TLC6C5716-Q1 Automotive 16-Channel, Full Diagnostics, Constant-Current LED Driver

1 Features

- AEC-Q100 Qualified for Automotive Applications
  - Device Temperature Grade 1: –40°C to 125°C, T_A
- 16 Constant-Current-Sink Output Channels
  - 50-mA Maximum Output Current
  - 8-V Maximum Output Voltage
  - Two Output Groups: OUTRn, OUTBn
- Output Current Adjustment
  - 7-Bit Dot Correction (DC) for Each Channel
  - 8-Bit Brightness Control (BC) for Each Group
- Integrated PWM Grayscale Generator
  - PWM Dimming for Each Individual Channel
  - Adjustable Global Grayscale Mode: 12-Bit, 10-Bit, 8-Bit
- Protection and Diagnostics
  - LED-Open Detection (LOD), LED-Short Detection (LSD), Output Short-to-GND Detection (OSD)
  - Adjacent-Pin Short (APS) Detection
  - Pre-Thermal Warning (PTW), Thermal Shutdown (TSD)
  - IREF Resistor Open- (IOF) and Short-Detection (ISF) and -Protection
  - Negate Bit Toggle for GCLK Error Detect and LOD_LSD Register Error Check
  - LOD_LSD Circuit Self-Test
- Programmable Output Slew Rate
- Output Channel Group Delay
- Serial Data Interface

2 Applications

- Automotive Cluster
- Automotive Local Dimming Display
- Automotive Faceplate
- Automotive HVAC Control Panel
- Automotive Center Stack Display
- Automotive Interior and RGB Ambient Lighting
- Automotive Shift-by-Wire and Gear Shifter

3 Description

There are automotive applications for indicators and for LCD local-dimming backlighting. For these applications, more persons think multi-channel constant-current LED drivers are necessary. The requirement is to get the same intensity and color temperature of LEDs. For system-level safety, it is necessary that the LED drivers can sense faults.

The TLC6C5716-Q1 device is an automotive 16-channel constant-current RGB LED driver that can do tests on the LEDs. The TLC6C5716-Q1 device supplies a maximum of 50-mA output current set by an external resistor. The device has a 7-bit dot correction with two ranges for each output. The device also has an 8-bit intensity control for the outputs of each color group.

A 12-,10-, or 8-bit grayscale control adjusts the intensity of each output. The device has circuits that sense faults in the system, including LED faults, adjacent-pin short faults, reference-resistor faults, and more. A slew rate control has 2 positions for adjustment to get the largest decrease in system noise. There is an interval between the changes of output level from one LED group to a different one. This interval helps to decrease the starting electrical current. The SDI and SDO pins let more than one device be connected in series for control through 1 serial interface.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLC6C5716-Q1	HTSSOP (38)	6.20 mm × 12.50 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application Schematic

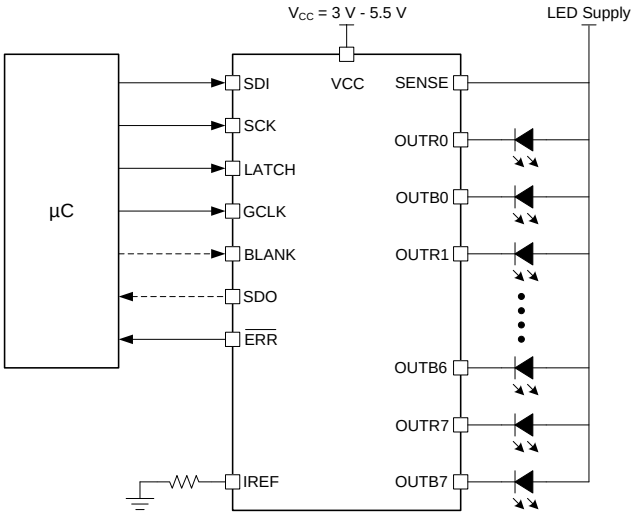


Table of Contents

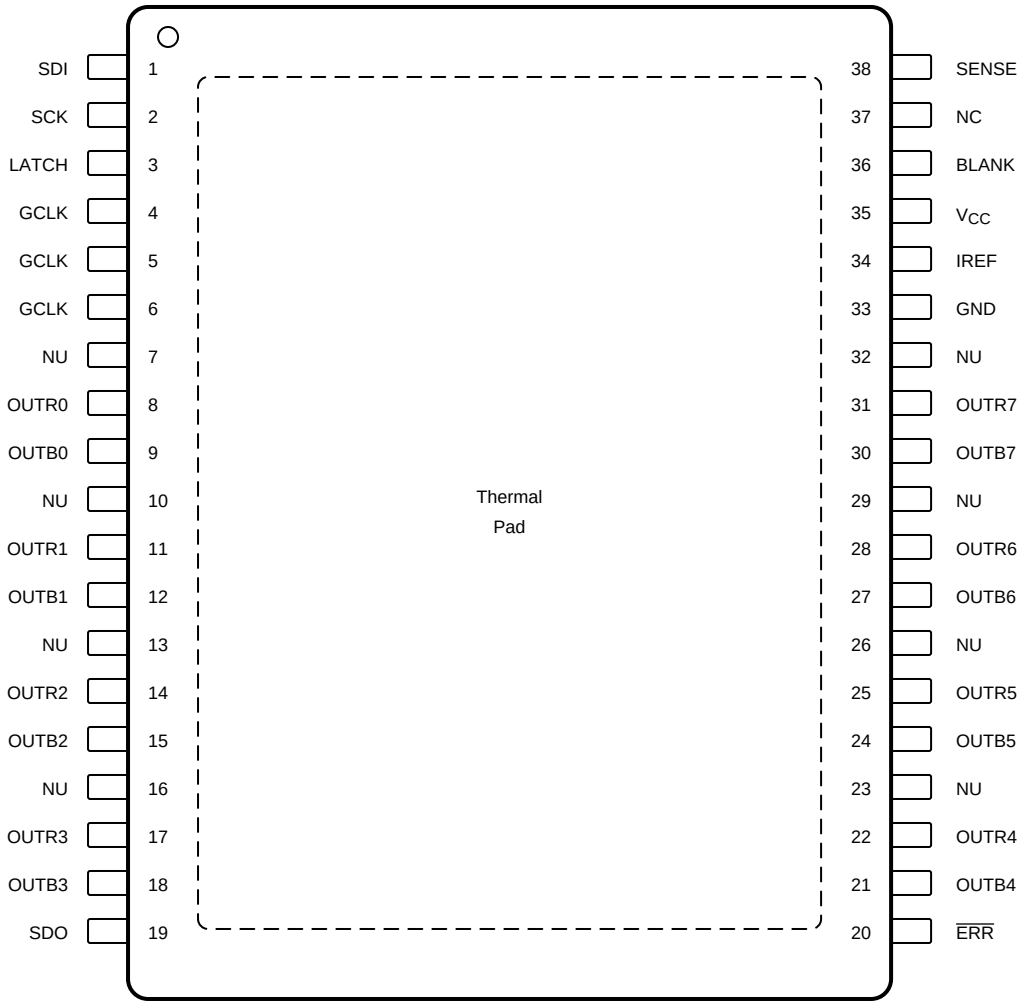
4 Revision History

Changes from Original (July 2018) to Revision A **Page**

- Changed the description for GCLK in ... 4
- Changed "indicates" to "initiates" in the Global Reset section ... 30
- Added "the SID" to the Fault Mode section to identify the register where the overtemperature fault is latched ... 31
- Changed "APS time" to "APS detection time" for bit 199 in Table 12 ... 32
- Changed "24 zones" to "16 zones" and "six TLC6C5716-Q1 units" to "eight TLC6C5716-Q1 units" in the *Detailed Design Procedure* section ... 49
- Added a new sentence preceding Figure 32 ... 49
- Added the *Application Curves* section ... 49
- Added two sentences to the *Power Supply Recommendations* section ... 50

5 Pin Configuration and Functions

DAP PowerPAD™ Package
38-Pin HTSSOP With Exposed Thermal Pad
Top View



Not to scale

NC – No internal connection

NU – Make no external connection

Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
BLANK	36	I	Blank all outputs. BLANK low forces all channels off. The grayscale counter resets and the grayscale PWM timing controller is initialized. BLANK high starts the grayscale PWM timing controller. Channels are controlled by the PWM timing controller.
$\overline{ERR}$	20	O	Open-drain error feedback
GCLK	4, 5, 6	I	Clock input for the grayscale PWM counter, three pins are internally connected together
GND	33	—	Power ground
IREF	34	I	Reference-current pin for setting the full-scale output current
LATCH	3	I	Latch-enable input pin
NC	37	—	No internal connection
NU	7, 10, 13,16, 23, 26, 29, 32	—	Not used, keep floating
OUTB0–OUTB7	9, 12, 15, 18, 21, 24, 27, 30	O	Constant-current outputs for group B
OUTR0–OUTR7	8, 11, 14,17, 22, 25, 28, 31	O	Constant-current outputs for group R
SCK	2	I	Input pin for the data-shift clock
SDI	1	I	Serial data-in pin
SDO	19	O	Serial data-out pin
SENSE	38	I	LED supply sensing pin
V_{CC}	35	I	Power supply pin
Thermal pad	—	—	Connect to ground to improve thermal performance

6 Specifications

6.1 Absolute Maximum Ratings

over operating junction temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Input voltage	V_{CC}	–0.3	6	V
	SENSE	–0.3	8	
	BLANK, GCLK, LATCH, SCK, SDI	–0.3	V_{CC} + 0.3	
Output voltage	$\overline{ERR}$, IREF, SDO	–0.3	V_{CC} + 0.3	V
	OUTR0–OUTR7, OUTB0–OUTB7	–0.3	8	
Output current	OUTR0–OUTR7, OUTB0–OUTB7	0	50	mA
Operating junction temperature, T_J		–40	150	°C
Storage temperature, T_{stg}		–55	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. Theseare stress ratings only, which do not imply functional operation of the device at these or anyother conditions beyond those indicated under *Recommended OperatingConditions*. Exposure to absolute-maximum-rated conditions for extended periods mayaffect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002, (1) HBM ESD classification level H2	±2000	V
		Charged-device model (CDM), AEC Q100 classification C4B, per AEC Q100-011 — All pins	±500	
		Charged-device model (CDM), AEC Q100 classification C4B, per AEC Q100-011 — Corner pins	±750	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordancewith the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

over operating junction temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
V_{CC}	Device supply voltage		3		5.5	V
V_{SENSE}	LED supply voltage				8	V
V_O	Output voltage				8	V
V_{IL}	Input logic-low voltage	BLANK, GCLK, LATCH, SCK, SDI	0		0.3 V_{CC}	V
V_{IH}	Input logic-high voltage	BLANK, GCLK, LATCH, SCK, SDI	0.7 V_{CC}		V_{CC}	V
I_{OH}	High-level output current	SDO			1	mA
I_{OL}	Low-level input current	SDO			1	mA
		$\overline{ERR}$			5	mA
I_O	Constant output sink current	OUTR0–OUTR7, OUTB0–OUTB7	2		50	mA
T_A	Operating ambient temperature		–40		125	°C
T_J	Operating junction temperature		–40		150	°C

6.4 Thermal Information

THERMAL METRIC(1)		TLC6C5716-Q1 DAP (HTSSOP) 38 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	39.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	31.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	18.0	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	18.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	2.0	°C/W

(1) For more information about traditional and newthermalmetrics, see *SemiconductorandICPackageThermal Metrics* .

6.5 Electrical Characteristics

V_{CC} = 3 V to 5.5 V, T_J=–40°Cto150°C,V_{SENSE} = 5 V, GS = FFFh, BC = FFh, DC = 7Fh with upper dotcorrection(DC)range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
POWER SUPPLIES (V_{CC}, GND)						
I_{CC}	Supply current	SDI, SCK, LATCH = L, BLANK = L, GCLK = L, V_{OUT} = 1 V, I_{OUT} = 2 mA		4.2	5.5	mA
		SDI, SCK, LATCH = L, BLANK = L, GCLK = L, V_{OUT} = 1 V, I_{OUT} = 20 mA		7.7	9	
		SDI, SCK, LATCH = L, BLANK = H, GCLK = 8 MHz, V_{OUT} = 1 V, I_{OUT} = 20 mA , auto-repeat on		8.3	10	
		SDI, SCK, LATCH = L, BLANK = H, GCLK = 8 MHz, V_{OUT} = 1 V, I_{OUT} = 50 mA , auto-repeat on		13.5	16	
LOGIC INPUTS (SDI, SCK, LATCH, GCLK, BLANK)						
I_{lkg}	Input leakage current	V_I at SCK, LATCH, GCLK = V_{CC}; V_I at SDI, SCK, LATCH, BLANK, GCLK = GND	–1		1	µA
R_{pd}	Pulldown resistance at BLANK, GCLK		250	500	750	kΩ
CONTROL OUTPUTS (IREF, $\overline{ERR}$, SDO)						
V_{IREF}	IREF voltage	R_{IREF} = 0.96 kΩ	1.17	1.2	1.23	V
V_{OH}	High-level output voltage	At SDO, I_{OH} = –1 mA	V_{CC} – 0.4		V_{CC}	V
V_{OL}	Low-level output voltage	At SDO, I_{OL} = 1 mA			0.4	V
V_{ERR}	$\overline{ERR}$ pin open-drain voltage drop	I_{ERR} = 4 mA			0.1 V_{CC}	V
$I_{lkg(ERR)}$	$\overline{ERR}$ pin leakage current	V_{ERR} = 5 V			1	µA
OUTPUT STAGE						
$V_{(OUT,min)}$	Minimum output voltage	V_{CC} = 3.6 V, I_{OUT} = 50 mA			0.67	V
		V_{CC} = 3 V, I_{OUT} = 50 mA			0.7	
$K_{(OUT)}$	Ratio of output current to IREF current, K = $I_{(OUTx)}$ / $I_{(IREF)}$			40		mA/mA
$I_{lkg(OUT)}$	Output leakage current	BLANK = L, V_{OUT} = 7 V, V_{SENSE} = 7 V, I_{OUT} = 50 mA			0.1	µA

Electrical Characteristics (continued)

V_{CC} = 3 V to 5.5 V, T_J=–40°Cto150°C,V_{SENSE} = 5 V, GS = FFFh, BC = FFh, DC = 7Fh with upper dotcorrection(DC)range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
CHANNEL ACCURACY						
$I_{(OUT)}$	Constant output current	V_{OUT} = 1 V, R_{IREF} = 24 kΩ	1.86	2	2.14	mA
		V_{OUT} = 1 V, R_{IREF} = 0.96 kΩ	46.5	50	53.5	
		V_{OUT} = 1V, R_{IREF} open or short	7	10	13	
$\Delta I_{(Ch-Ch)}$ (1)	Current accuracy (channel-to-channel in same color group)	V_{OUT} = 1 V, I_{OUT} = 50 mA	–4%		4%	
		V_{OUT} = 1 V, I_{OUT} = 2 mA	–4%		4%	
$\Delta I_{(Dev-Dev)}$ (2)	Current accuracy (device-to-device)	V_{OUT}= 1 V, I_{OUT} = 50 mA	–4%		4%	
		V_{OUT} = 1 V, I_{OUT} = 2 mA	–4%		4%	
$\Delta I_{(Ch-Ideal)}$ (3)	Current accuracy (channel-to-ideal output)	V_{OUT} = 1 V, I_{OUT} = 50 mA	–7%		7%	
		V_{OUT} = 1 V, I_{OUT} = 2 mA	–7%		7%	
$\Delta I_{(OUT-VCC)}$ (4)	Line regulation	V_{OUT} = 1 V, I_{OUT} = 50 mA	–0.7		0.7	%/V
		V_{OUT} = 1 V, I_{OUT} = 2 mA	–0.7		0.7	
$\Delta I_{(OUT-VOUT)}$ (5)	Load regulation	V_{OUT} = 1 V to 3 V, I_{OUT} = 50 mA	–0.7		0.7	
		V_{OUT} = 1 V to 3 V, I_{OUT} = 2 mA	–0.7		0.7	
PROTECTION CIRCUITS						
V_{LOD}	LED open-circuit detection threshold	LOD_VOLTAGE = 0b	0.275	0.3	0.32	V
		LOD_VOLTAGE = 1b	0.48	0.5	0.52	

(1) Channel to channel accuracy in the same color group iscalculated by the formula below. (X = color group; i,j = 0 to 7)

$$\Delta I_{(Ch-Ch)} = \left(\frac{8 \times I_{OUTXi}}{\sum_{j=0}^{7} I_{OUTXj}} - 1 \right) \times 100\%$$

(2) Device to device accuracy is calculated by the formulabelow.

