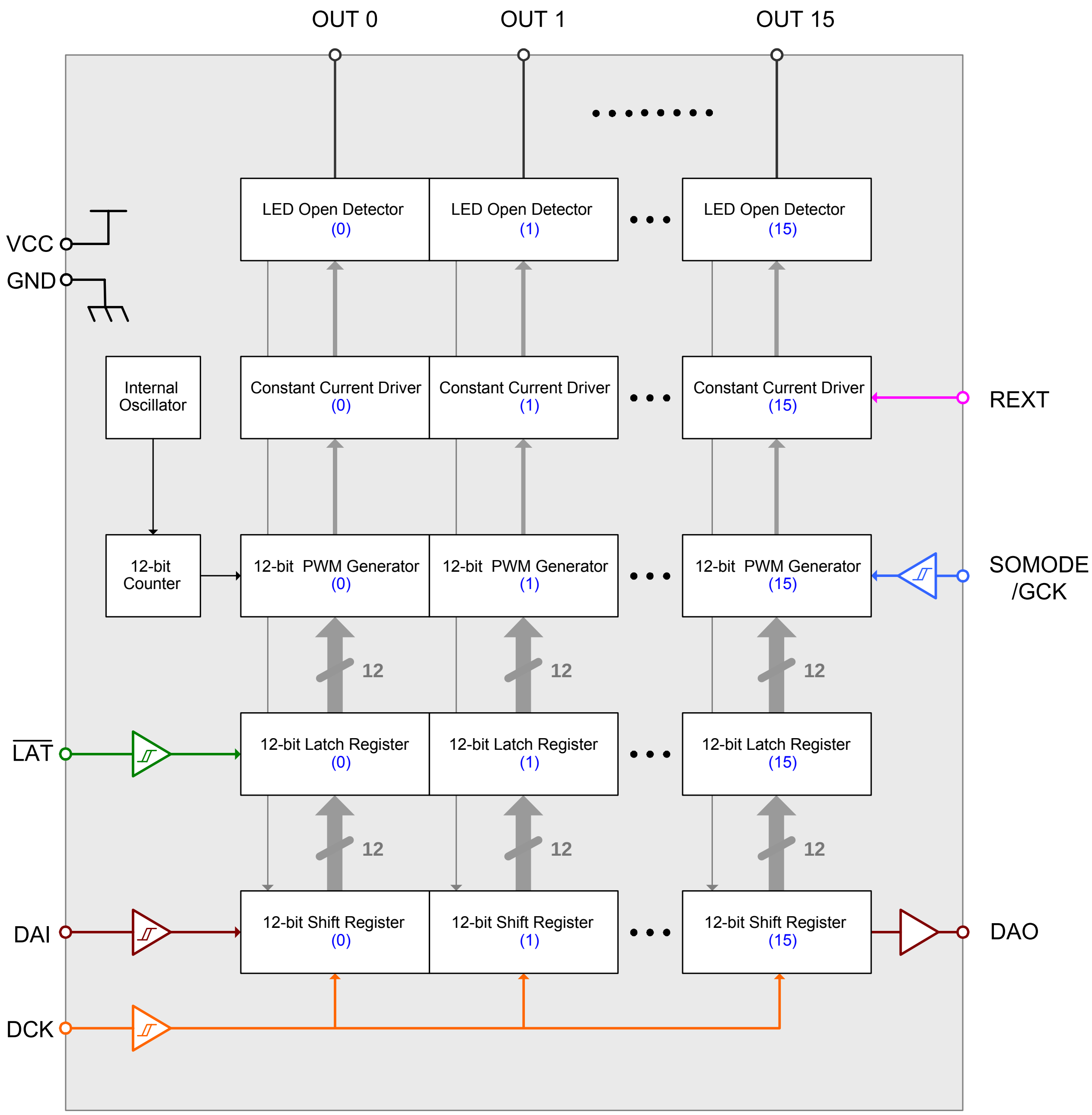
Applications

- Indoor/Outdoor LED Video Display
- LED Variable Message Signs (VMS) System
- LED Decorative Lighting

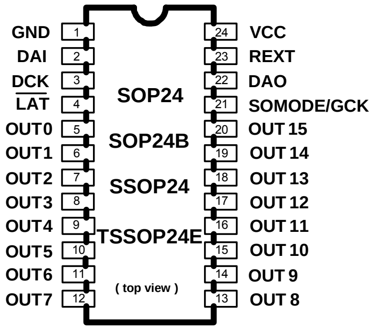
Package Types

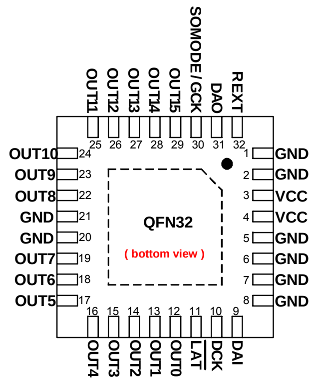
- SOP24, SOP24B, SSOP24, TSSOP24E (with exposed pad), QFN32 (with exposed pad)

Block Diagram



Pin Connection



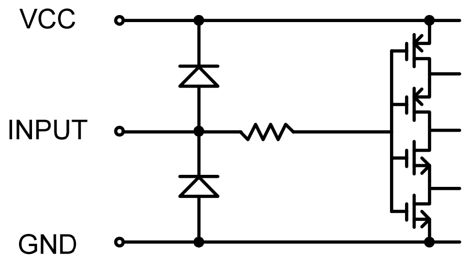


Pin Description

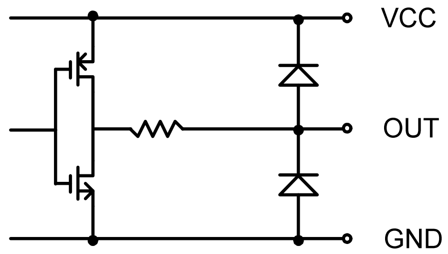
PIN No.	PIN NAME	FUNCTION
SOP24/SOP24B/SSOP24 /TSSOP24E: 1 TSSOP24E, QFN32: exposed pad QFN32: 1, 2, 5, 6, 7, 8, 20,21	GND	Ground terminal.
SOP24/SOP24B/SSOP24 /TSSOP24E: 2 QFN32: 9	DAI	Serial data input terminal.
SOP24/SOP24B/SSOP24 /TSSOP24E: 3 QFN32: 10	DCK	Synchronous clock input terminal for serial data transfer. Data is sampled at the rising edge of DCK.
SOP24/SOP24B/SSOP24 /TSSOP24E: 4 QFN32: 11	$\overline{\text{LAT}}$	Input terminal of data strobe: (level trigger) **'H'** means latch register keep data **'L'** means latch register gets data
SOP24/SOP24B/SSOP24/TSSOP24E: 5~20 QFN32: 12~19, 22~29	OUT0~15	Sink constant-current outputs (open-drain).
SOP24/SOP24B/SSOP24 /TSSOP24E: 21 QFN32: 30	SOMODE /GCK	Serial Out Mode Selection(SOMODE) : **'H'**: DAO is shifted out and synchronized to falling edge of DCK, **'L'** : DAO is shifted out and synchronized to rising edge of DCK. Gray Scale Clock(GCK) : Input terminal for PWM operation.
SOP24/SOP24B/SSOP24 /TSSOP24E: 22 QFN32: 31	DAO	Serial data output terminal.
SOP24/SOP24B/SSOP24 /TSSOP24E: 23 QFN32: 32	REXT	External resistors connected between REXT and GND for output current value setting.
SOP24/SOP24B/SSOP24 /TSSOP24E: 24 QFN32: 3, 4	VCC	Supply voltage terminal.