$$\Delta I_{(Dev-Dev)} = \left(\frac{\frac{\sum_{i=0}^{7} \left(I_{OUTRi} + I_{OUTBi} \right)}{16} - I_{OUT,ideal}}{I_{OUT,ideal}} \right) \times 100\%$$

$$I_{OUT,ideal} = \frac{V_{IREF}}{R_{IREF}} \times K_{(OUT)}$$

(3) Channel to ideal accuracy is calculated by the formulabelow.

$$\Delta I_{(Ch-Ideal)} = \left(\frac{I_{OUTXi}}{I_{OUT,ideal}} - 1 \right) \times 100\%$$

(4) Line regulation accuracy is calculated by the formulabelow.

$$\Delta I_{(OUT-VCC)} = \left(\frac{I_{(OUTXi,VCC=5.5V)} - I_{(OUTXi,VCC=3V)}}{I_{(OUTXi,VCC=3V)}} \right) \times \frac{100}{5.5-3} \%/V$$

(5) Load regulation accuracy is calculated by the formulabelow.

$$\Delta I_{(OUT-VOUT)} = \left(\frac{I_{(OUTXi,VOUT=3V)} - I_{(OUTXi,VOUT=1V)}}{I_{(OUTXi,VOUT=1V)}} \right) \times \frac{100}{3-1} \%/V$$

Electrical Characteristics (continued)

V_{CC} = 3 V to 5.5 V, T_J=–40°Cto150°C,V_{SENSE} = 5 V, GS = FFFh, BC = FFh, DC = 7Fh with upper dotcorrection(DC)range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{LSD}	LED short-circuit detection threshold	LSD_VOLTAGE = 0b	V_{SENSE} – 0.4	V_{SENSE} – 0.3	V_{SENSE} – 0.2	V
		LSD_VOLTAGE = 1b	V_{SENSE} – 0.8	V_{SENSE} – 0.7	V_{SENSE} – 0.6	
I_{IREF_OC}	IREF resistor open-circuit detection threshold	V_{CC} = 5 V	8	10	12	µA
I_{IREF_OCHYS}	IREF resistor open-circuit detection threshold hysteresis	V_{CC} = 5 V		5		µA
I_{IREF_SC}	IREF resistor short-circuit-detection threshold	V_{CC} = 5 V	2	2.7	3.2	mA
I_{IREF_SCHYS}	IREF resistor short-circuit-detection threshold hysteresis	V_{CC} = 5 V		0.3		mA
T_{PTW}	Pre-thermal warning flag threshold		125	135	145	°C
T_{HYS_PTW}	Pre-thermal warning flag hysteresis			10		°C
T_{SD}	Thermal error flag threshold		150	160	170	°C
T_{HYS_TEF}	Thermal error flag hysteresis			10		°C

6.6 Timing Requirements

V_{CC} = 3 V to 5.5 V,T_J=–40°Cto150°C.

		MIN	NOM	MAX	UNIT
$f_{CLK(SCK)}$	SCK data-shift clock frequency			4	MHz
$f_{CLK(GCLK)}$	GCLK grayscale clock frequency			8	MHz
t_{WH0}	SCK high pulse duration	60			ns
t_{WL0}	SCK low pulse duration	60			ns
t_{WH1}	LATCH high pulse duration	80			ns
t_{WL1}	LATCH low pulse duration	80			ns
t_{WL2}	BLANK pulse duration	80			ns
t_{WH3}	GCLK high pulse duration	40			ns
t_{WL3}	GCLK low pulse duration	40			ns
t_{SU0}	SDI↑ – SCK↑ setup time	55			ns
t_{SU1}	BLANK↑– GCLK↑ setup time	60			ns
t_{SU2}	LATCH↑–SCK↑ setup time	200			ns
t_{SU3}	LATCH↑ for GS data–GCLK↑when display timing reset mode is disabled, setup time	90			ns
t_{SU4}	LATCH↑for GS data–GCLK↑ when display timing reset mode is enabled, setup time	150			ns
t_{H0}	SCK↑– SDI↑hold time	55			ns
t_{H1}	SCK↑– LATCH↑ hold time	85			ns
t_{H2}	SCK↑–LATCH↓ hold time	55			ns
t_{RI0}	SDI SCK LATCH rise time			50	ns
t_{RI1}	GCLK rise time			30	ns
t_{FI0}	SDI SCK LATCH fall time			50	ns
t_{FI1}	GCLK fall time			30	ns

6.7 Switching Characteristics

over operating junction temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{ro0}	Rise time from 10% V_{SDO} to 90% V_{SDO}			60		ns
t_{ro1}	Rise time from 10% V_{OUT} to 90% V_{OUT}	I_{OUT} = 50 mA, SLEW_RATE = 0b		200		ns
t_{ro2}	Rise time from 10% V_{OUT} to 90% V_{OUT}	I_{OUT} = 50 mA, SLEW_RATE = 1b	60	100	140	ns
t_{fo0}	Fall time from 90% V_{SDO} to 10% V_{SDO}			30		ns
t_{fo1}	Fall time from 90% V_{OUT} to 10% V_{OUT}	I_{OUT} = 50 mA , SLEW_RATE = 0b		200		ns
t_{fo2}	Fall time from 90% V_{OUT} to 10% V_{OUT}	I_{OUT} = 50 mA, SLEW_RATE = 1b	30	80	130	ns
t_{pd0}	Propagation delay, SCK↑to SDO		100	140	200	ns
t_{pd1}	Propagation delay, LATCH↑to SDO		130	180	220	ns
t_{pd2}	Propagation delay, BLANK↓ to OUTR0, -B0, -R4, -B4 off		10	120	260	ns
t_{pd3}	Propagation delay, GCLK↑ to OUTR0, -B0, -R4, -B4 on		80	160	260	ns
t_{pd4}	Propagation delay, GCLK↑ to OUTR1, -B1, -R5, -B5 on		120	200	330	ns
t_{pd5}	Propagation delay, GCLK↑ to OUTR2, -B2, -R6, -B6 on		160	250	370	ns
t_{pd6}	Propagation delay, GCLK↑ to OUTR3, -B3, -R7, -B7 on		190	280	400	ns
t_{pd7}	Propagation delay, LATCH↑ to V_{OUT}	Changing by dot correction control (control data are 0Ch→72h or 72h→0Ch with upper DC range), BC -R, -B = FFh	10	80	120	ns
t_{pd8}	Propagation delay, LATCH↑ to V_{OUT}	Changing by global brightness control (control data are 19h→E6h or E6h→19h with DC -Rn, -Bn = 7Fh with upper DC range	10	130	200	ns
t_{pd9}	Propagation delay, LATCH↑ to APS register and APS flag change	SINK_CURRENT = 0b		5		ns
t_{pd10}	Propagation delay, LATCH↑ to APS register and APS flag change	SINK_CURRENT = 1b		10		ns
t_{pd11}	Propagation delay, LATCH↑ to LOD self-flag change	No failure in LOD-LSD detector circuit		24		ns

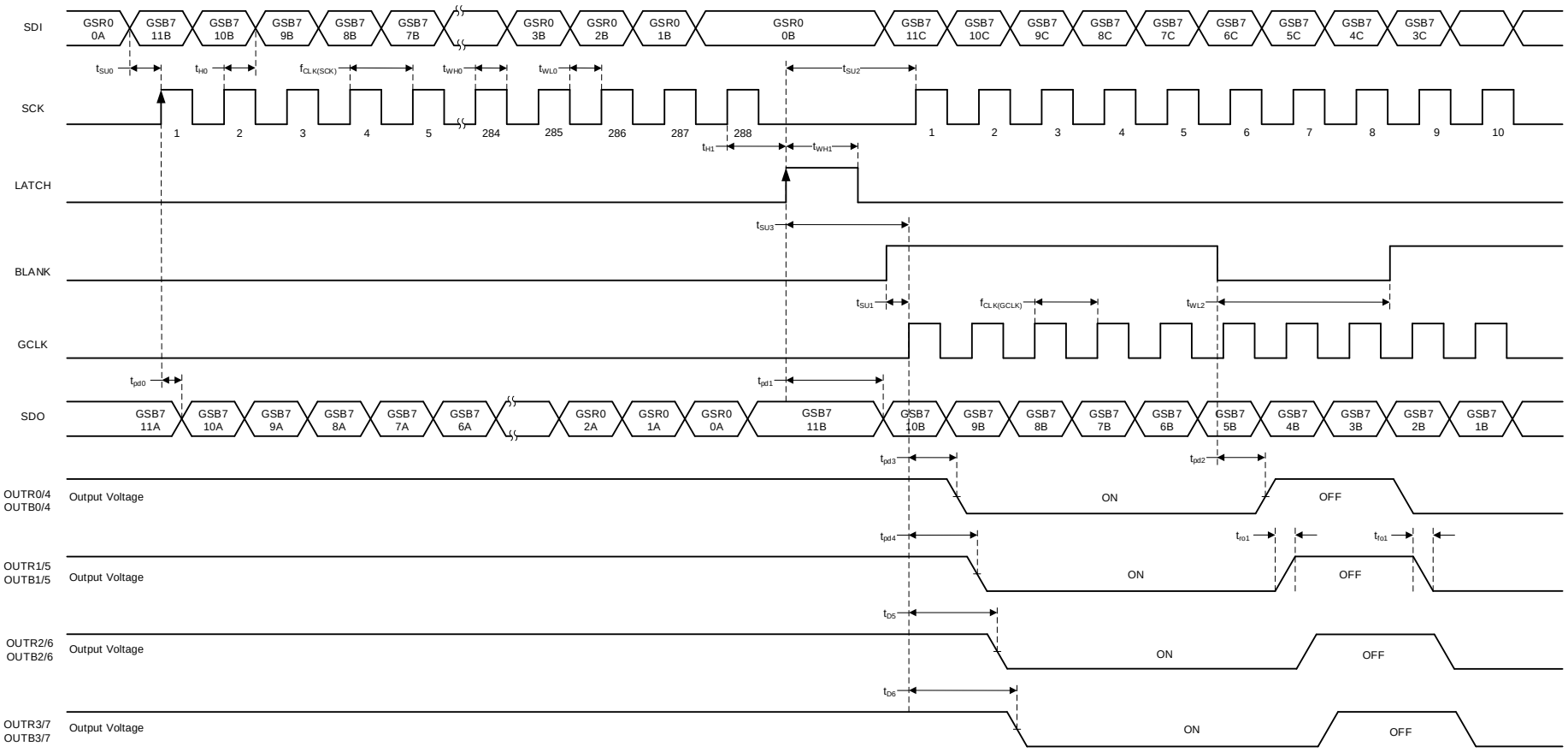


Figure 1. Grayscale Data (GS) Write

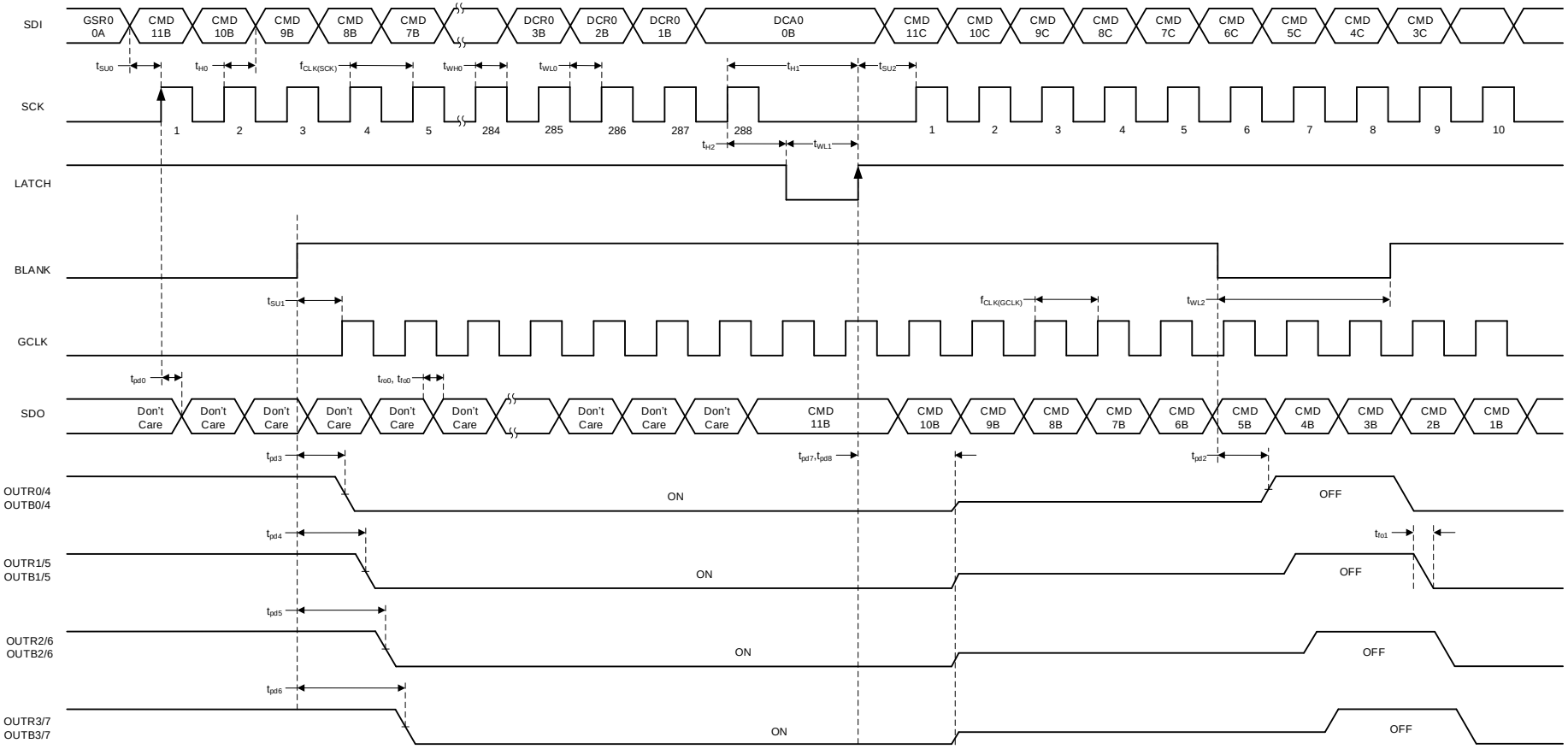


Figure 2. Function-Control, Brightness-Control, and Dot-Correction (FC-BC-DC) Data Write

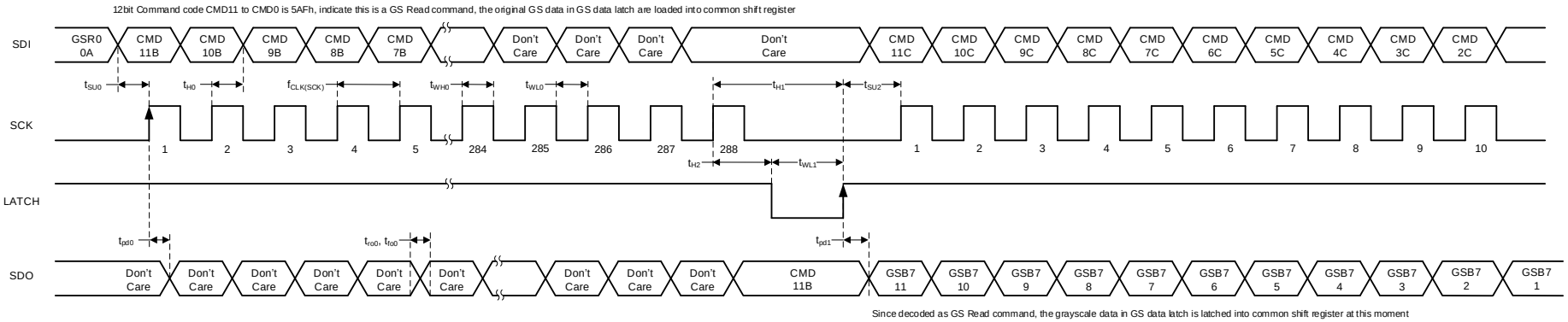


Figure 3. Grayscale (GS) Data Read

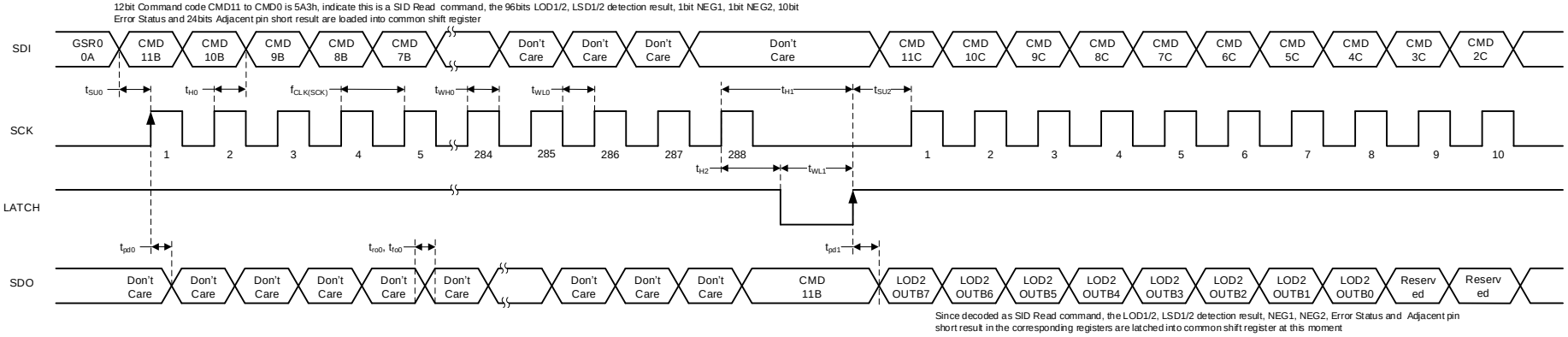


Figure 4. Status Information Data (SID) Read

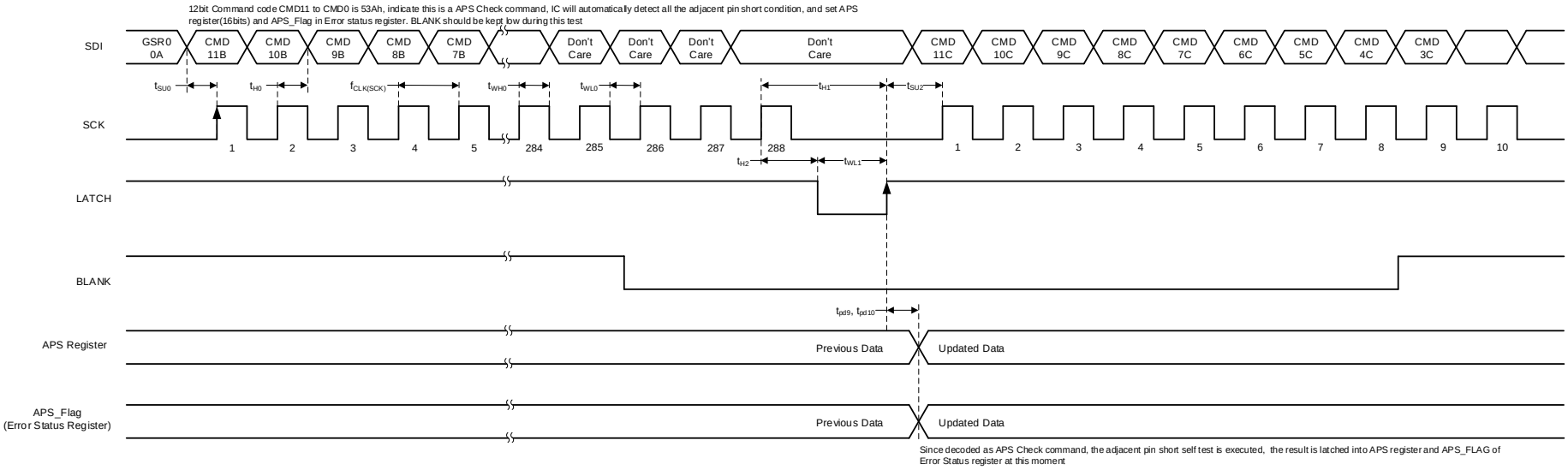


Figure 5. Adjacent-Pin-Short (APS) Check

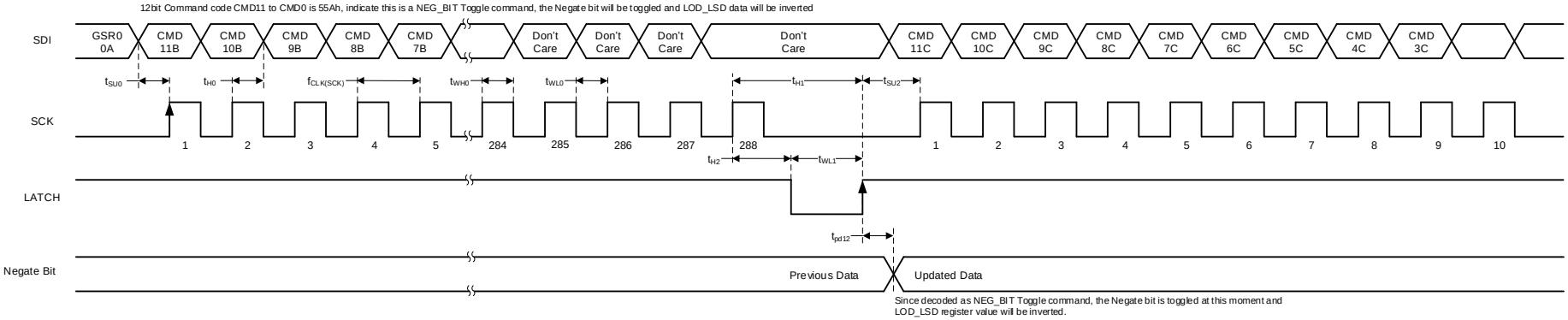


Figure 6. Negate Bit Toggle

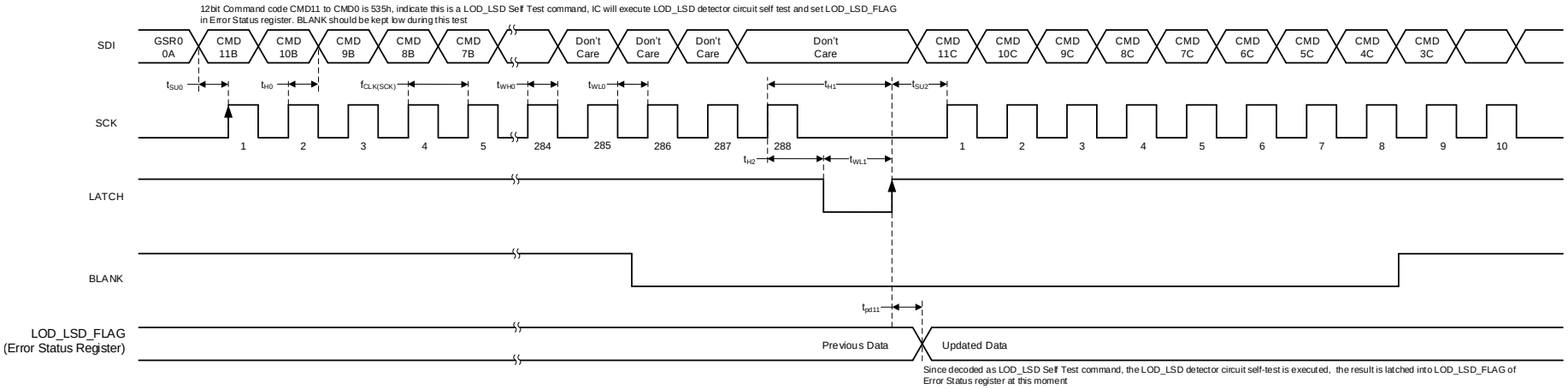


Figure 7. LOD_LSD Self-Test

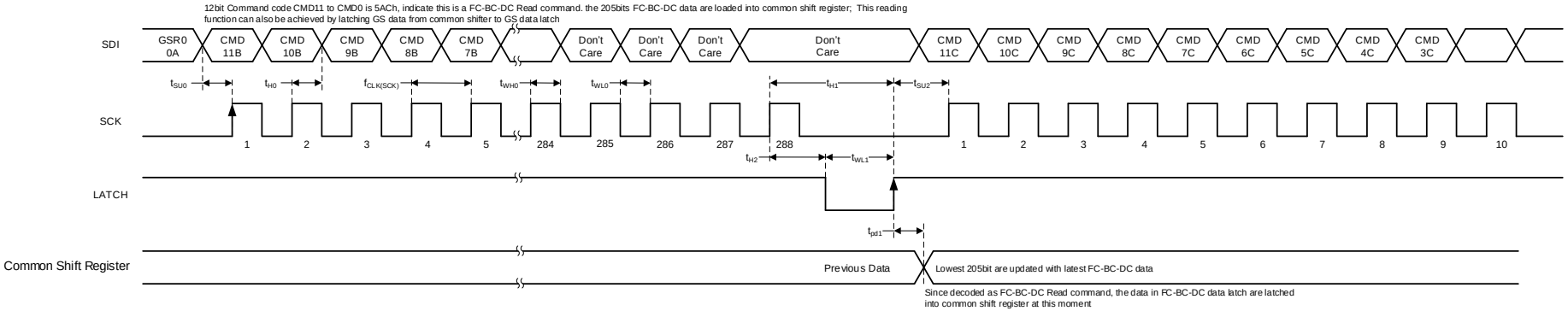


Figure 8. Function Control, Brightness Control, and Dot Correction (FC-BC-DC) Data Read