Equivalent Circuit of Inputs and Outputs

1. DCK, DAI, $\overline{\text{LAT}}$, SOMODE/GCK terminals



2. DAO terminals



PCB Layout Consideration

To connect an external resistor to REXT pin and ground can determine the maximum output current. If there is any disturbance occurred to REXT pin, the constant current output may be unstable or noisy. Since REXT (pin23), DAO (pin22), and SOMODE/GCK (pin21) are next to each other, the most possible interference is caused by DAO or SOMODE/GCK signal. Accordingly, it is recommended that adding some shielding area within the above pins in PCB layout, or laying the signal line of above pins on different PCB layer will prevent the noise problems effectively.

Maximum Ratings (Ta=25°C, Tj(max) = 150°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Supply Voltage	VCC	-0.3 ~ 7.0	V
Input Voltage	VIN	-0.3 ~ VCC+0.3	V
Output Current	IOUT	100	mA
Output Voltage	VOUT	-0.3 ~ 17	V
Input Clock Frequency	FDCK	25	MHz
GND Terminal Current	IGND	1600	mA
Power Dissipation (4 layer PCB, Ta=25℃)	PD	4.46 (QFN32)	W
		4.17 (TSSOP24E)	
		2.45 (SOP24)	
		2.19 (SOP24B)	
		1.79 (SSOP24)	
Thermal Resistance (4 layer PCB, Ta=25℃)	Rth(j-a)	28.0 (QFN32)	°C/W
		30.0 (TSSOP24E)	
		51.0 (SOP24)	
		66.0 (SOP24B)	
		70.0 (SSOP24)	
Operating Temperature	Top	-40 ~ 85	°C
Storage Temperature	Tstg	-55 ~ 150	°C

Recommended Operating Condition

CHARACTERISTIC	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Supply Voltage	VCC	—	3.3	5.0	5.5	V
Output Voltage	VOUT	Driver On [*1]	1.0	—	0.5VCC	V
Output Voltage	VOUT	Driver Off [*2]	—	—	17	
Output Current	IO	OUTn	5	—	90	mA
	IOH	VOH = VCC – 0.4 V	- 0.8	—	-2	
	IOL	VOL = 0.2 V	+ 0.8	—	+ 2	
Input Voltage	VIH	VCC = 3.3 V ~ 5.5V	0.8VCC	—	VCC	V
	VIL		0.0	—	0.2VCC	
Input Clock Frequency	FDCK	Single Chip Operation	—	—	25	MHz
Input PWM Frequency	FGCK	VCC = 3.3 V ~ 5.5V	—	—	25	
$\overline{\text{LAT}}$ Pulse Width	tw $\overline{\text{LAT}}$	VCC = 5.0V	15	—	—	ns
DCK Pulse Width	tw DCK		15	—	—	
Set-up Time for DAI	tsetup(D)		10	—	—	
Hold Time for DAI	thold(D)		10	—	—	
Set-up Time for $\overline{\text{LAT}}$	tsetup(L)		10	—	—	
Hold Time for $\overline{\text{LAT}}$	thold(L)		10	—	—	
Internal Oscillator Frequency	FOSC		14.4	18	21.6	MHz

[*1] Notice that the power dissipation is limited to its package and ambient temperature.
[*2] The driver output voltage including any overshoot stress has to be compliant with the maximum voltage (17V).

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Electrical Characteristics (VCC = 5.0 V, Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Input Voltage "H" Level	VIH	CMOS logic level	0.8*VCC	—	VCC	V
Input Voltage "L" Level	VIL	CMOS logic level	GND	—	0.2*VCC	
Output Leakage Current	IOL	VOH = 17 V	—	—	±1.0	uA
Output Voltage (S-OUT)	VOL	IOL = 1.25 mA	—	—	0.2	V
	VOH	IOH= 1.2 mA	VCC-0.4	—	—	
Output Current Skew (Channel-to-Channel)[*1]	IOL1	VOUT = 1.0 V Rrext = 2.2 KΩ	—	—	±3	%
Output Current Skew (Chip-to-Chip)[*2]	IOL2		25.79	—	29.08	mA
Output Voltage Regulation	% / VOUT	Rrext = 2.2 KΩ VOUT = 1 V ~ 3 V	—	±0.1	±0.5	% / V
Supply Voltage Regulation	% / VCC	Rrext = 2.2 KΩ	—	±1	±4	
LED Open Detection Threshold	V(od)	all outputs turn on	—	0.3	—	V
Supply Current[*3]	$I_{DD(off)}$	power on all pins are open unless VCC and GND (fee-running mode)	—	5.39	6.5	mA
	$I_{DD(off)}$	power on all pins are open unless VCC and GND (external GCK mode)	—	4.57	—	
	$I_{DD(on)}$	input signal is static Rrext = 12.4 KΩ all outputs turn off	—	5.91	—	
	$I_{DD(on)}$	input signal is static Rrext = 2.2 KΩ all outputs turn off	—	8.10	—	
	$I_{DD(on)}$	input signal is static Rrext = 570 Ω all outputs turn off	—	17.11	—	

[*1] Channel-to-channel skew is defined as the ratio between (any Iout – average Iout) and average Iout, where average Iout = (Imax + Imin) / 2.
[*2] Chip-to-Chip skew is defined as the range into which any output current of any IC falls.
[*3] IO excluded.

Electrical Characteristics (VCC = 3.3 V, Ta = 25°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Input Voltage “H” Level	VIH	CMOS logic level	0.8*VCC	—	VCC	V
Input Voltage “L” Level	VIL	CMOS logic level	GND	—	0.2*CC	
Output Leakage Current	IOL	VOH = 17 V	—	—	±1.0	uA
Output Voltage (S-OUT)	VOL	IOL = 1.25 mA	—	—	0.2	V
	VOH	IOH= 1.2mA	VCC-0.4	—	—	
Output Current Skew (Channel-to-Channel)[*1]	IOL1	VOUT = 1.0 V Rrext = 2.2 KΩ	—	—	±3	%
Output Current Skew (Chip-to-Chip)[*2]	IOL2		25.79	—	29.08	mA
Output Voltage Regulation	% / VOUT	Rrext = 2.2 KΩ VOUT = 1 V ~ 3 V	—	±0.1	±0.5	% / V
Supply Voltage Regulation	% / VCC	Rrext = 2.2 KΩ	—	±1	±4	
LED Open Detection Threshold	V(od)	all outputs turn on	—	0.3	—	V
Supply Current[*3]	$I_{DD(off)}$	power on all pins are open unless VCC and GND (fee-running mode)	—	3.8	—	mA
	$I_{DD(off)}$	power on all pins are open unless VCC and GND (external GCK mode)	—	3.39	—	
	$I_{DD(on)}$	input signal is static Rrext = 12.4 KΩ all outputs turn off	—	4.33	—	
	$I_{DD(on)}$	input signal is static Rrext = 2.2 KΩ all outputs turn off	—	6.54	—	
	$I_{DD(on)}$	input signal is static Rrext = 570 Ω all outputs turn off	—	15.10	—	

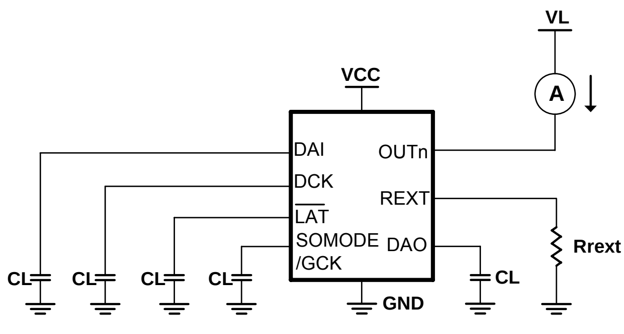
[*1] Channel-to-channel skew is defined as the ratio between (any Iout – average Iout) and average Iout, where average Iout = (Imax + Imin) / 2.
[*2] Chip-to-Chip skew is defined as the range into which any output current of any IC falls.
[*3] IO excluded.

Switching Characteristics (VCC = 5.0V, Ta = 25°C unless otherwise noted)

CHARACTERISTIC		SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Propagation Delay ('L' to 'H')	GCK-to-OUT	tpLH	VIH = VCC VIL = GND Rrext = 2.3 KΩ VL = 5.0 V CL = 13 pF	—	45.74	—	ns
	DCK(rising edg)-to-DAO			—	37.16	—	
	DCK(falling edg)-to-DAO			—	14.4	—	
Propagation Delay ('H' to 'L')	GCK-to-OUT	tpHL		—	23.76	—	
	DCK(rising edg)-to-DAO			—	27.82	—	
	DCK(falling edg)-to-DAO			—	9.7	—	
Output Current Rise Time		tor		—	18	—	
Output Current Fall Time		tof		—	6.96	—	
Output to output Delay Time Unit		td		—	33	—	
Output Current (Propagation Delay after $\overline{\text{LAT}}$ trigger)		top[*1]		—	—	288	us

Switching Characteristics (VCC = 3.3V, Ta = 25°C unless otherwise noted)

CHARACTERISTIC		SYMBOL	CONDITION	MIN.	TYP.	MAX.	UNIT
Propagation Delay ('L' to 'H')	GCK-to-OUT	tpLH	VIH = VCC VIL = GND Rrext = 2.3 KΩ VL = 3.3 V CL = 13 pF	—	48.8	—	ns
	DCK(rising edg)-to-DAO			—	21.2	—	
	DCK(falling edg)-to-DAO			—	18.3	—	
Propagation Delay ('H' to 'L')	GCK-to-OUT	tpHL		—	29.6	—	
	DCK(rising edg)-to-DAO			—	17.6	—	
	DCK(falling edg)-to-DAO			—	14.4	—	
Output Current Rise Time		tor		—	20	—	
Output Current Fall Time		tof		—	8.25	—	
Output to output Delay Time Unit		td		—	34	—	
Output Current (Propagation Delay after $\overline{\text{LAT}}$ trigger)		top[*1]		—	—	288	us



Switching Characteristics Test Circuit

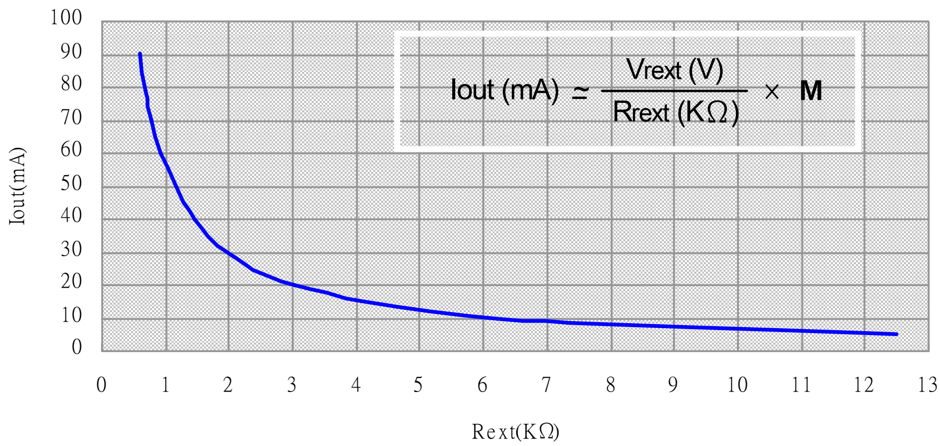
[*1] Reload the new PWM data at the end of the last PWM frame.

Constant-Current Output

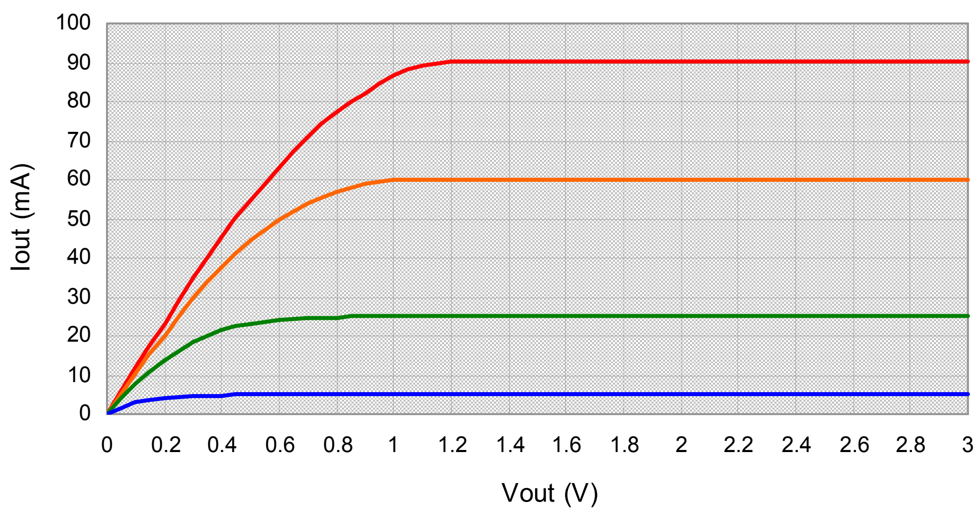
Constant-current value(Iout[*1]) of each output channel is set by an external resistor connected between the REXT pin and GND. The current scale ranging can be adjusted from 5mA to 90mA by varying the resistor value. The reference voltage of REXT terminal (Vrext) is approximately 1.23V. The output current value is calculated by the following equation:

Iout(mA)	5	10	20	30	40	50	60	70	80	90
M	50.40	49.38	49.16	48.40	47.60	46.72	45.03	44.32	43.62	42.69

Output Current as a Functiono Rext value



Output Current as a Function of Output Voltage



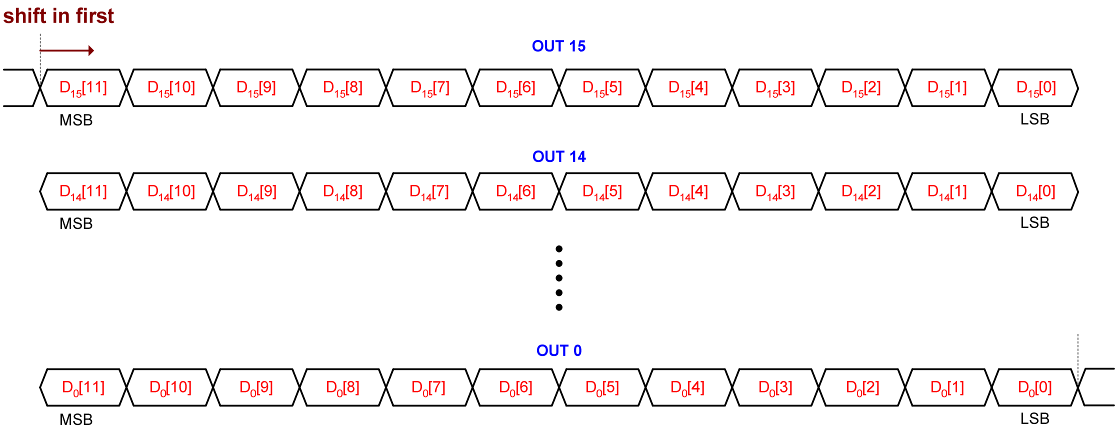
In order to obtain a good performance of constant-current output, a suitable output voltage is necessary. Users can get related information about the minimum output voltage above.

[*1] Iout is typical current value setting under 100% PWM duty cycle and 95 D_{GBC} Value.

Serial Data Interface

The serial-in data (DAI) will be clocked into 16 × 12 bit shift registers synchronized on the rising edge of the clock (DCK). The data will be transferred into the 16 × 12 bit latch registers when the strobe signal ($\overline{\text{LAT}}$) is kept at high level (level trigger); otherwise, the data will be held. The latch pulse should be sent after the falling edge of the last clock within a frame data. The trigger timing of the serial-out data (DAO) will be shifted out on synchronization to the rising edge of the clock if serial out selection (SOMODE) is kept at low level. And if serial out selection (SOMODE) is kept at high level, the serial-out data (DAO) will be shifted out on synchronization to the falling edge of the clock (DCK).