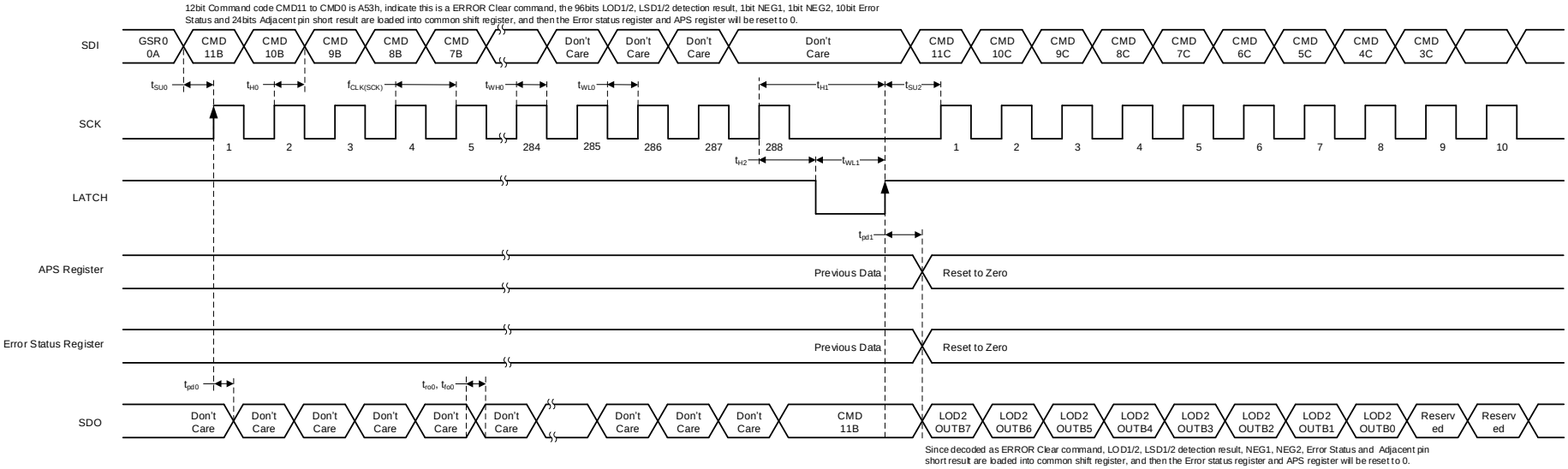


Figure 9. ERROR Clear

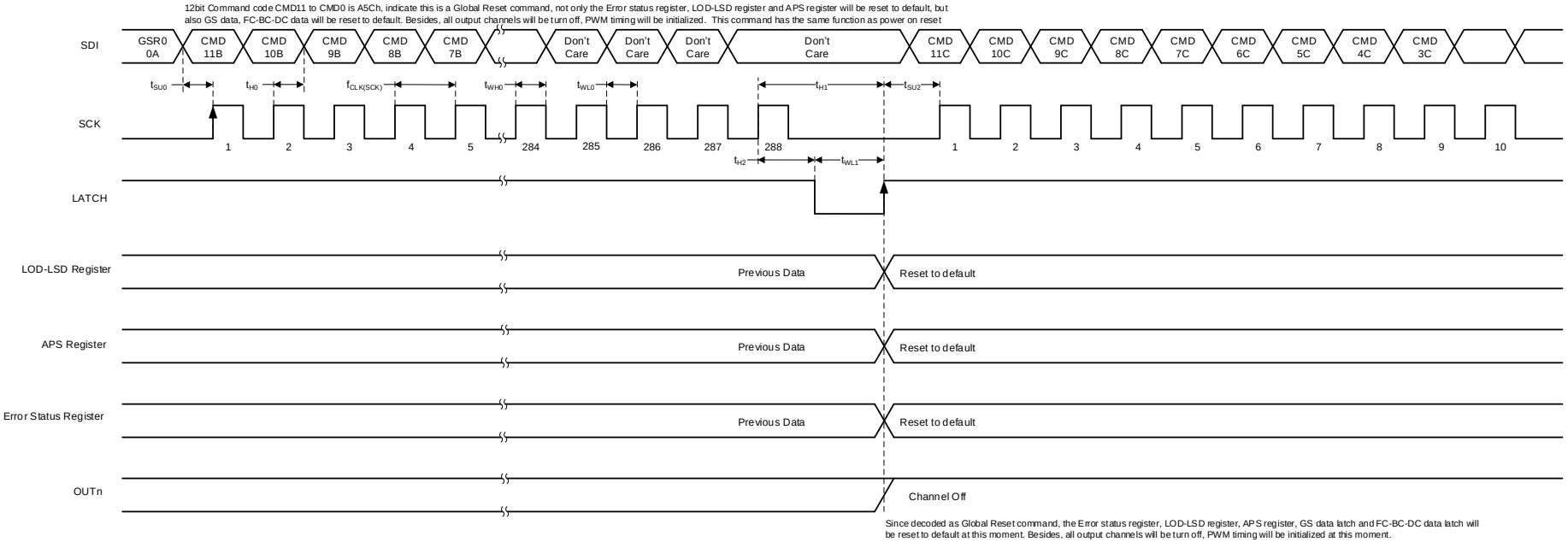


Figure 10. Global Reset

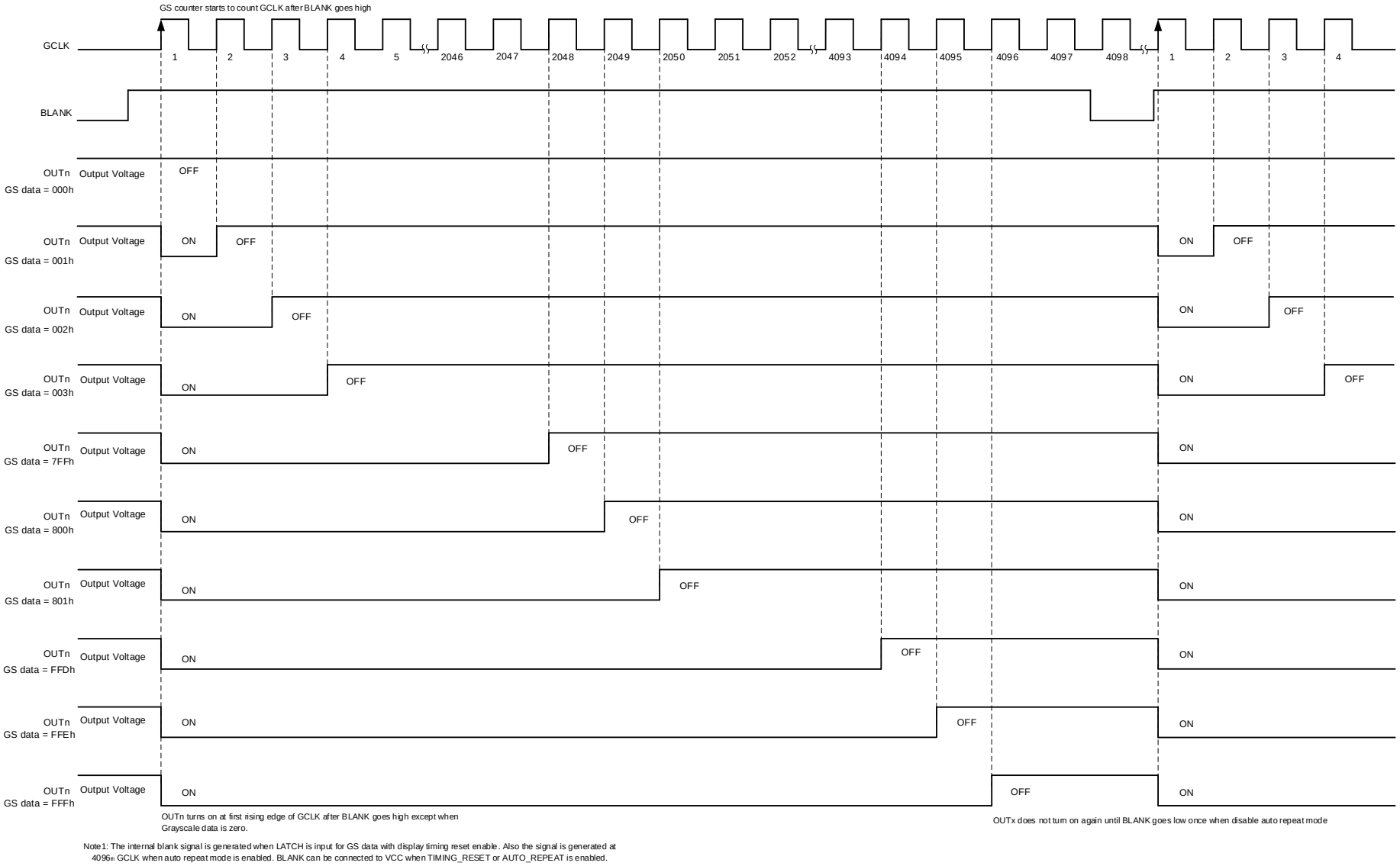


Figure 11. 12-Bit Mode PWM Counter Without Auto-Repeat Mode

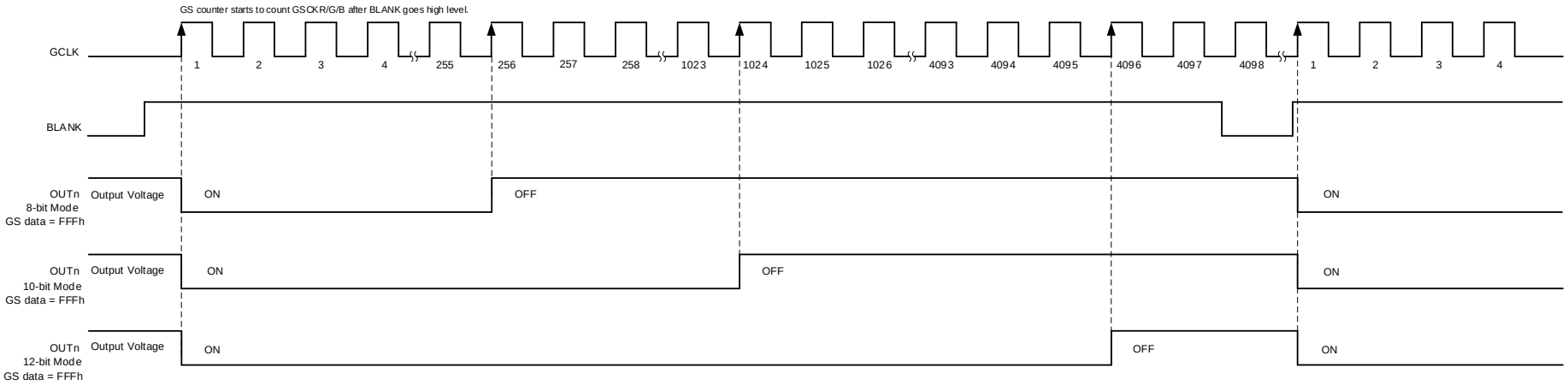


Figure 12. 8-, 10-, 12-Bit Mode PWM Counter Without Auto-Repeat Mode

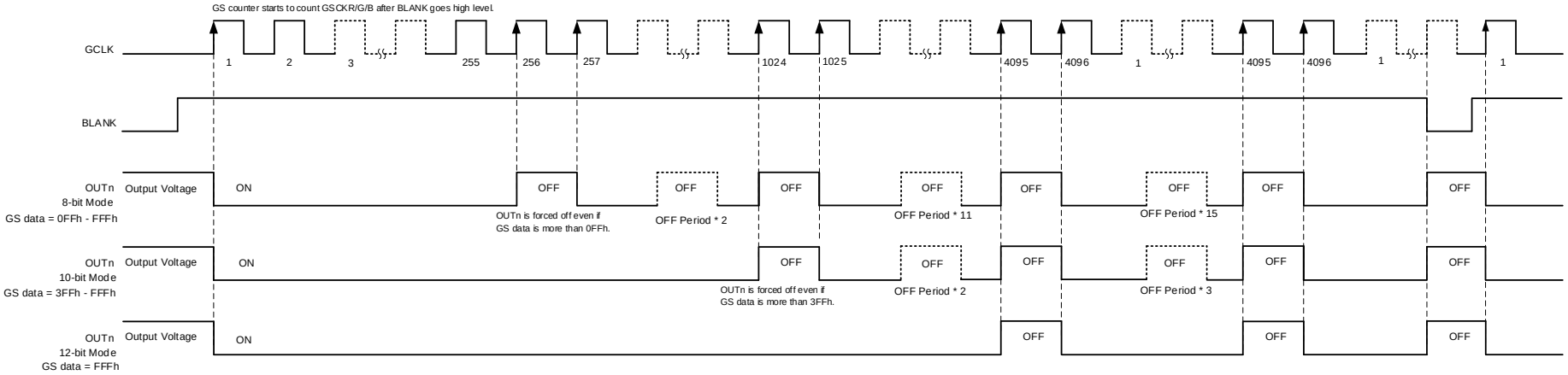


Figure 13. 8-, 10-, 12-Bit Mode PWM Counter With Auto-Repeat Mode

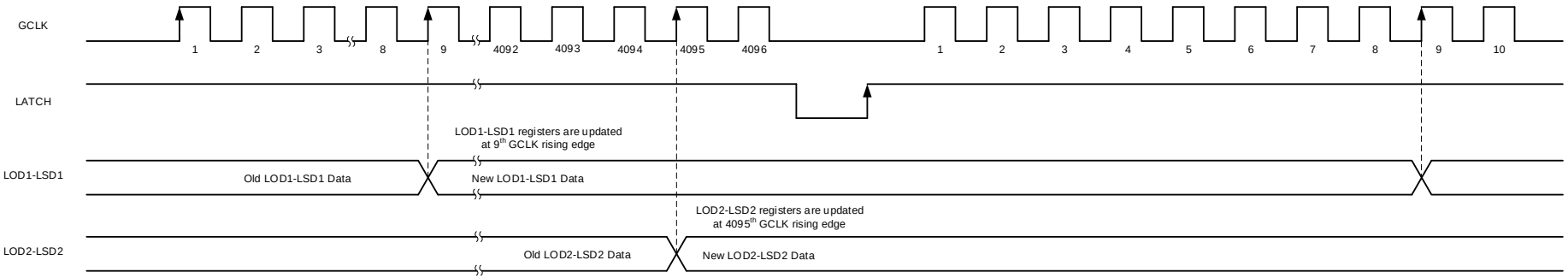


Figure 14. LOD-LSD Register Update Timing

6.8 Typical Characteristics

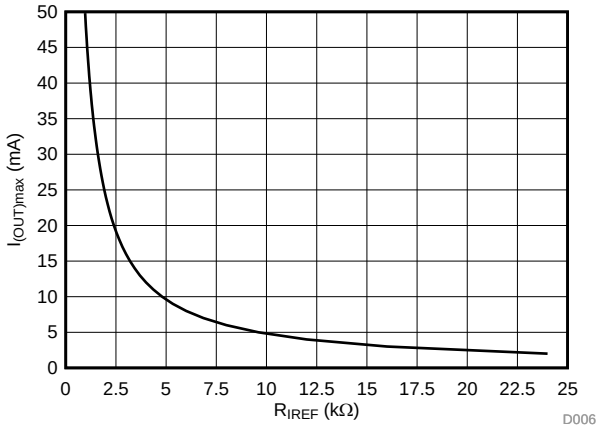
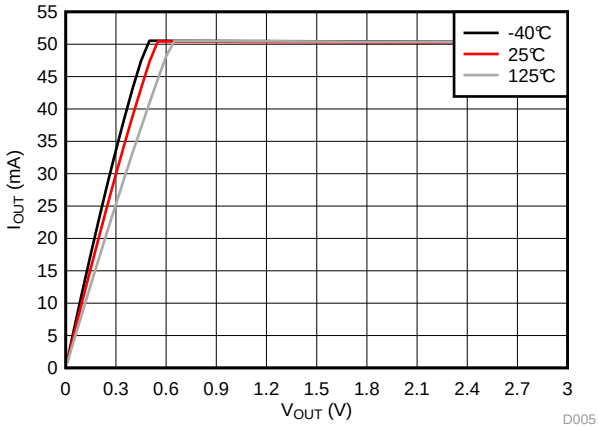
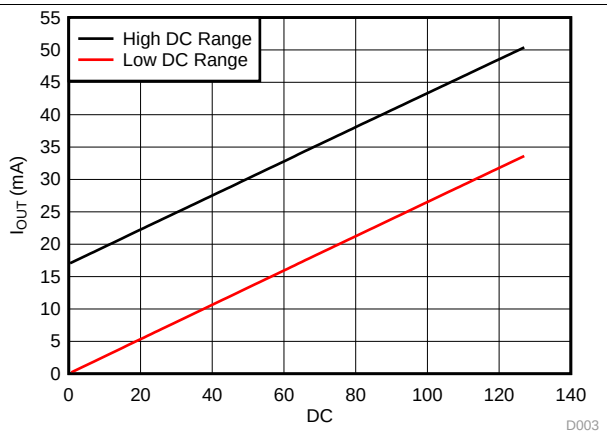


Figure 15. $I_{(OUT)max}$ vs R_{IREF}



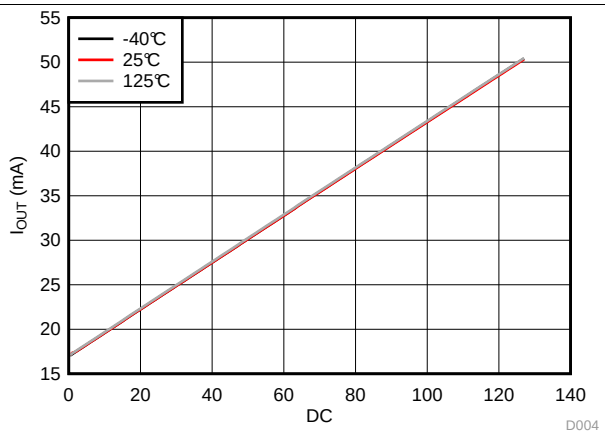
V_{CC} = 3.3 V BC = FFh GS = FFFh
DC = 7Fh in high range

Figure 16. I_{OUT} vs V_{OUT}



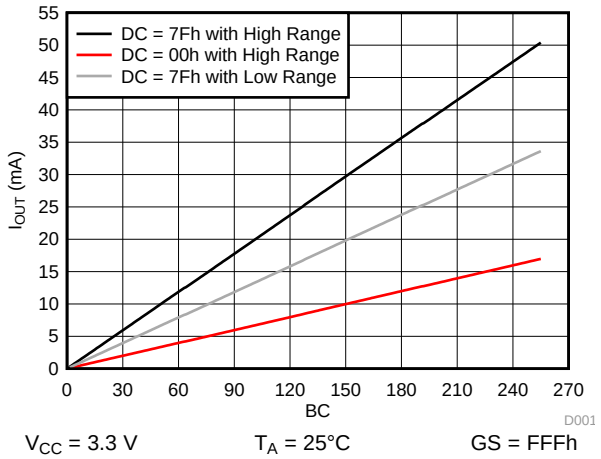
V_{CC} = 3.3 V T_A = 25°C GS = FFFh
BC = FFh

Figure 17. I_{OUT} vs Dot Correction in Different DC Ranges



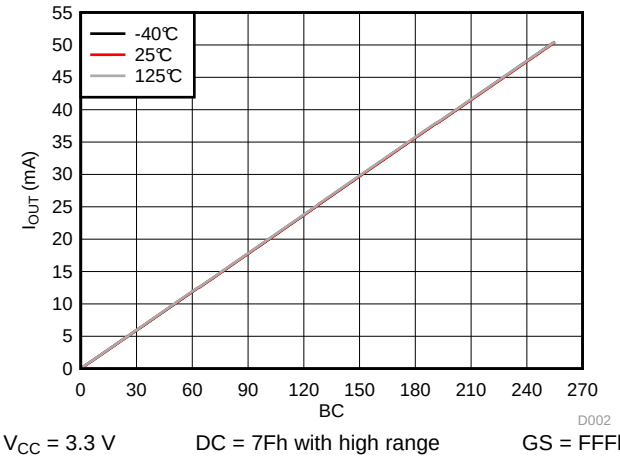
V_{CC} = 3.3 V BC = FFh in the high DC range GS = FFFh

Figure 18. I_{OUT} vs Dot Correction at Different Ambient Temperatures



V_{CC} = 3.3 V T_A = 25°C GS = FFFh

Figure 19. I_{OUT} vs Brightness Control in Different DC Ranges



V_{CC} = 3.3 V DC = 7Fh with high range GS = FFFh

Figure 20. I_{OUT} vs Brightness Control at Different Ambient Temperatures

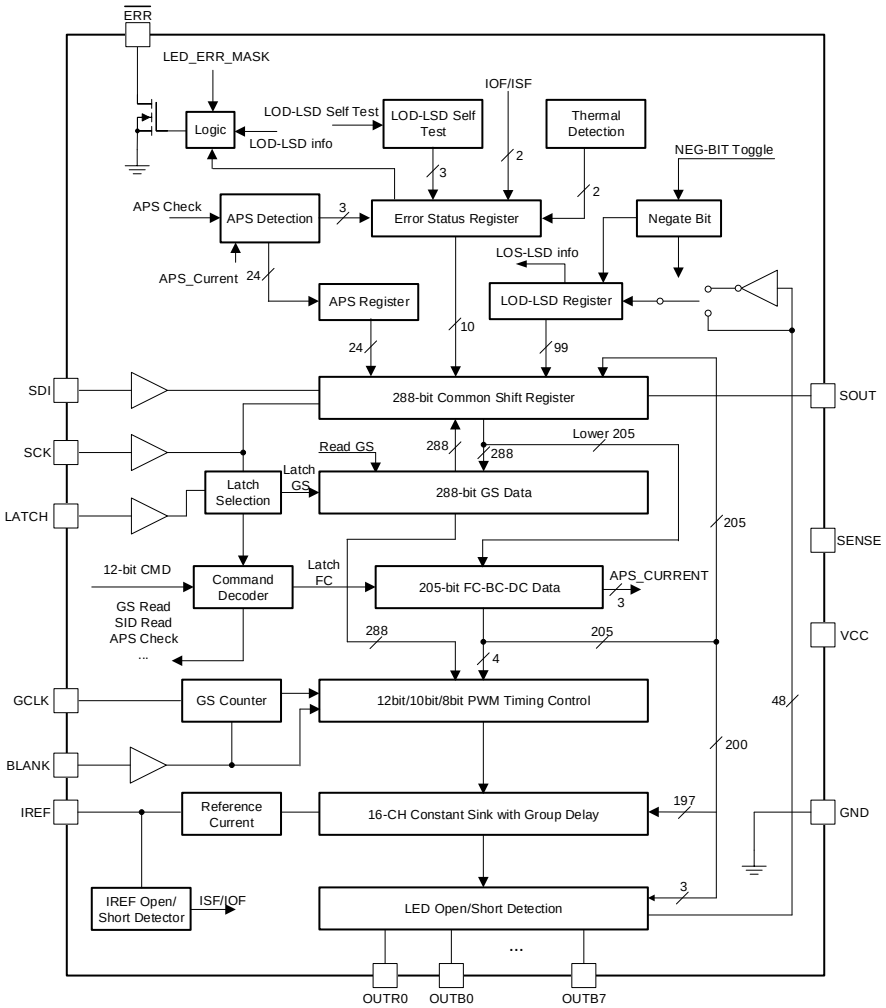
7 Detailed Description

7.1 Overview

In automotive indicator and local dimming backlighting applications, the demand for multi-channel constant current LED drivers is increasing to achieve uniformity of LED brightness and color temperature. System-level safety considerations require fault detection capability and device self-check features.