Input Data Format

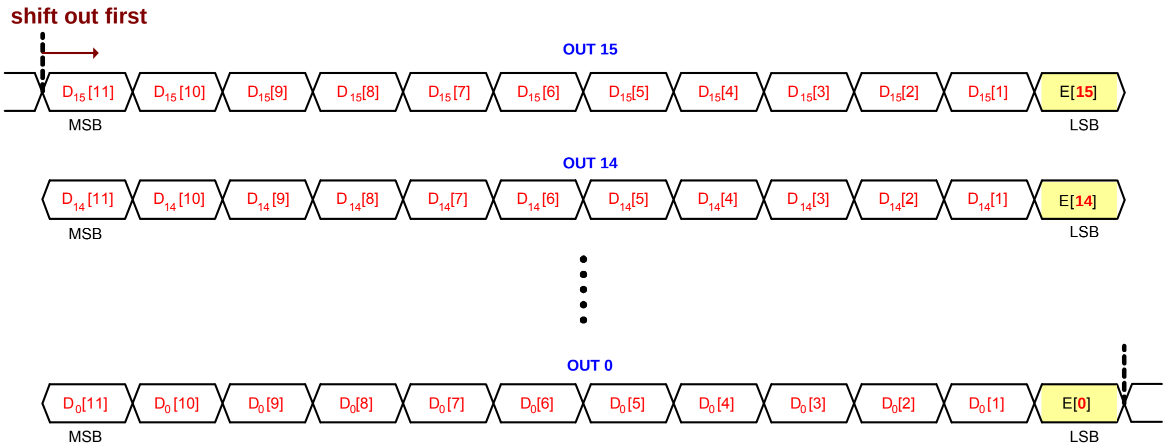


$$\text{Active width per frame(\%)} = \frac{D[11]\times2^{11}+D[10]\times2^{10}+D[9]\times2^{9}+D[8]\times2^{8}+D[7]\times2^{7}+D[6]\times2^{6}+D[5]\times2^{5}+D[4]\times2^{4}+D[3]\times2^{3}+D[2]\times2^{2}+D[1]\times2^{1}+D[0]\times2^{0}}{4096}$$

LED Open Detection

DM631 provides a real time monitor of LED open detection function without extra components or circuit design. It will be identified as a LED open failure when the output is turned on but the output voltage is below 0.3V. The test result of each channel will write to its correspondent shift register which is in LSB position ($D_{15}[0]$, $D_{14}[0]$, …., $D_0[0]$) while strobe signal is active. User can refer to timing diagram on page13. Detecting report could be retrieved from serial-out (DAO) data. If the system reads ‘1’ back, that indicates LED is in normal status. But if ‘0’ was retrieved then LED open failure has occurred. In order to make sure LED open detection function is in well operating condition, it is recommended that all the luminance data are wrote to ‘1’ then almost turning on the outputs during detection process.

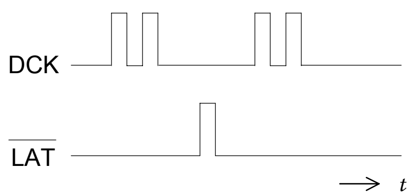
Serial-out Data Format



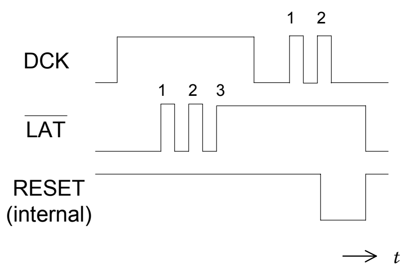
*E[15], E[14],⋯ ,E[0] are Error Message of LED Open Detection. ‘1’ is normal, and ‘0’ is abnormal.

Selection of Internal/External PWM Frequency

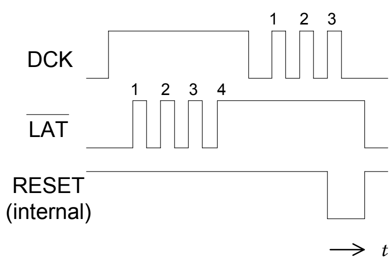
The default operation mode is the **free-running** PWM signal generated by internal oscillator after power-on. Users could switch internal to external PWM frequency source by following timing sequence. There are two alternative options could be selected. The option 1 shows three rising edge of latch pulses ($\overline{\text{LAT}}$) when the clock (DCK) kept at high level then two rising edge of clock (DCK) pulses when the latch pulse ($\overline{\text{LAT}}$) kept at high level. Then the SOMODE/GCK pin could input external frequency to operate PWM function. The option 2 shows four rising edge of latch pulses($\overline{\text{LAT}}$) when clock(DCK) kept at high level then sending three rising edge of clock (DCK) signal, while latch($\overline{\text{LAT}}$) signal kept high level at the same time. Meanwhile the GCK external mode can be set back to the free-running mode. Notice that when internal RESET at low level, all the shift registers in DM631 will be cleared (Kept at Low level) and all output current will be off immediately.



Normal Operation



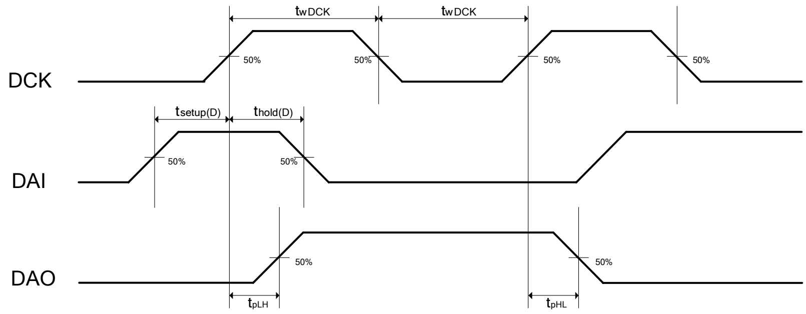
Option 1 : Timing Combination to set up external GCK mode



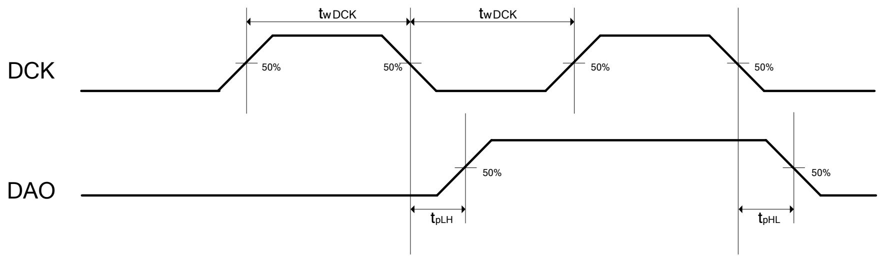
Option 2 : Timing Combination to set up free-running mode

Timing Diagram

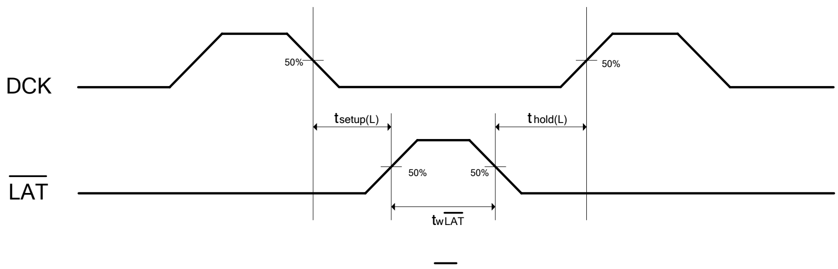
1. DCK-DAI, DAO (SOMODE = ”L” at free-running mode, or external GCK mode)