The TLC6C5716-Q1 is an automotive 16-channel constant-current LED driver with LED diagnostics. The TLC6C5716-Q1 provides up to 50 mA of output current set by an external resistor. The current can be adjusted by 7-bit dot correction with two subranges for individual outputs, and an 8-bit brightness control for all the outputs of each color group. The brightness can be adjusted individually for each channel through a 12-, 10-, or 8-bit grayscale control. Fault-detection circuits are available to detect system faults including LED faults, adjacent-pin short faults, reference-resistor faults, and more. Negate bit toggle and LOD-LSD self-test provide a device self-check function to improve system reliability. Configurable slew-rate control optimizes the noise generation of the system and improves the system EMC performance. Output-channel group delay helps to reduce inrush current to optimize the system design. The SDI and SDO pins allow more than one device to be connected in a daisy chain for control through one serial interface.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Maximum Constant-Sink-Current Setting

LED full-scale current can be set using an external resistor connected between the IREF pin and GND. The R_{IREF} resistor value is calculated with the following formula.

$$R_{IREF} = K \times \frac{V_{IREF}}{I_{(OUT)max}}$$

where

- V_{IREF} is the reference voltage
- K is the IREF current to output current ratio
- $I_{(OUT)max}$ is full-scale current for each output (1)

Figure 15 shows the reference-resistor calculation curve.

7.3.2 Brightness Control and Dot Correction

The TLC6C5716-Q1 device implements an 8-bit group brightness control (BC) and 7-bit individual dot correction (DC) to calibrate the output current. The 16 output channels are divided into two groups: OUTRn and OUTBn. Each group contains 8 output channels. There are two configurable ranges for the DC value of each group. One is the low DC range with output current from 0 to 66.7% $I_{(OUT)max}$, the other is the high DC range with output current from 33.3% $I_{(OUT)max}$ to 100% $I_{(OUT)max}$. The IREF resistor, BC, DC, and DC range together determine the channel output current, as shown in Figure 21. Equation 2 and Equation 3 are the detailed output current calculation formulas.

Equation 2 determines the output sink current for each group when DC is in high adjustment range.

$$I_{OUT} = \left(\frac{1}{3} \times I_{(OUT)max} + \frac{2}{3} \times I_{(OUT)max} \times \frac{DC}{127}\right) \times \frac{BC}{255} \quad (2)$$

Equation 3 determines the output sink current for each group when DC is in the low adjustment range.

$$I_{OUT} = \frac{2}{3} \times I_{(OUT)max} \times \frac{DC}{127} \times \frac{BC}{255} \quad (3)$$

Feature Description (continued)

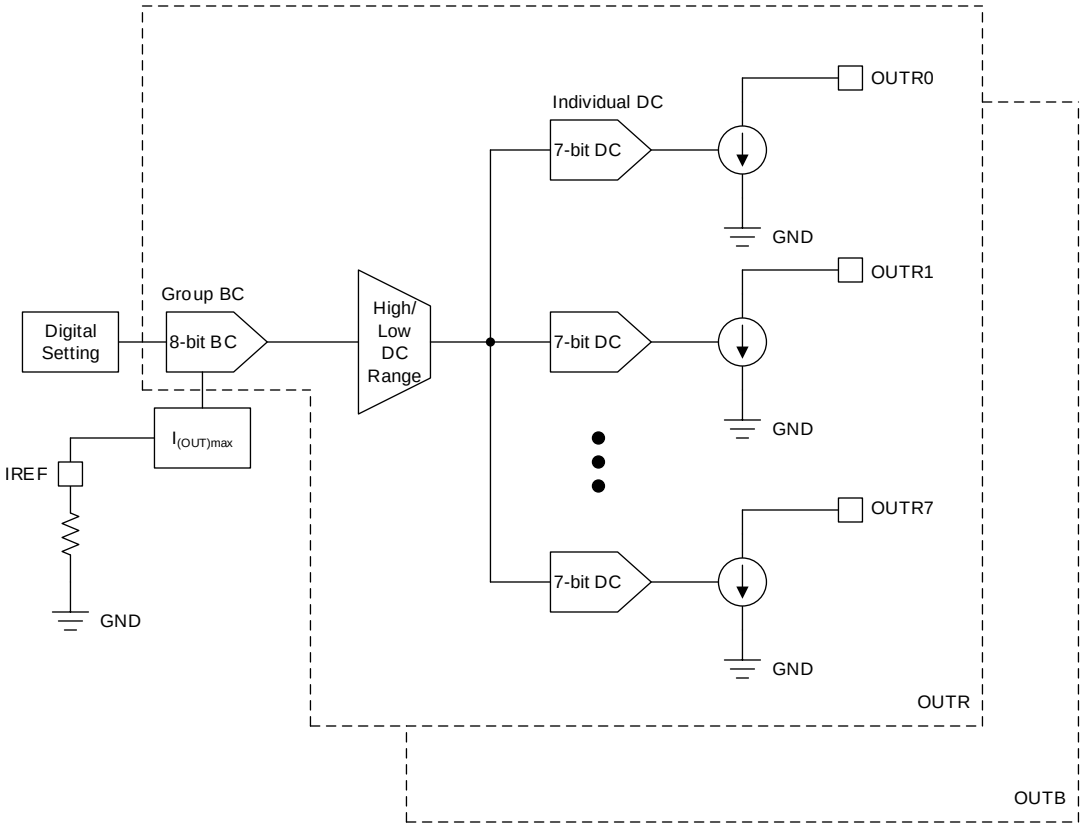


Figure 21. Brightness Control and Dot Correction Block Diagram

7.3.3 Grayscale Configuration

The TLC6C5716-Q1 device implements a grayscale configuration function to realize an individual PWM dimming function for the output channels. The grayscale has three global configuration modes, 12-bit, 10-bit and 8-bit. The GCLK input provides the clock source for the internal PWM generator. The GS counter counts the GCLK number and compares the number with channel grayscale register value, and the output channel turns off when the GS counter value reaches the grayscale register value. Figure 22 shows the detailed block diagram of the PWM generator.

To start a new PWM cycle, users can use two methods. One is to toggle the BLANK pin after the GS counter reaches the maximum count value, because BLANK low resets the GS counter and BLANK high restarts the GS counter. Another is to pull BLANK high and set the AUTO_REPEAT&TIMING_RESET register bit to 1, Table 12. The PWM starts a new cycle automatically after the GS counter reaches its maximum count value.

Feature Description (continued)

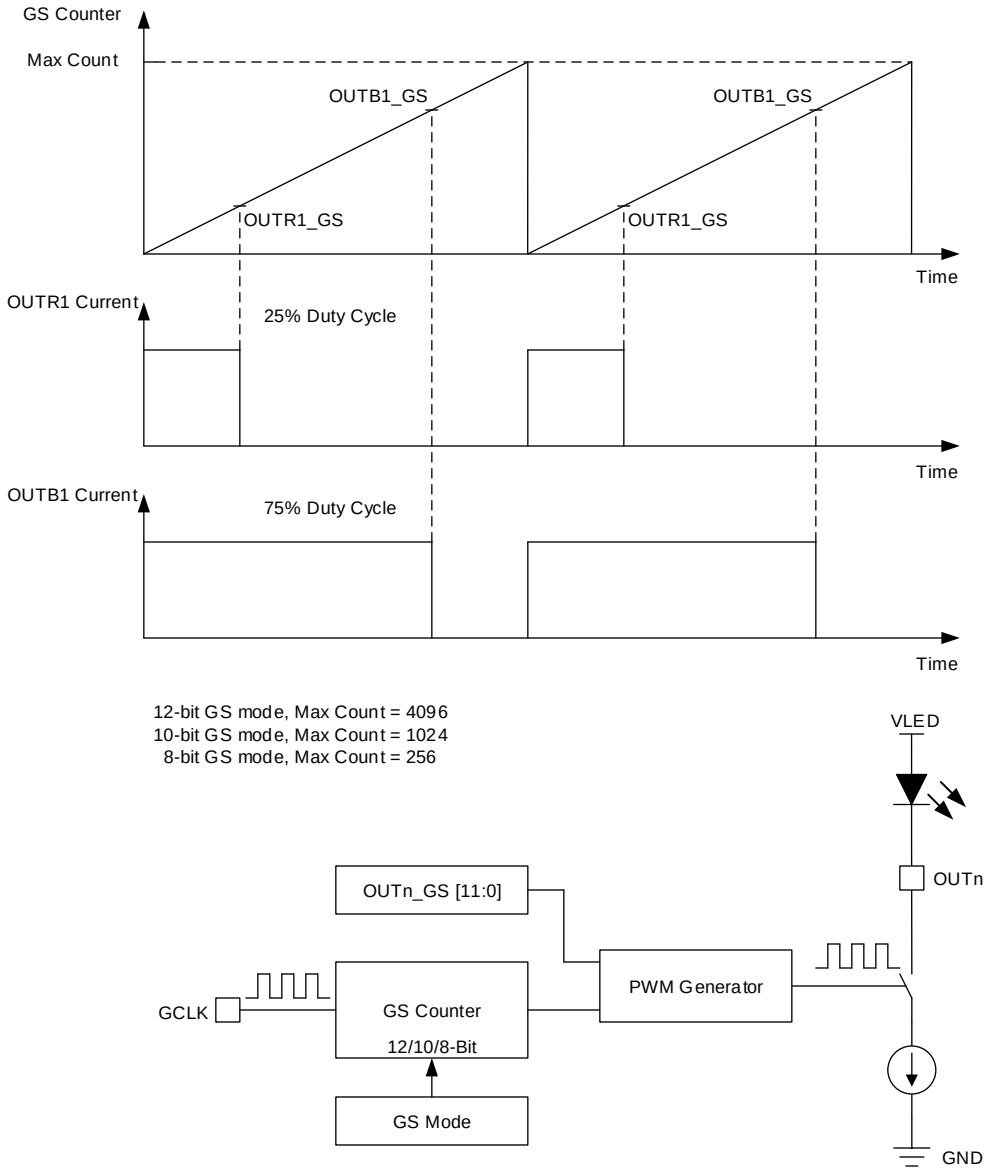


Figure 22. PWM Generator

7.3.3.1 PWM Auto Repeat

The PWM auto repeat function is configured by the AUTO_REPEAT bit. The AUTO_REPEAT bit is 0 by default, and the PWM auto repeat function is disabled in this condition. The PWM cycle only executes once, so users must toggle BLANK to start a new PWM cycle. Figure 11 and Figure 12 show the PWM operation in this mode. When the AUTO_REPEAT bit is 1, the PWM auto repeat function is enabled, and the PWM cycle automatically repeats as long as BLANK is high and GCLK is present, as shown in Figure 13.

Feature Description (continued)

7.3.3.2 PWM Timing Reset

The PWM timing reset function is configured by the TIMING_RESET bit. The PWM timing reset function can restart a PWM cycle with a newly configured duty cycle after a GS data write. The TIMING_RESET bit is 0 by default, and the PWM timing reset function is disabled in this condition. The PWM cycle is not influenced by a GS data write, and the newly configured PWM duty cycle only is valid after the current PWM cycle finishes. When the TIMING_RESET bit is 1, the PWM timing reset function is enabled, and the PWM cycle restarts with new PWM duty cycle immediately after the GS data write.

7.3.4 Diagnostics

The TLC6C5716-Q1 device integrates a full LED diagnostics function, such as LED-open detection (LOD), LED-short detection (LSD), and output short-to-GND detection (OSD), which helps to improve the system safety.

7.3.4.1 LED Diagnostics

An LOD-LSD detection circuit compares the output voltage with the LOD threshold and LSD threshold, and Table 1 shows the output results.

Table 1. LOD-LSD Detection

OUTPUT VOLTAGE CONDITION	DETECTOR OUTPUT BIT VALUE	
	LOD	LSD
V_{OUTn} < LOD_VOLTAGE	1	0
LOD_VOLTAGE < V_{OUTn} < LSD_VOLTAGE	0	0
V_{OUTn} > LSD_VOLTAGE	0	1

The LOD threshold can be configured by the LOD_VOLTAGE bit in the FC-BC-DC register, Table 12 . The threshold is 0.3 V when LOD_VOLTAGE = 0, and the threshold is 0.5 V when LOD_VOLTAGE = 1.

Table 2. LOD Threshold

LOD_VOLTAGE BIT	LOD THRESHOLD
0 (Default)	0.3 V
1	0.5 V

The LSD threshold is configured by the LSD_VOLTAGE bit in the FC-BC-DC register, Table 12. The threshold is V_{VSENSE} – 0.3 V when LSD_VOLTAGE = 0, and the threshold is V_{VSENSE} – 0.7 V when LSD_VOLTAGE = 1.

Table 3. LSD Threshold

LSD_VOLTAGE BIT	LSD THRESHOLD
0 (Default)	V_{SENSE} – 0.3 V
1	V_{SENSE} – 0.7 V

There are two sets of LOD-LSD registers in the device, one is the LOD1-LSD1 registers, the other is the LOD2-LSD2 registers. Each group of registers consists of 24 bits of LOD data and 24 bits of LSD data, corresponding to the 24 channel outputs. The device updates the LOD1-LSD1 registers at the 9th GCLK rising edge. The device updates the LOD2-LSD2 registers at the Nth GCLK rising edge. N is the maximum GCLK number in a PWM period minus 1, see Table 4.

To detect all kinds of LED faults, the output channel should turn ON at the 9th GCLK rising edge, and turn OFF at the Nth GCLK rising edge.

The device integrates an internal pullup circuit for LED diagnostics, shown in Figure 23. The circuit turns off during the channel on-state, but turns on to charge the output pin during the channel-off state. For an LED-short fault, both LSD1 and LSD2 are 1. For an LED-open fault, both LOD1 and LSD2 are 1. For an output short-to-GND fault, both LOD1 and LOD2 are 1. Table 5 shows the details.

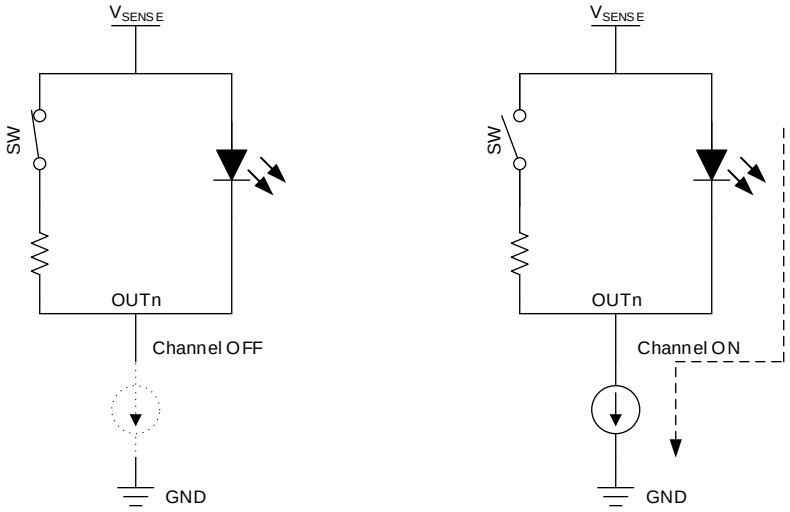


Figure 23. Internal Pullup Circuit

Table 4. LOD-LSD Register Latch Timing

GS COUNTER MODE	LOD1-LSD1	LOD2-LSD2
12-bit	9th GCLK rising edge	4095th GCLK rising edge
10-bit	9th GCLK rising edge	1023rd GCLK rising edge
8-bit	9th GCLK rising edge	255th GCLK rising edge

Table 5. LED Status Lookup Table

LED STATUS	LOD-LSD RESULT			
	LOD1-LSD1 Updated at 9th GCLK		LOD2-LSD2 Updated at Nth GCLK(1)	
LED Ok	LOD1	0	LOD2	0
	LSD1	0	LSD2	1
LED open	LOD1	1	LOD2	0
	LSD1	0	LSD2	1
LED short	LOD1	0	LOD2	0
	LSD1	1	LSD2	1
Output short-to-GND	LOD1	1	LOD2	1
	LSD1	0	LSD2	0

(1) N = 4095 for 12-bit GS mode, 1023 for 10-bit GS mode, 255 for 8-bit GS mode.

In some cases, users may need to turn off output channels before the 9th GCLK to disable the output channels, or turn on the output channels at the Nth GCLK to get more brightness. LOD_LSD faults are reported as shown in Table 6. Users can ignore the fault according to the GS register setting value.

Table 6. PWM Status Lookup Table

PWM STATUS	LOD-LSD Result			
	LOD1-LSD1 UPDATED AT 9th GCLK		LOD2-LSD2 UPDATED AT Nth GCLK (1)	
PWM OK	LOD1	0	LOD2	0
	LSD1	0	LSD2	1
Channel off before 9th GCLK	LOD1	0	LOD2	0
	LSD1	1	LSD2	1
Channel on at Nth GCLK	LOD1	0	LOD2	0
	LSD1	0	LSD2	0

(1) N = 4095 for 12-bit GS mode, 1023 for 10-bit GS mode, 255 for 8-bit GS mode

The LOD_LSD status is updated every PWM cycle. Figure 14 is an example of the LOD-LSD register update timing for the 12-bit GS mode.

7.3.4.2 Adjacent-Pin-Short Check

The device implements an APS check function to detect the adjacent-pin-short failure during system initialization. TI recommends to do an APS check when the channels are all off. The APS check can be executed by writing the APS check command.

If there is no adjacent-pin-short failure, the device passes the APS check and 011b is latched into the APS FLAG in the error status register. The 24-bit APS register is 0. If there are two adjacent pins shorted, 110b is latched into the APS_FLAG in the error status register. The corresponding bit in the APS register is set to 1. Users can read out the 24-bit data from APS register to check if two channels have this short fault. Table 7 shows the details of the APS_FLAG and APS register. Table 8 shows the bit arrangement of APS register. To read these APS information, see Status Information Data Read in the *Status Information Data Read* section.

Table 7. APS Flag and APS Register

REGISTER	VALUE	DESCRIPTION
APS_FLAG	011b	Pass, no adjacent pins short
	110b	Fail, adjacent pins short
Bit in APS register (24-bit total)	0b	This OUTn pin is not shorted with other pins
	1b	This OUTn pin is shorted with other pins

Table 8. Bit Arrangement of APS register

BITS OF APS REGISTERS	CORRESPONDING OUTPUTS
Bit 23	OUTB7
Bit 22	OUTB6
Bit 21	OUTB5
Bit 20	OUTB4
Bit 19	OUTB3
Bit 18	OUTB2
Bit 17	OUTB1
Bit 16	OUTB0
Bit 15	Pin 7
Bit 14	Pin 10
Bit 13	Pin 13
Bit 12	Pin 16
Bit 11	Pin 23
Bit 10	Pin 26
Bit 9	Pin 29
Bit 8	Pin 32
Bit 7	OUTR7
Bit 6	OUTR6
Bit 5	OUTR5
Bit 4	OUTR4
Bit 3	OUTR3
Bit 2	OUTR2
Bit 1	OUTR1
Bit 0	OUTR0

The APS_FLAG and APS registers are all 0 by default. After an APS check command, the APS_FLAG should be 011b or 110b. Otherwise, there is a failure on the APS check circuit. If the APS check result fails, the ERR pin is pulled low, the APS_FLAG value is 110b and the ERR pin status stays unchanged until the fault is removed and the user executes an ERROR clear command. Figure 5 and Figure 4 show more detail.

As different LEDs have different parasitic capacitance, to make sure the APS Check function is suitable for all kinds of LEDs, the device provides two configuration bits for APS current and APS time. The APS current is selected by APS_CURRENT as Table 9. The APS time is selected by APS_TIME as shown in Table 10.

Table 9. APS Current Selection

APS_CURRENT BIT	APS CURRENT
0b	20 µA
1b	40 µA

Table 10. APS Time Selection

APS_TIME BIT	ADJACENT-PIN SHORT-DETECTION TIME
0b	10 µs
1b	20 µs

7.3.4.3 IREF-Short and IREF-Open Detection

To protect the device from reference resistor short and open faults, the device integrates IREF short and open protection. In an IREF short or open fault condition, the device reports the fault and sets the output current to a default value to help improve the system safety.

By default, the ISF and IOF flags are 0. When the IREF current exceeds the fault detection threshold, the ERR pin is pulled down, the ISF or IOF flag is set to 1, and the error flag and ERR pin status stay unchanged until the fault is removed and there is an ERROR clear command.

Once there is an ISF or IOF failure, the output current is set to a default value, and $I_{(OUT)max}$ is 10 mA; see Table 11. Once the ISF or IOF failure is removed, the output current returns back to the set IREF value immediately.

Table 11. Criteria of ISF and IOF Judgement and Corresponding Actions

I_{IREF}	ISF	IOF	OUTPUT
$I_{IREF} \leq 10\ \mu A$	0	1	$I_{(OUT)max}$= 10 mA
$10\ \mu A < I_{IREF} \leq 3$ mA	0	0	$I_{(OUT)max} = V_{IREF} \times 40 / R_{IREF}$
$I_{IREF} > 3$ mA	1	0	$I_{(OUT)max}$ = 10 mA

7.3.4.4 Pre-Thermal Warning Flag

The TLC6C5716-Q1 device implements a pre-thermal warning (PTW) function. Once the junction temperature exceeds the PTW threshold, the ERR pin is pulled low, the PTW flag in the error status register is set to 1, and the PTW_FLAG and ERR pin status stay unchanged until the junction temperature drops below $T_{PTW} - T_{HYS\_PTW}$ and there is an ERROR clear command.

7.3.4.5 Thermal Error Flag

The TLC6C5716-Q1 device monitors the junction temperature all the time. Once the junction temperature exceeds the thermal shutdown threshold, all of the constant-current outputs turn off, the ERR pin is pulled low, and the thermal error flag and ERR pin status are set to 1 and stay unchanged until the fault is removed and there is an ERROR clear command. During this state, all the digital functions work normally, and users can read or write data through the common shift registers. After the junction temperature drops below $T_{TEF} - T_{HYS\_TEF}$, the device goes back to normal operation again. Users can reset the TEF flag by sending an ERROR clear command.

7.3.4.6 Negate-Bit Toggle

TLC6C5716-Q1 implements a negate-bit toggle function to check the LOD-LSD registers and GCLK signal, which is useful for safety-related applications.

There are NEG1 and NEG2 bits in the registers, and their values are both 0 by default. After executing the negate-bit toggle command, both NEG1 and NEG2 change to 1. The LOD-LSD results are reversed in this condition. If the LOD-LSD registers get stuck, the LOD-LSD results are not be toggled, which means there is a fault in the LOD-LSD registers.

The LOD1-LSD1 registers only update on the 9th GCLK rising edge, and the LOD2-LSD2 registers only update on the Nth GCLK rising edge. So after a negate-bit toggle command, users must wait for at least one GS counter cycle (4096 GCLKs for the 12-bit GS counter mode, 1024 GCLKs for the 10-bit GS counter mode, and 256 GCLKs for the 8-bit GS counter mode) before reading the SID registers. So if the GCLK signal is lost, the loss can also be detected by the negate-bit toggle function.

7.3.4.7 LOD_LSD Self-Test

The TLC6C5716-Q1 device implements an LOD_LSD self-test function to check the LOD_LSD detection circuit to help improve the system reliability. If the LOD_LSD detection circuit fails to detect the LED failure, the LOD_LSD self-test function can identify and report the malfunction.

The LOD_LSD self-test function can be executed by sending the LOD_LSD self-test command. The LOD_LSD_FLAG is 000b by default. After the LOD_LSD self-test command, if there is no fault on the LOD_LSD detection circuit, the LOD_LSD_FLAG value is 011b. If there are failures on LOD_LSD detection circuits, the LOD_LSD_FLAG value is 110b, the ERR pin is pulled low, and the bit values stay unchanged until the fault is removed and an ERROR clear command is executed. If the LOD_LSD_FLAG is neither 011b nor 110b, there should be something wrong in the self-test procedure.

7.3.4.8 $\overline{\text{ERR}}$ Pin

The TLC6C5716-Q1 device supports an active-low open-drain error output. Figure 24 shows the error pulldown block diagram. Ten bits of error status information control the error pulldown circuit directly. But an LED failure can be masked by the LED_ERR_MASK bit. The LED_ERR_MASK default value is 1, and the LED failure is masked from the error pulldown circuit. Even if there is an LED failure, the ERR pin is not pulled down by this LED failure. If the LED_ERR_MASK is 0, the ERR pin is pulled down by the LED failure to indicate an error scenario. Users can use an MCU interrupt to read out the fault information.

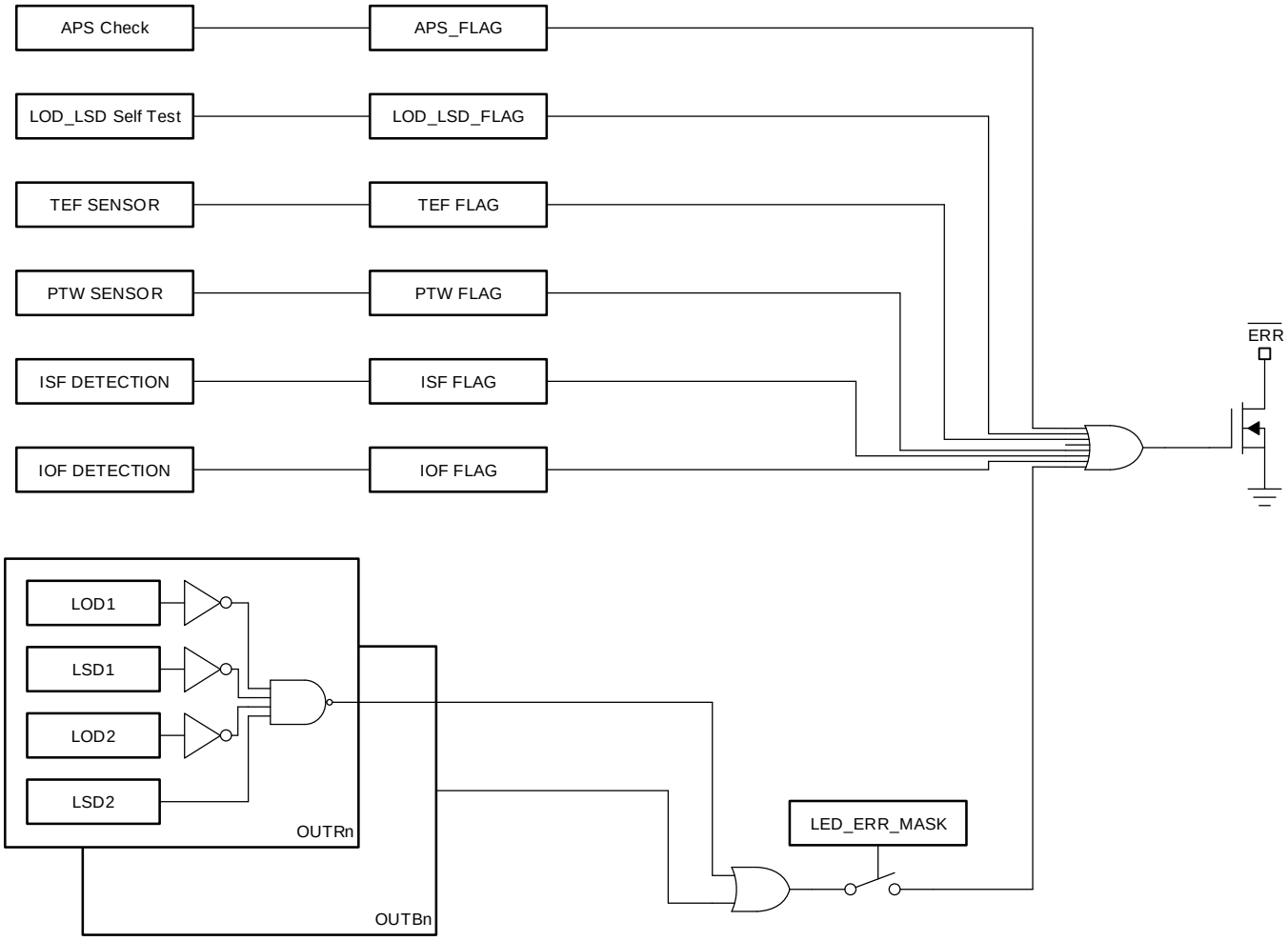


Figure 24. $\overline{\text{ERR}}$ Pin Pulldown Scheme

7.3.4.9 ERROR Clear

This command is used to clear the error flags in the error status register and APS register. The A53h 12-bit command code initiates an ERROR clear command. After executing an ERROR clear command, the 96-bit LOD_LSD registers, 1-bit NEG1, 1-bit NEG2, 10-bit error status, and 24-bit adjacent-pin-short results are loaded into the common shift register, and the error status registers and APS registers are reset to 0 if the error is removed. See Figure 9 for more detail.

7.3.4.10 Global Reset

This command is used to implement a power-on reset with software input. The A5Ch 12-bit command code initiates a global reset command. After executing a global reset command, all internal registers are reset to their default values. See Figure 10 for more detail.

7.3.4.11 Slew Rate Control

To improve system EMI performance, the TLC6C5716-Q1 device implements a programmable slew rate control for the output channels. This output slew rate is configured by the SLEW_RATE bit in the FC-BC-DC register. The SLEW_RATE bit is 0 by default, with output rise and fall times of 200 ns. When the SLEW_RATE bit is 1, the rise and falll times of each output are 100 ns.

7.3.4.12 Channel Group Delay

Large surge currents may flow through the system if all 24 channels turn on simultaneously. These large current surges could induce detrimental noise and electromagnetic interference (EMI) into other circuits. The TLC6C5716-Q1 device implements channel turnon delay for each group to reduce the surge current. The output channels are grouped into four groups.

Group 1: OUTR0, -B0, OUTR4, -B4.
Group 2: OUTR1, -B1, OUTR5, -B5.
Group 3: OUTR2, -B2, OUTR6, -B6.
Group 4: OUTR3, -B3, OUTR7, -B7.

All group 2 channels turn on and off 50 ns later then group 1 channels, all group 3 channels turn on and off 50 ns later than group 2 channels, and all group 4 channels turn on and off 50 ns later than group 3 channels. Figure 1 shows the details.

7.4 Device Functional Modes

7.4.1 Power Up

To make the device work normally, users must provide two power supples to the TLC6C5716-Q1 device. One is V_{CC}, 3 V–5.5 V, for device internal logic power; the other is a supply up to 8 V, which is the power supply for the LED loads. To make sure the LED diagnostic features work normally, the LED supply must connect to the SENSE pin directly.

7.4.2 Device Initialization

After device power on, users must send the error clear command and global reset command to initialize the device and make sure there are no existing faults in the circuit.

7.4.3 Fault Mode

The TLC6C5716-Q1 has full diagnostics features. The device can detect faults and latch the faults into registers. For device faults such as IREF resistor open or short, the device enters a self-protection state, in which it reports the faults and sets the output current to a default value. For the overtemperature fault, the device turns off the output channels and latches the fault into the SID register. Except for these two faults, for all other faults including LED faults, the device only detects and reports the faults, but does not take actions to handle the faults, and the channels keep their configured status. Users must read out faults and decide how to handle the faults.

7.4.4 Normal Operation

Users must program the device through the serial interface for normal operation. Users write to the FC-BC-DC registers to set the operation mode and output current, write to the grayscale registers to set the PWM duty cycle for each channel, and read the SID registers to get device fault information.

7.5 Programming

7.5.1 Register Write and Read

The TLC6C5716-Q1 device is programmable via serial interface. It contains a 288-bit common shift register to shift data from SDI into the device. The register LSB connects to SDI and the MSB connects to SDO. On each SCK rising edge, the data on SDI shifts into the register LSB and all 288-bit data shifts towards the MSB. The data appears on SDO when the 288-bit common shift register overflows.

The TLC6C5716-Q1 data write command contains 288-bit data. According to the following different criteria, there are three types of data write commands: FC-BC-DC write, GS data write, and special commands.

Programming (continued)

- When LATCH is high at the 288th SCK rising edge, and the 12 MSBs of the 288-bit data are 0, the 205 LSBs of the 288-bit data shift to the function control (FC), brightness control (BC). and dot correction (DC) registers on the LATCH rising edge, as shown in Figure 2.
- When LATCH is low at the 288th SCK rising edge, all 288-bit data shifts into the grayscale (GS) configuration registers on the LATCH rising edge, as shown in Figure 1.
- When LATCH is high at the 288th SCK rising edge, and the 12 MSBs of the 288-bit data match any of the eight 12-bit command codes, the device executes the corresponding command after the LATCH rising edge, as shown in Special Command Function.

When the device powers on, the default value of the 288-bit common shift register is 0.

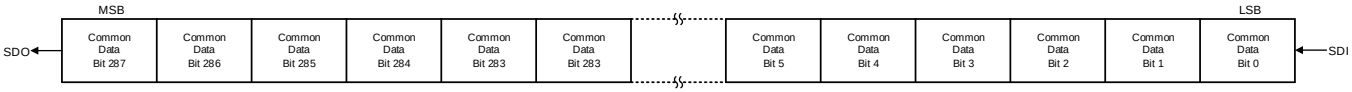


Figure 25. TLC6C5716-Q1 Common Register

7.5.1.1 FC-BC-DC Write

The device latches the 205 LSBs of data in the 288-bit common shift register into the FC-BC-DC registers at the rising edge of the latch signal when the 12 MSBs of the 288-bit data are 0.

When the device is powered on, the FC-BC-DC data latch is reset to all 0s. Therefore, data must be written to the 288-bit common shift register and latched into the FC-BC-DC registers before turning on the constant-current outputs. It is better to keep BLANK low to prevent the outputs from turning on.