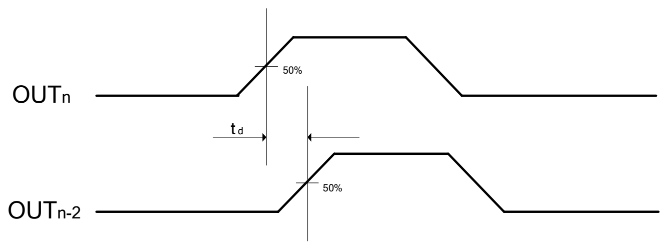
2. DCK, DAO (SOMODE = “H” at free-running mode)



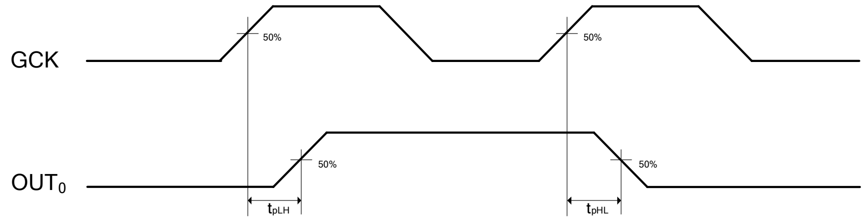
3. DCK-$\overline{LAT}$



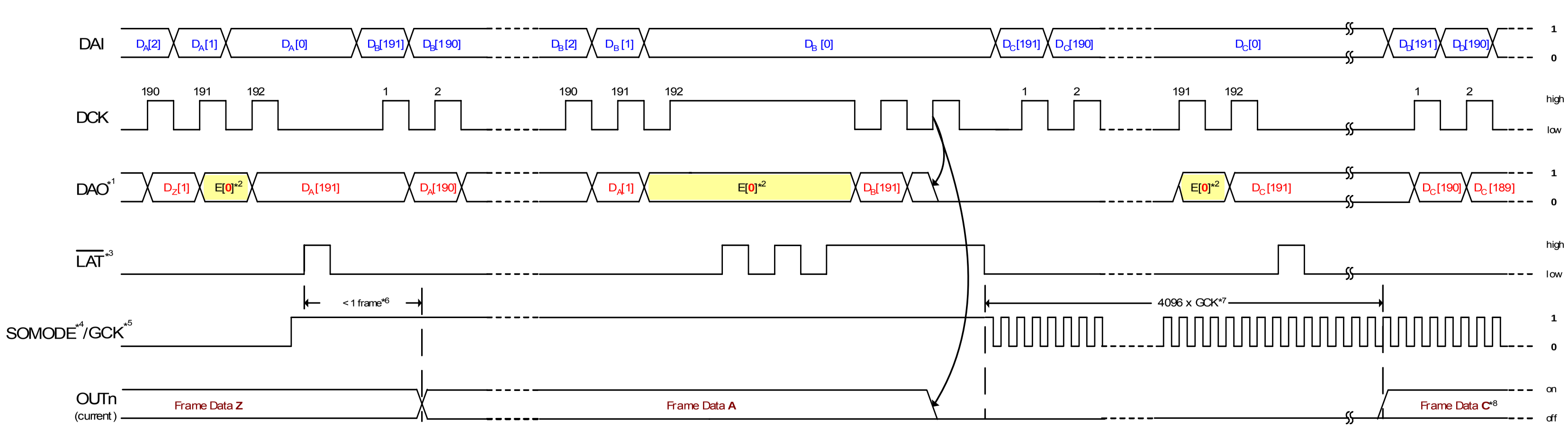
4. Output to Output Delay Time Unit (n=2,3,4,5,6,7,10,11,12,13,14,15)



5. GCK-OUT_0



5. Timing Diagram (free-running mode switch to external GCK mode)



*1 DAO is shifted out on synchronization to rising / falling edge of DCK according to SOMODE is ‘**L**’ / ‘**H**’ .

*2 E[0] is the error message of LED open detection.

*3 $\overline{\text{LAT}}$ is level trigger, not edge trigger.

*4 SOMODE function work in free-running mode.

*5 While switching to external GCK mode, all registers in DM631 will be reset simultaneously.

*6 Starting the new PWM frame after the last PWM period finish completely.

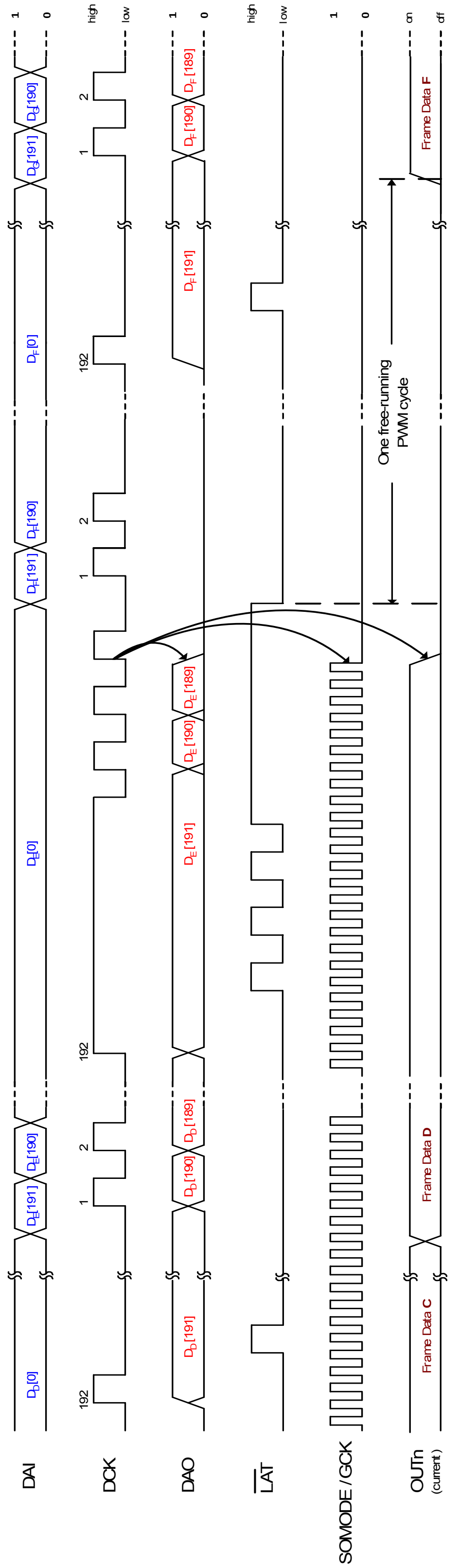
*7 While switching to external GCK mode, outputs will be active after 4096 GCK pulse.

*8 When using external frequency for PWM operation, the PWM refresh rate (frame rate) can be calculated by following equation:

$$\text{Refresh Rate (Hz)} = \frac{\text{Input GCK Frequency (Hz)}}{\text{Total PWM resolution } (2^{12})}$$

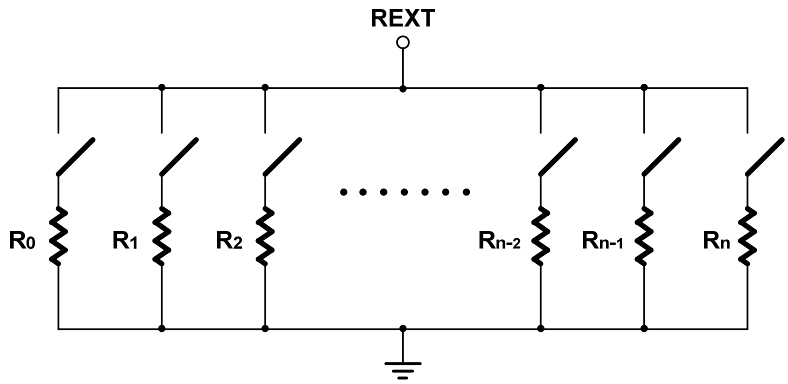
For example, if the refresh rate in display system is higher than 60Hz, the input GCK frequency must be higher than 246kHz.