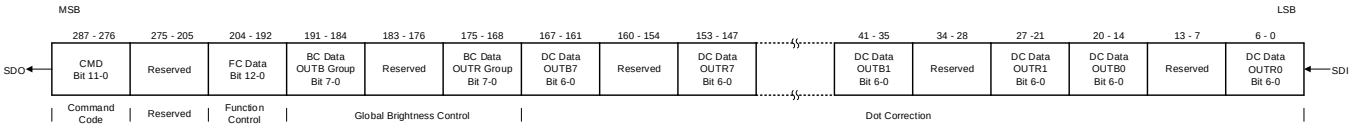


Figure 26. FC-BC-DC Register

7.5.1.1.1 FC Data Write

The FC data is 13 bits in length, located from bit 204 to bit 192. See Table 12 for the detailed description. The default value for all FC data is 0, except for the LED_ERR_MASK bit which is 1.

Table 12. Function-Control Data-Bit Assignment

BIT	NAME	DESCRIPTION
204	LED_ERR_MASK	LOD-LSD failure or PWM error information mask bit 0b = Any LOD-LSD failure or PWM error pulls down the ERR pin 1b = LOD-LSD failure or PWM error is masked from affecting the ERR pin
203	SLEW_RATE	Turnon and turnoff speed configuration bit 0b = 200-ns rise and fall times. 1b = 100-ns rise and fall times.
202	LOD_VOLATGE	LED open-detection (LOD) threshold 0b = LOD threshold is 0.3 V 1b = LOD threshold is 0.5 V
201	LSD_VOLTAGE	LED short-detection (LSD) threshold 0b = LSD threshold is V_{SENSE} – 0.3 V 1b = LSD threshold is V_{SENSE} – 0.7 V
200	APS_CURRENT	Adjacent-pin short-detection sink current 0b = 20-µA APS current 1b = 40-µA APS current
199	APS_TIME	Adjacent-pin short-detection time 0b = 10-µs APS detection time 1b = 20-µs APS detection time

Programming (continued)

Table 12. Function-Control Data-Bit Assignment (continued)

BIT	NAME	DESCRIPTION
198–197	GS_MODE	Grayscale-counter mode selection. 00 or 01b = 12-bit mode 10b = 10-bit mode 11b = 8-bit mode
196	TIMING_RESET	Display-timing reset mode 0b = Disabled 1b = Enabled
195	AUTO_REPEAT	Auto-display repeat mode 0b = Disabled 1b = Enabled
194	DC_RANGE_B	Dot-correction adjustment range for the BLUE color output 0b = Low range, 0%–66.7% 1b = High range, 33.3%–100%
193	Reserved	Reserved
192	DC_RANGE_R	Dot–correction adjustment range for the RED color output 0b = Low range, 0%–66.7% 1b = High range, 33.3%–100%

The grayscale counter has 12-bit, 10-bit, and 8-bit configurations. Bits 198–197 in the FC register configure the grayscale counter mode.

Table 13. GS Counter Mode Table

GRAYSCALE COUNTER MODE (GS_MODE)		FUNCTION MODE
Bit 198	Bit 197	
0	Don't care	12-bit counter mode
1	0	10-bit counter mode, the lowest 10 bits of the 12-bit GS data are valid
1	1	8-bit counter mode, the lowest 8 bits of the 12-bit GS data are valid

7.5.1.1.2 BC Data Write

The BC data is 24 bits in length, located from bit 191 to bit 168. The data of the BC data latch are used to adjust the constant-current values for eight channels of constant-current drivers for each color group. The current can be adjusted by a brightness control with 8-bit resolution from 0% to 100% of maximum for each output.

Table 14. Brightness-Control Data-Bit Assignments

BITS	BRIGHTNESS CONTROL DATA
191–184	OUTB0-OUTB7 group
183–176	Reserved
175–168	OUTR0-OUTR7 group

7.5.1.1.3 DC Data Write

The DC data is 168 bits in length, which located from bit 167 to bit 0. The TLC6C5716-Q1 device can adjust the output current of each channel using the DC function. Each DC function has two adjustment ranges with 7-bit resolution. Table 15 shows the DC data assignments in the DC registers. The high adjustment range DC can adjust output current from 33.3% to 100% of $I_{(OUT)max}$. The low adjustment range DC can configure output current from 0% to 66.7% of $I_{(OUT)max}$. The range control bits, which are bits 194–192 in the function control data latch, select the high or low adjustment. Bit 194 controls the OUTB DC range. Bit 192 controls the OUTR DC range. For details, see Table 12.

Table 15. DC Data Assignments

BITS	DATA	BITS	DATA
167–161	OUTB7	83–77	OUTB3
160–154	Reserved	76–70	Reserved
153–147	OUTR7	69–63	OUTR3
146–140	OUTB6	62–56	OUTB2
139–133	Reserved	55–49	Reserved
132–126	OUTR6	48–42	OUTR2
125–119	OUTB5	41–35	OUTB1
118–112	Reserved	34–28	Reserved
111–105	OUTR5	27–21	OUTR1
104–98	OUTB4	20–14	OUTB0
97–91	Reserved	13–7	Reserved
90–84	OUTR4	6–0	OUTR0

Table 16. Output Current vs High DC Range

DC DATA (BINARY)	DC DATA (DECIMAL)	DC DATA (HEX)	BC DATA (HEX)	CURRENT RATIO (%)	CURRENT ($I_{(OUT)max}$ = 40 mA)	CURRENT ($I_{(OUT)max}$ = 2 mA)
000 0000	0	00	FF	33.3	13.33	0.67
000 0001	1	01	FF	33.9	13.54	0.68
000 0010	2	02	FF	34.4	13.75	0.69
...	...	...	...	...	...	...
111 1101	125	7D	FF	99	39.58	1.98
111 1110	126	7E	FF	99.5	39.79	1.99
111 1111	127	7F	FF	100	40	2

Table 17. Output Current vs Low DC Range

DC DATA (BINARY)	DC DATA (DECIMAL)	DC DATA (HEX)	BC DATA (HEX)	CURRENT RATIO (%)	CURRENT ($I_{(OUT)max}$ = 40 mA)	CURRENT ($I_{(OUT)max}$ = 2 mA)
000 0000	0	00	FF	0	0.	0
000 0001	1	01	FF	0.5	0.21	0.01
000 0010	2	02	FF	1	0.42	0.02
...	...	...	...	...	...	...
111 1101	125	7D	FF	65.6	26.25	1.31
111 1110	126	7E	FF	66.1	26.46	1.32
111 1111	127	7F	FF	66.7	26.67	1.33

Table 18. Output Current vs BC (High DC Range)

BC DATA (BINARY)	BC DATA (DECIMAL)	BC DATA (HEX)	BC DATA (HEX)	CURRENT RATIO (%)	CURRENT ($I_{(OUT)max}$ = 40 mA)	CURRENT ($I_{(OUT)max}$ = 2 mA)
0000 0000	0	00	7F	0	0	0
0000 0001	1	01	7F	0.4	0.16	0.01
0000 0010	2	02	7F	0.8	0.32	0.02
...	...	...	...	...	...	...
1111 1101	253	FD	7F	99.2	39.69	1.98
1111 1110	254	FE	7F	99.6	39.84	1.99
1111 1111	255	FF	7F	100	40	2

7.5.1.2 Grayscale Data Write

The grayscale data is 288 bits long, and contains a 12-bit grayscale value for each output. The grayscale value sets the channel turnon time.Figure 27 shows the GS register configuration. Figure 1 is the GS write timing diagram. Data is latched from the 288-bit common shift register into the GS data latch at the rising edge of the LATCH pin. When data is latched into the GS registers, the new data is immediately available on the constant-current outputs. If the data is latched with BLANK high, the outputs may turn on or off unexpectedly. So users should update the GS data when BLANK is low.

The 12-bit GS function has 4096 brightness steps, from 0% to 99.97% brightness. The GS function is controlled by a 12-bit GS counter. The GS counter increments on each rising edge of the grayscale reference clock GCLK. The falling edge of BLANK resets the GS counter value to 0. The GS counter value stays at 0 while BLANK is low, even if there is a GCLK input. Pulling BLANK high enables the 12-bit GS counter. The first rising edge of a GS clock after BLANK goes high increments the GS counter by one and turns on the outputs. Each additional rising edge increases the GS counter by one. The GS counter monitors the number of clock pulses on the GCLK pin. The output stays on while the counter value is less than or equal to the GS setting value. The output turns off at the rising edge of the GS counter value when the counter is larger than the GS setting value. Table 20 is the on-time duty cycle of each GS data bit when the 12-bit GS counter mode is selected.

When the device is powered up, the 288-bit common shift register and GS data latch are reset to 0.

Equation 4 describes each output on-time.

$$t_{ON} = t_{GCLK} \times GS \quad (4)$$

where

- t_{GCLK} is the GS clock period
- GS is the programmed grayscale value for each output.

Equation 5 shows the duty-cycle calculation equation.

$$Dutycycle = \frac{GS}{4096} \quad (5)$$

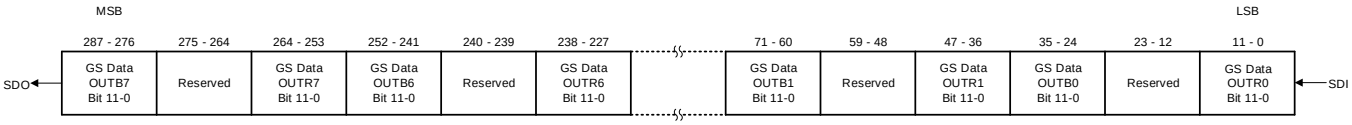


Figure 27. TLC6C5716-Q1 Grayscale Register

Once the GS data is latched into the GS registers at the rising edge of the LATCH signal, the FC-BC-DC data latch shifts into the lowest 205 bits of the common shift register. So, the FC-BC-DC data can be read out from SDO in GS write. This FC-BC-DC read function can also be realized by the read FC-BC-DC command, see FC-BC-DC Read and Figure 8 for the timing diagram.

Table 19. Grayscale Data Bit Assignments

BITS	DATA	BITS	DATA
287–276	OUTB7	143–132	OUTB3
275–264	Reserved	131–120	Reserved
263–252	OUTR7	119–108	OUTR3
251–240	OUTB6	107–96	OUTB2
239–228	Reserved	95–84	Reserved
227–216	OUTR6	83–72	OUTR2
215–204	OUTB5	71–60	OUTB1
203–192	Reserved	59–48	Reserved
191–180	OUTR5	47–36	OUTR1
179–168	OUTB4	35–24	OUTB0
167–156	Reserved	35–24	Reserved
155–144	OUTR4	11–0	OUTR0

Table 20. GS Data vs Output On Time

GS DATA (BINARY)	GS DATA (DECIMAL)	GS DATA (HEX)	DUTY CYCLE (%)	ON-TIME BASED ON 33-MHz GS CLOCK (ns)
0000 0000 0000	0	000	0	0
0000 0000 0001	1	001	0.02	30
0000 0000 0010	2	002	0.05	61
...	...	...	...	...
0111 1111 1111	2047	7FF	49.97	62 030
1000 0000 0000	2048	800	50.00	62 061
1000 0000 0001	2049	801	50.02	62 091
...	...	...	...	...
1111 1111 1101	4093	FFD	99.93	124 030
1111 1111 1110	4094	FFE	99.95	124 061
1111 1111 1111	4095	FFF	99.98	124 091

7.5.1.3 Special Command Function

There are eight special command codes defined in the TLC6C5716-Q1 device, shown in Table 21. To input the command, the level of LATCH at the last SCK before the LATCH rising edge must be high, and the highest 12 bits should be one of the below 8 command codes. In this condition, the device ignores other bits and no data are latched into FC-BC-DC registers. Normally users can write other bits to 0 in the special command. The corresponding command function executes after the rising edge of LATCH signal.

If no special command code is identified, the command is a NULL command and no special command is executed. The command is the same as the FC-BC-DC write function.

Table 21. Special Command Codes

COMMAND	COMMAND CODE	FUNCTION
GS read	5AFh (0101 1010 1111b)	Load GS data into common register.
SID read	5A3h (0101 1010 0011b)	Load SID data into common register.
FC-BC-DC read	5ACh (0101 1010 1100b)	Load FC-BC-DC data into common register. This reading function can also be achieved by GS data write.
APS check	53Ah (0101 0011 1010b)	Adjacent pin short detection, APS test starts at the rising edge of Latch signal, then set APS register(24bits) and APS_Flag in SID register according to the test result. Keep all channels off during this test.
LOD_LSD self-test	535h (0101 0011 0101b)	LOD-LSD detector circuit self test and set LOD_LSD_FLAG in SID register according to the test result.
Negate bit toggle	55Ah (0101 0101 1010b)	Toggle Negate Bit. When Negate Bit = 0, the 48 bits LOD-LSD detector output data will be latched into LOD1-LSD1 and LOD2-LSD2 register without invert. When Negate Bit =1, the 48 bits LOD-LSD detector output data will invert, and latch into LOD1-LSD1 and LOD2-LSD2 register.
ERROR clear	A53h (1010 0101 0011b)	Load SID data into common register, and then reset the Error status register and APS register to 0.
GLOBAL reset	A5Ch (1010 0101 1100b)	All internal registers are reset. The command has the same function as power on reset.
NULL	Different from any of the above commands	The same function as FC-BC-DC write.

7.5.1.3.1 GS Read

The GS read command loads the 288-bit GS data into the common register. By applying 288 SCK clocks, the GS data shifts out from SDO pin. For details, see Figure 3.

7.5.1.3.2 FC-BC-DC Read

There are two ways to read the FC-BC-DC data latch.

One way is latching data into the GS data latch. After the GS write finishes, the FC-BC-DC data latches into the lowest 205 bits of the common shift register.

Another way is using the FC-BC-DC read command. After the FC-BC-DC read command finishes, the FC-BC-DC data latches into the lowest 205 bits of the common shift register.

By applying 288 SCK clocks, the FC-BC-DC data shifts out from the SDO pin. For details, see Figure 8

7.5.1.3.3 Status Information Data Read

Status information data (SID) is 132 bits long and contains device status information and LED fault information. Table 22 describes the bit mapping when the SID data loads into the common shift register.

Bits 287–240 are the LED-open information for the output channels, bits 203–144 are the LED-short information for the output channels, bits 239–216 are the adjacent-pin-short information for the output channels, bits 215–206 are the error status registers, bits 205–204 are the negate bits, and the others are reserved registers.

After power on, all error status registers are set to 0. If any one of the error-status-register flags (bits 215-206) asserts, the registers latch the faults until a reset error command is executed to clear the faults. But the LOD_LSD data continues to update every PWM cycle.

Table 22. SID Register

BITS OF COMMON SHIFT REGISTER	DESCRIPTION
287–280	LOD2 data for OUTB7–OUTB0
279–272	Reserved
271–264	LOD2 data for OUTR7–OUTR0
263–256	LOD1 data for OUTB7–OUTB0
255–248	Reserved
247–240	LOD1 data for OUTR7–OUTR0
239–232	APS data for OUTB7–OUTB0
231–224	APS data for NU pins [pin 7, pin 10, pin 13, pin 16, pin 23, pin 26, pin 29, pin 32]
223–216	APS data for OUTR7–OUTR0
215	Thermal error flag (TEF). 0b = Normal temperature condition, 1b = High-temperature condition.
214	Pre-thermal warning (PTW). 0b = No pre-thermal warning, 1b = Pre-thermal threshold triggered.
213–211	Adjacent-pin short-check result (APS_FLAG). 011b: pass, 110b: fail.
210	IREF-resistor short flag (ISF). 0b = IREF resistor is not shorted, 1b = IREF resistor short detected.
209	IREF-resistor open flag (IOF). 0b = IREF Resistor is not open, 1b = IREF resistor open detected.
208–206	LOD-LSD detection circuit self-test result (LOD_LSD_FLAG). 011b: pass, 110b: fail.
205	Negate bit for LOD1-LSD1 register (NEG1)
204	Negate bit for LOD2-LSD2 register (NEG2)
203–192	Reserved
191–184	LSD2 data for OUTB7–OUTB0
183–176	Reserved
175–168	LSD2 data for OUTR7–OUTR0
167–160	LSD1 data for OUTB7–OUTB0
159–152	Reserved
151–144	LSD1 data for OUTR7–OUTR0
143–0	Reserved

7.6 Register Maps

The TLC6C5716-Q1 register map includes three sections: GS registers, FC_BC_DC registers, and SID registers. Users can write to the GS registers and FC_BC_DC registers through the serial interface. Status information can be read out though the serial interface.

Register Maps (continued)

7.6.1 GRAYSCALE Registers

Table 23 lists the memory-mapped registers for the GRAYSCALE. All register offset addresses not listed in Table 23 should be considered as reserved locations and the register contents should not be modified.