Timing Diagram (external GCK mode switch to free-running mode)

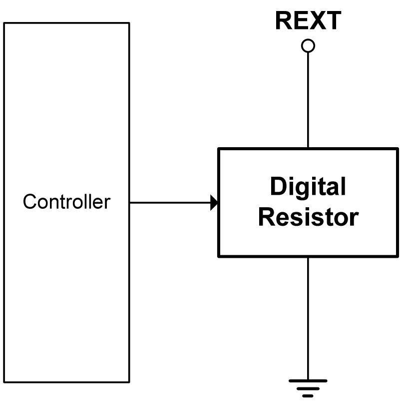


Global Brightness Control

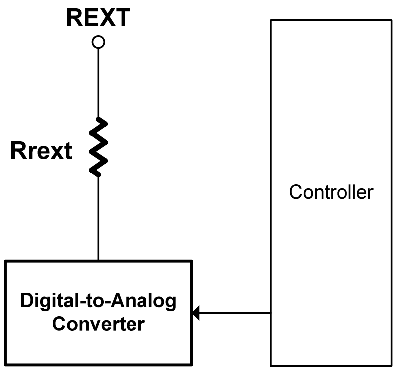
DM631 has no built-in global brightness control feature. In order to obtain a lower resolution of global brightness control effect, two methods could be utilized. Here show different ways to adjust the Rrext value or voltage drop across the external resistor. Please see the reference circuit below:



Global Brightness Control with Resistor Ladder



Global Brightness Control
with Digital Resistor



Global Brightness Control
with D/A converter

Output to Output Delay

DM631 has build-in output to output delay with a special arrangement. This arrangement help chip avoid noise cause by large current during channels switching. The arrangement details are shown as following table.

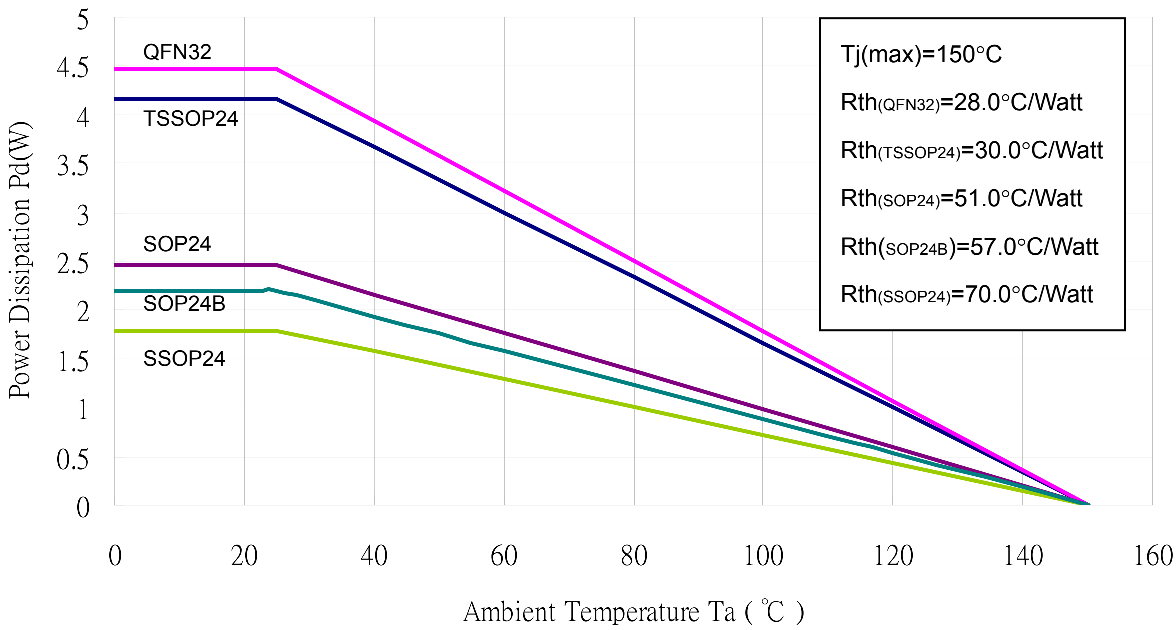
Channel	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Delay units	0	4	1	5	2	6	3	7	3	7	2	6	1	5	0	4

Power Dissipation

The power dissipation of a semiconductor chip is limited to its package and ambient temperature, in which the device requires the maximum output current calculated for given operating conditions. The maximum allowable power consumption can be calculated by the following equation:

$$Pd(max)(Watt) = \frac{Tj(junction\ temperature)(max)(^\circ C) - Ta(ambient\ temperature)(^\circ C)}{Rth(junction\text{-}to\text{-}air\ thermal\ resistance)(^\circ C/Watt)}$$

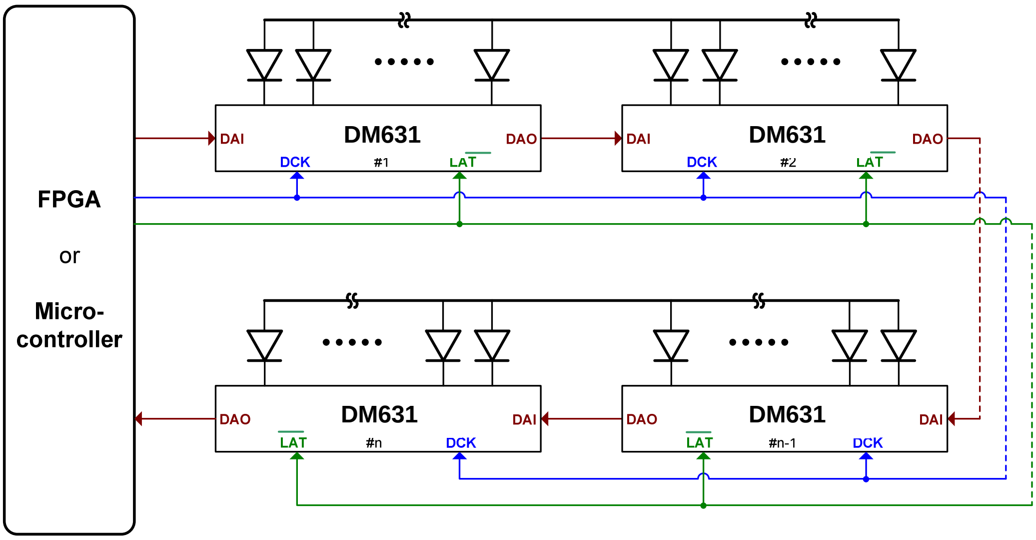
The relationship between power dissipation and operating temperature can be refer to the figure below:



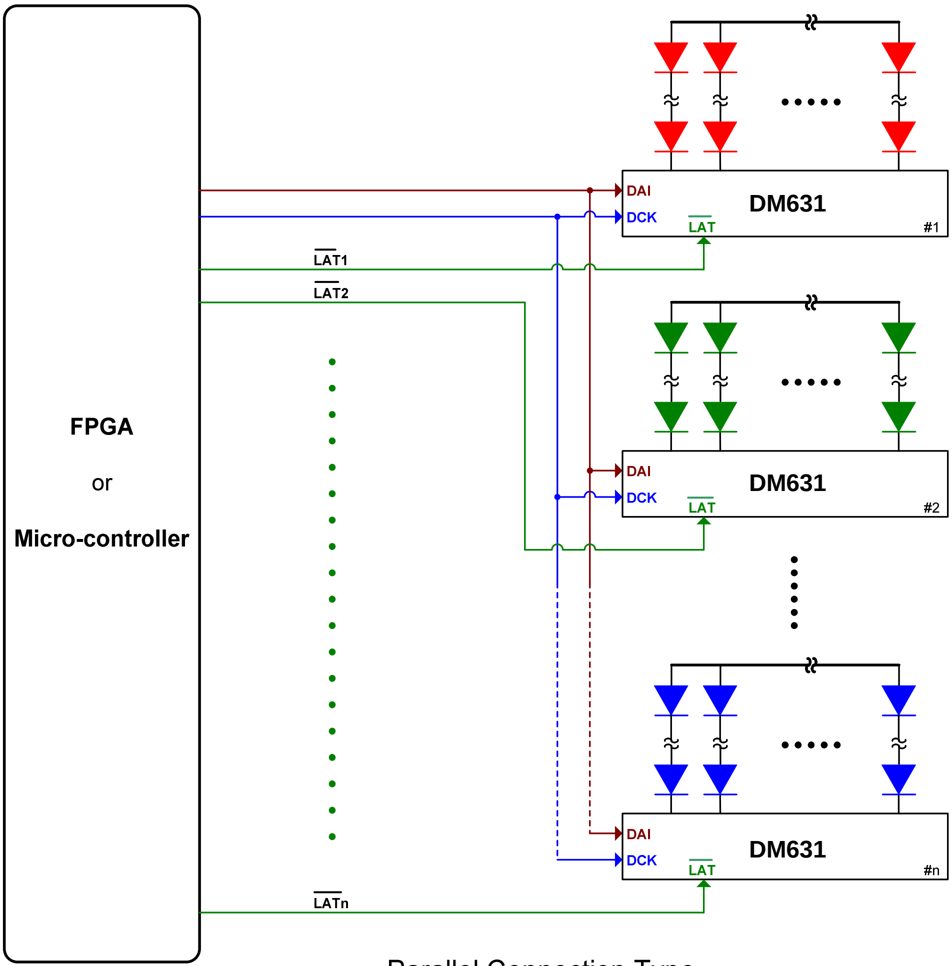
The power consumption of IC can be determined by the following equation and should be less than the maximum allowable power dissipation:

$$Pd(W) = V_{CC}(V) \times I_{DD}(A) + Vout0 \times Iout0 \times Duty0 + \cdots + Vout15 \times Iout15 \times Duty15 \leq Pd(max)(W)$$

Typical Application



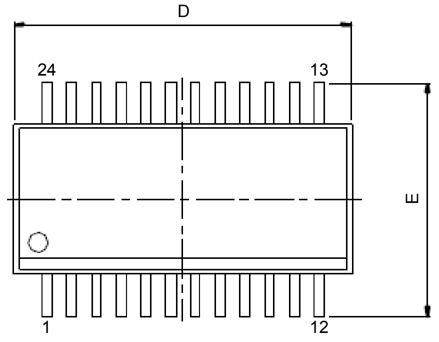
Serial Connection Type

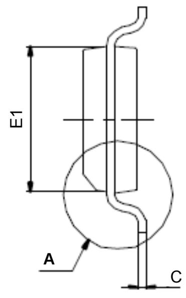


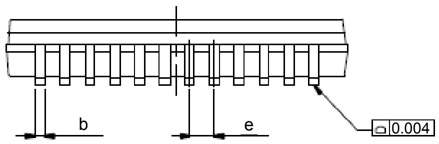
Parallel Connection Type

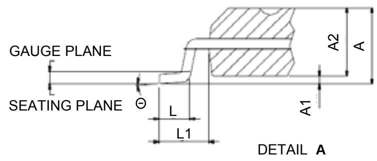
Package Outline Dimension

DM631-SSOP





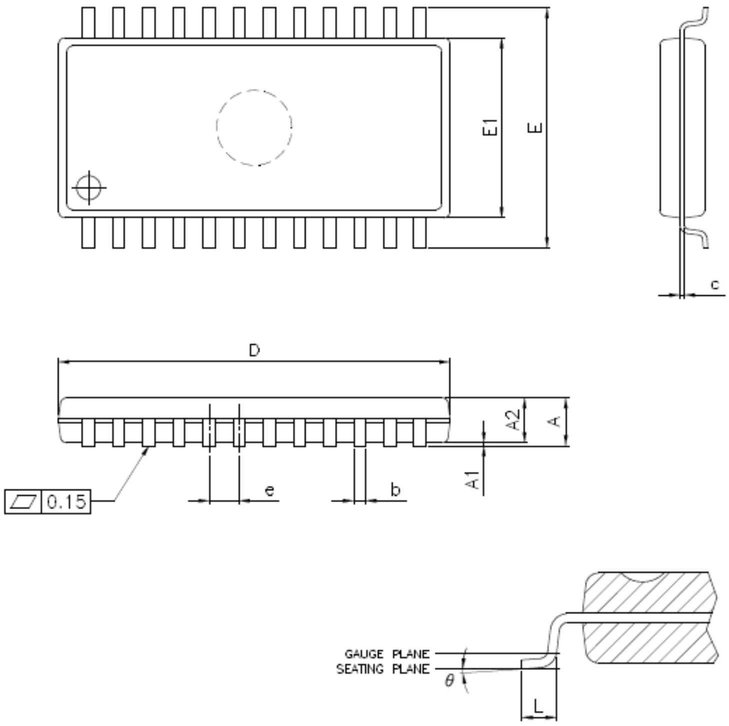




	DIMENSIONS IN INCH		DIMENSIONS IN MM	
SYMBOLS	MIN.	MAX.	MIN.	MAX.
A	0.053	0.069	1.346	1.753
A1	0.004	0.010	0.102	0.254
A2	-	0.059	-	1.499
b	0.008	0.012	0.203	0.305
C	0.007	0.010	0.178	0.254
D	0.337	0.344	8.560	8.738
E	0.228	0.244	5.791	6.198
E1	0.150	0.157	3.810	3.988
e	0.025 BSC.		0.635 BSC	
L	0.016	0.050	0.406	1.270
L1	0.041 BSC		1.041 BSC	
Θ	0°	8°	0°	8°

Package Outline Dimension

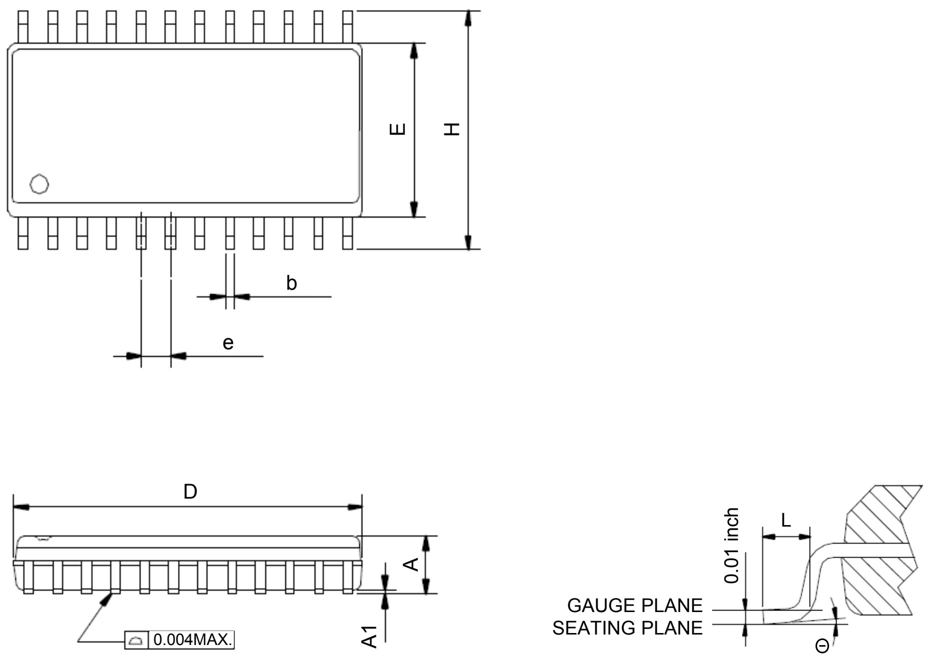
DM631-SOPB



	DIMENSIONS IN INCH		DIMENSIONS IN MM	
SYMBOLS	MIN.	MAX.	MIN.	MAX.
A	-	0.075	-	1.900
A1	0.002	0.008	0.050	0.200
A2	0.051	0.067	1.300	1.700
b	0.012	0.020	0.300	0.500
c	0.004	0.010	0.100	0.250
D	0.504	0.520	12.800	13.200
E	0.303	0.327	7.700	8.300
e	0.0394 BSC		1.000 BSC	
E1	0.228	0.244	5.800	6.200
L	0.010	0.026	0.250	0.650
θ	0°	10°	0°	10°

Package Outline Dimension

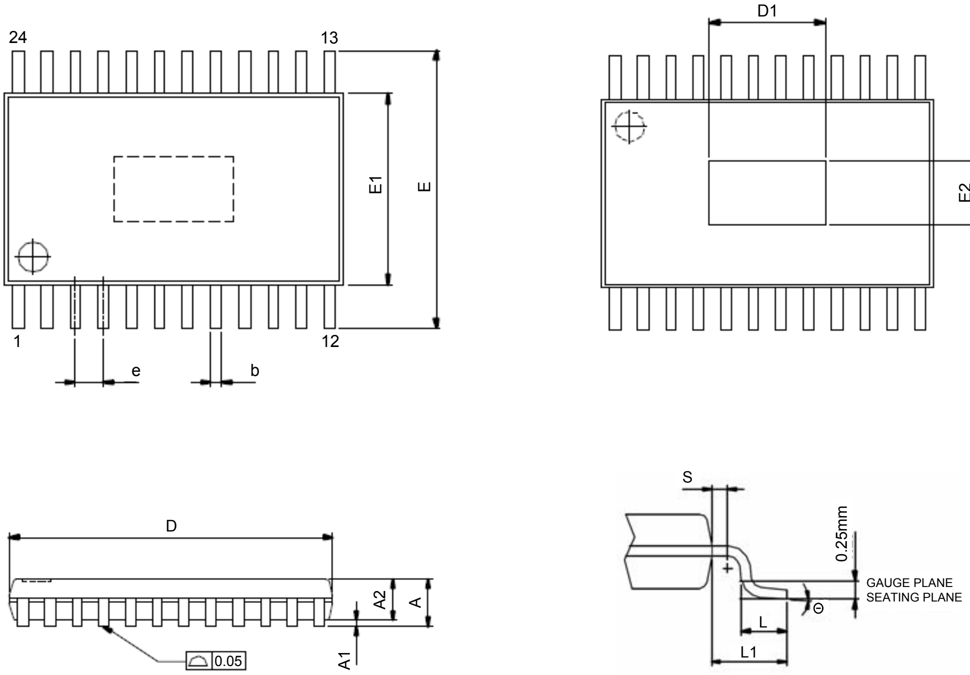
DM631-SOP



	DIMENSIONS IN INCH		DIMENSIONS IN MM	
SYMBOLS	MIN.	MAX.	MIN.	MAX.
A	-	0.104	-	2.642
A1	0.004	-	0.102	-
b	0.016 BSC		0.406 BSC	
D	0.612	0.624	15.545	15.850
E	0.292	0.299	7.417	7.595
e	0.050 BSC		1.270 BSC	
H	0.405	0.419	10.287	10.643
L	0.021	0.041	0.533	1.041
Θ	0°	8°	0°	8°

Package Outline Dimension

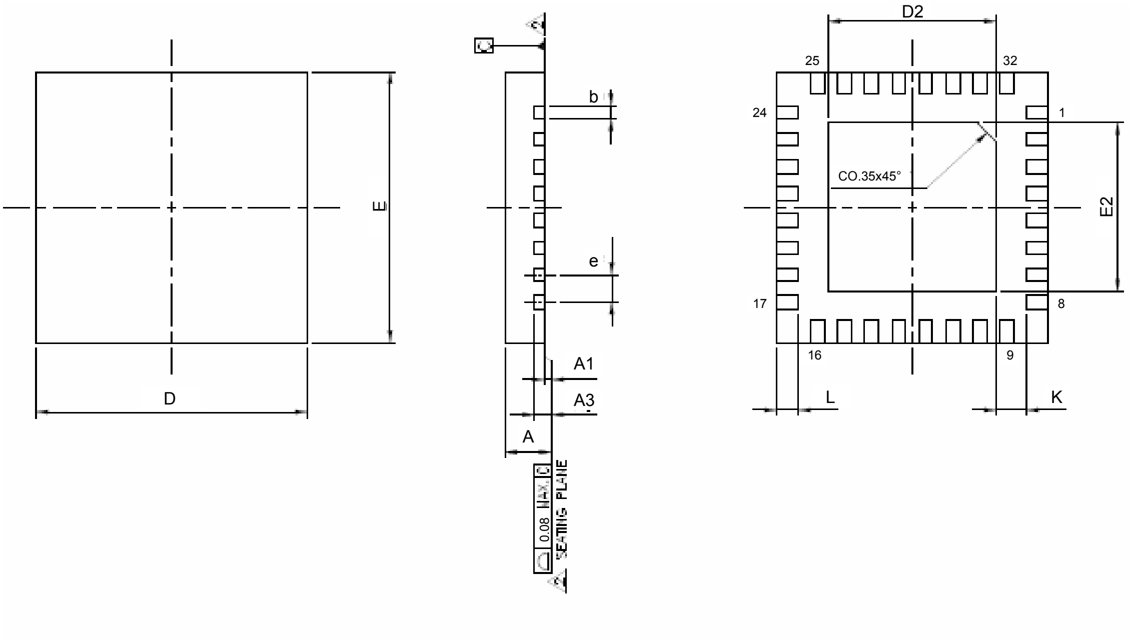
DM631-TSSOP (exposed pad)



	DIMENSIONS IN INCH		DIMENSIONS IN MM	
SYMBOLS	MIN.	MAX.	MIN.	MAX.
A	-	0.047	-	1.20
A1	0.000	0.006	0.00	0.15
A2	0.031	0.041	0.80	1.05
b	0.007	0.012	0.19	0.30
D	0.303	0.311	7.70	7.90
E1	0.169	0.177	4.30	4.50
E	0.252 BSC		6.400 BSC	
e	0.026 BSC		0.650 BSC	
L1	0.039 REF		1.000 REF.	
L	0.018	0.030	0.45	0.75
S	0.008	-	0.20	-
Θ	0°	8°	0°	8°
E2	0.0898	0.1122	2.280	2.850
D1	0.146	1.819	3.700	4.620

Package Outline Dimension

DM631-QFN (exposed pad)



	DIMENSIONS IN INCH		DIMENSIONS IN MM	
SYMBOLS	MIN.	MAX.	MIN.	MAX.
A	0.028	0.031	0.70	0.80
A1	0	0.002	0	0.05
A3	0.008 REF.		0.203 REF.	
b	0.007	0.012	0.180	0.300
D	0.193	0.201	4.900	5.100
E	0.193	0.201	4.900	5.100
e	0.0197 BSC		0.500 BSC	
L	0.012	0.020	0.30	0.50
K	0.0079	-	0.2	-
D2	0.049	0.128	1.25	3.25
E2	0.049	0.128	1.25	3.25

Note: 1.DIMENSIONING AND TOLERANCING CONFORM TO ASME Y145.5M-1994.

2. REFER TO JEDEC STD. MO-220 WHHD-2 ISSUE A

The products listed herein are designed for ordinary electronic applications, such as electrical appliances, audio-visual equipment, communications devices and so on. Hence, it is advisable that the devices should not be used in medical instruments, surgical implants, aerospace machinery, nuclear power control systems, disaster/crime-prevention equipment and the like. Misusing those products may directly or indirectly endanger human life, or cause injury and property loss.
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