Grayscale Register

Table 23. GRAYSCALE Registers

Offset	Acronym	Register Name	Section
0h	OUTn_GS	OUTn_GS Register	Go

Complex bit access types are encoded to fit into small table cells. Table 24 shows the codes that are used for access types in this section.

Table 24. GRAYSCALE Access Type Codes

Access Type	Code	Description
Read Type		
R	R	Read
Write Type		
W	W	Write
Reset or Default Value		
-n		Value after reset or the default value

7.6.1.1 OUTn_GS Register (Offset = 0h)

OUTn_GS is shown in Figure 28 and described in Table 25.

Return to Summary Table.

OUTn Grayscale Register

Figure 28. OUTn_GS Register

287	286	285	284	283	282	281	280	279	278	287	286
OUTB7_GS											
R/W-0h											
275	274	273	272	271	270	269	268	267	266	265	264
RESERVED											
R/W-0h											
263	262	261	260	259	258	257	256	255	254	253	252
OUTR7_GS											
R/W-0h											
251	250	249	248	247	246	245	244	243	242	241	240
OUTB6_GS											
R/W-0h											
239	238	237	236	235	234	233	232	231	230	229	228
RESERVED											
R/W-0h											
227	226	225	224	223	222	221	220	219	218	217	216
OUTR6_GS											
R/W-0h											
215	214	213	212	211	210	209	208	207	206	205	204
OUTB5_GS											
R/W-0h											

203	202	201	200	199	198	197	196	195	194	193	192
RESERVED											
R/W-0h											
191	190	189	188	187	186	185	184	183	182	181	180
OUTR5_GS											
R/W-0h											
179	178	177	176	175	174	173	172	171	170	169	168
OUTB4_GS											
R/W-0h											
167	166	165	164	163	162	161	160	159	158	157	156
RESERVED											
R/W-0h											
155	154	153	152	151	150	149	148	147	146	145	144
OUTR4_GS											
R/W-0h											
143	142	141	140	139	138	137	136	135	134	133	132
OUTB3_GS											
R/W-0h											
131	130	129	128	127	126	125	124	123	122	121	120
RESERVED											
R/W-0h											
119	118	117	116	115	114	113	112	111	110	109	108
OUTR3_GS											
R/W-0h											
107	106	105	104	103	102	101	100	99	98	97	96
OUTB2_GS											
R/W-0h											
95	94	93	92	91	90	89	88	87	86	85	84
RESERVED											
R/W-0h											
83	82	81	80	79	78	77	76	75	74	73	72
OUTR2_GS											
R/W-0h											
71	70	69	68	67	66	65	64	63	62	61	60
OUTB1_GS											
R/W-0h											
59	58	57	56	55	54	53	52	51	50	49	48
RESERVED											
R/W-0h											
47	46	45	44	43	42	41	40	39	38	37	36
OUTR1_GS											
R/W-0h											
35	34	33	32	31	30	29	28	27	26	25	24
OUTB0_GS											
R/W-0h											
23	22	21	20	19	18	17	16	15	14	13	12
RESERVED											
R/W-0h											
11	10	9	8	7	6	5	4	3	2	1	0
OUTR0_GS											
R/W-0h											

Table 25. OUTn_GS Register Field Descriptions

Bit	Field	Type	Default	Description
287–276	OUTB7_GS[11:0]	R/W	0h	Grayscale register for OUTB7
275–264	RESERVED	R/W	0h	Reserved
263–252	OUTR7_GS[11:0]	R/W	0h	Grayscale register for OUTR7
251–240	OUTB6_GS[11:0]	R/W	0h	Grayscale register for OUTB6
239–228	RESERVED	R/W	0h	Reserved
227–216	OUTR6_GS[11:0]	R/W	0h	Grayscale register for OUTR6
215–204	OUTB5_GS[11:0]	R/W	0h	Grayscale register for OUTB5
203–192	RESERVED	R/W	0h	Reserved
191–180	OUTR5_GS[11:0]	R/W	0h	Grayscale register for OUTR5
179–168	OUTB4_GS[11:0]	R/W	0h	Grayscale register for OUTB4
167–156	RESERVED	R/W	0h	Reserved
155–144	OUTR4_GS[11:0]	R/W	0h	Grayscale register for OUTR4
143–132	OUTB3_GS[11:0]	R/W	0h	Grayscale register for OUTB3
131–120	RESERVED	R/W	0h	Reserved
119–108	OUTR3_GS[11:0]	R/W	0h	Grayscale register for OUTR3
107–96	OUTB2_GS[11:0]	R/W	0h	Grayscale register for OUTB2
95–84	RESERVED	R/W	0h	Reserved
83–72	OUTR2_GS[11:0]	R/W	0h	Grayscale register for OUTR2
71–60	OUTB1_GS[11:0]	R/W	0h	Grayscale register for OUTB1
59–48	RESERVED	R/W	0h	Reserved
47–36	OUTR1_GS[11:0]	R/W	0h	Grayscale register for OUTR1
35–24	OUTB0_GS[11:0]	R/W	0h	Grayscale register for OUTB0
23–12	RESERVED	R/W	0h	Reserved
11–0	OUTR0_GS[11:0]	R/W	0h	Grayscale register for OUTR0

7.6.2 FC-BC-DC Registers

Table 26 lists the memory-mapped registers for the CONFIGURATION. All register offset addresses not listed in Table 26 should be considered as reserved locations and the register contents should not be modified.

Configuration Register

Table 26. FC-BC-DC Registers

Offset	Acronym	Register Name	Section
1h	Config	Configuration Register	Go

Complex bit access types are encoded to fit into small table cells. Table 27 shows the codes that are used for access types in this section.

Table 27. FC-BC-DC Access Type Codes

Access Type	Code	Description
Read Type		
R	R	Read
Write Type		
W	W	Write
Reset or Default Value		
-n		Value after reset or the default value

7.6.2.1 FC-BC-DC Register (Offset = 1h)

FC-BC-DC is shown in Figure 29 and described in Table 28.

Return to Summary Table.

FC-BC-DC Register

Figure 29. FC-BC-DC Register

287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272
CMD												RESERVED			
R/W-0h												R/W-0h			
271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256
RESERVED															
R/W-0h															
255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240
RESERVED															
R/W-0h															
239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224
RESERVED															
R/W-0h															
223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208
RESERVED															
R/W-0h															
207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192
RESERVED			LED_ERR_MASK	SLEW_RATE	LOD_VOLTAGE	LSD_VOLTAGE	APS_CURRENT	APS_TIME	GS_MODE		TIMING_RESET	AUTO_REPEAT	DC_RANGE_B	RESERVED	DC_RANGE_R
R/W-0h			R/W-1h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h		R/W-0h	R/W-0h	R/W-0h	R/W-0h	R/W-0h
191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176
OUTB_BC								RESERVED							
R/W-0h								R/W-0h							
175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160
OUTR_BC								OUTB7_DC							→
R/W-0h								R/W-0h							→
159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144
←	RESERVED					OUTR7_DC							OUTB6_DC		
←	R/W-0h					R/W-0h							R/W-0h		
143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128
OUTB6_DC				RESERVED							OUTR6_DC				
R/W-0h				R/W-0h							R/W-0h				

127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112
OUTR6_DC							OUTB5_DC						RESERVED		
R/W-0h							R/W-0h						R/W-0h		
111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96
OUTR5_DC							OUTB4_DC							RESERVED	
R/W-0h							R/W-0h							R/W-0h	
95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80
RESERVED					OUTR4_DC							OUTB3_DC			
R/W-0h					R/W-0h							R/W-0h			
79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64
OUTB3_DC			RESERVED							OUTR3_DC					→
R/W-0h			R/W-0h							R/W-0h					→
63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
←	OUTB2_DC							RESERVED							→
←	R/W-0h							R/W-0h							→
47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
←	OUTR2_DC					OUTB1_DC							RESERVED		
←	R/W-0h					R/W-0h							R/W-0h		
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RESERVED				OUTR1_DC							OUTB0_DC				
R/W-0h				R/W-0h							R/W-0h				
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OUTB0_DC				RESERVED						OUTR0_DC					
R/W-0h				R/W-0h						R/W-0h					

Table 28. FC-BC-DC Register Field Descriptions

Bit	Field	Type	Default	Description
287–276	CMD[11:0]	R/W	0h	Command function 25Ch = Global reset 535h = LOD_LSD self-test 53Ah = APS check 55Ah = NEG-BIT toggle 5A3h = SID read 5ACh = FC_BC_DC read 5AFh = GS read A53h = ERROR clear All other values = NULL
275–205	RESERVED	R/W	0h	Reserved
204	LED_ERR_MASK	R/W	1h	LED error mask 0h = Unmask LED error 1h = Mask LED error
203	SLEW_RATE	R/W	0h	Output slew-rate 0h = 100 ns 1h = 200 ns
202	LOD_VOLTAGE	R/W	0h	LED-open detection voltage 0h = 0.3 V 1h = 0.5 V
201	LSD_VOLTAGE	R/W	0h	LED-short detection voltage 0h = V_{VSENSE} – 0.3 V 1h = V_{VSENSE} – 0.7 V

Table 28. FC-BC-DC Register Field Descriptions (continued)

Bit	Field	Type	Default	Description
200	APS_CURRENT	R/W	0h	Adjacent-pin short-detection sink current 0h = 20 µA 1h = 40 µA
199	APS_TIME	R/W	0h	Adjacent-pin short-detection time 0h = 10 µs 1h = 20 µs
198–197	GS_MODE[1:0]	R/W	0h	Grayscale counter mode 0h or 1h = 12-bit counter mode 2h = 10-bit counter mode 3h = 8-bit counter mode
196	TIMING_RESET	R/W	0h	Display timing reset 0h = Disabled 1h = Enabled
195	AUTO_REPEAT	R/W	0h	Auto repeat 0h = Disabled 1h = Enabled
194	DC_RANGE_B	R/W	0h	Dot correction range for OUTB group 0h = Low range 1h = High range
193	RESERVED	R/W	0h	Reserved
192	DC_RANGE_R	R/W	0h	Dot correction range for OUTR group 0h = Low range 1h = High range
191–184	OUTB_BC[7:0]	R/W	0h	Brightness control for OUTB group
183–176	RESERVED	R/W	0h	Reserved
175–168	OUTR_BC[7:0]	R/W	0h	Brightness control for OUTR group
167–161	OUTB7_DC[6:0]	R/W	0h	Dot correction for OUTB7
160–154	RESERVED	R/W	0h	Reserved
153–147	OUTR7_DC[6:0]	R/W	0h	Dot correction for OUTR7
146–140	OUTB6_DC[6:0]	R/W	0h	Dot correction for OUTB6
139–133	RESERVED	R/W	0h	Reserved
132–126	OUTR6_DC[6:0]	R/W	0h	Dot correction for OUTR6
125–119	OUTB5_DC[6:0]	R/W	0h	Dot correction for OUTB5
118–112	RESERVED	R/W	0h	Reserved
111–105	OUTR5_DC[6:0]	R/W	0h	Dot correction for OUTR5
104–98	OUTB4_DC[6:0]	R/W	0h	Dot correction for OUTB4
97–91	RESERVED	R/W	0h	Reserved
90–84	OUTR4_DC[6:0]	R/W	0h	Dot correction for OUTR4
83–77	OUTB3_DC[6:0]	R/W	0h	Dot correction for OUTB3
76–70	RESERVED	R/W	0h	Reserved
69–63	OUTR3_DC[6:0]	R/W	0h	Dot correction for OUTR3
62–56	OUTB2_DC[6:0]	R/W	0h	Dot correction for OUTB2

Table 28. FC-BC-DC Register Field Descriptions (continued)

Bit	Field	Type	Default	Description
55–49	RESERVED	R/W	0h	Reserved
48–42	OUTR2_DC[6:0]	R/W	0h	Dot correction for OUTR2
41–35	OUTB1_DC[6:0]	R/W	0h	Dot correction for OUTB1
34–28	RESERVED	R/W	0h	Reserved
27–21	OUTR1_DC[6:0]	R/W	0h	Dot correction for OUTR1
20–14	OUTB0_DC[6:0]	R/W	0h	Dot correction for OUTB0
13–7	RESERVED	R/W	0h	Reserved
6–0	OUTR0_DC[6:0]	R/W	0h	Dot correction for OUTR0

7.6.3 SID Registers

Table 29 lists the memory-mapped registers for the SID. All register offset addresses not listed in Table 29 should be considered as reserved locations and the register contents should not be modified.

SID Register

Table 29. SID Registers

Offset	Acronym	Register Name	Section
2h	SID	SID Register	Go

Complex bit access types are encoded to fit into small table cells. Table 30 shows the codes that are used for access types in this section.

Table 30. SID Access Type Codes

Access Type	Code	Description
Read Type		
R	R	Read
Reset or Default Value		
-n		Value after reset or the default value

7.6.3.1 SID Register (Offset = 2h)

SID is shown in Figure 30 and described in Table 31.

Return to Summary Table.

Status information data

Figure 30. SID Register

287	286	285	284	283	282	281	280	279	278	277	276	275	274	273	272
OUTB_LOD2								RESERVED							
R-0h								R-0h							
271	270	269	268	267	266	265	264	263	262	261	260	259	258	257	256
OUTR_LOD2								OUTB_LOD1							
R-0h								R-0h							
255	254	253	252	251	250	249	248	247	246	245	244	243	242	241	240
RESERVED								OUTR_LOD1							
R-0h								R-0h							
239	238	237	236	235	234	233	232	231	230	229	228	227	226	225	224
OUTB_APS								NU_PIN_APS							
R-0h								R-0h							

223	222	221	220	219	218	217	216	215	214	213	212	211	210	209	208
OUTR_APS								TEF	PTW	APS_FLAG			ISF	IOF	→
R-0h								R-0h	R-0h	R-0h			R-0h	R-0h	→
207	206	205	204	203	202	201	200	199	198	197	196	195	194	193	192
← LOD_LSD_FLAG		NEG1	NEG0	RESERVED											
← R-0h		R-0h	R-0h	R-0h											
191	190	189	188	187	186	185	184	183	182	181	180	179	178	177	176
OUTB_LSD2								RESERVED							
R-0h								R-0h							
175	174	173	172	171	170	169	168	167	166	165	164	163	162	161	160
OUTR_LSD2								OUTB_LSD1							
R-0h								R-0h							
159	158	157	156	155	154	153	152	151	150	149	148	147	146	145	144
RESERVED								OUTR_LSD1							
R-0h								R-0h							
143	142	141	140	139	138	137	136	135	134	133	132	131	130	129	128
RESERVED															
R-0h															
127	126	125	124	123	122	121	120	119	118	117	116	115	114	113	112
RESERVED															
R-0h															
111	110	109	108	107	106	105	104	103	102	101	100	99	98	97	96
RESERVED															
R-0h															
95	94	93	92	91	90	89	88	87	86	85	84	83	82	81	80
RESERVED															
R-0h															
79	78	77	76	75	74	73	72	71	70	69	68	67	66	65	64
RESERVED															
R-0h															
63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
RESERVED															
R-0h															
47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32
RESERVED															
R-0h															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RESERVED															
R-0h															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RESERVED															
R-0h															

Table 31. SID Register Field Descriptions

Bit	Field	Type	Default	Description
287–280	OUTB_LOD2[7:0]	R	0h	LOD2 for OUTB7–OUTB0. For each channel: 0h = No fault detected 1h = Fault detected
279–272	RESERVED	R	0h	Reserved

Table 31. SID Register Field Descriptions (continued)

Bit	Field	Type	Default	Description
271–264	OUTR_LOD2[7:0]	R	0h	LOD2 for OUTR7–OUTR0. For each channel: 0h = No fault detected 1h = Fault detected
263–256	OUTB_LOD1[7:0]	R	0h	LOD1 for OUTB7–OUTB0. For each channel: 0h = No fault detected 1h = Fault detected
255–248	RESERVED	R	0h	Reserved
247–240	OUTR_LOD1[7:0]	R	0h	LOD1 for OUTR7–OUTR0. For each channel: 0h = No fault detected 1h = Fault detected
239–232	OUTB_APS[7:0]	R	0h	APS status for OUTB7–OUTB0. For each channel: 0h = No fault detected 1h = Fault detected
231–224	NU_PIN_APS[7:0]	R	0h	APS status of not-used pins , NU_PIN_APS[7:0] = [pin7, pin10, pin13, pin16, pin23, pin26, pin29, pin32] 0h = No fault detected 1h = Fault detected
223–216	OUTR_APS[7:0]	R	0h	APS status for OUTR7–OUTR0. For each channel: 0h = No fault detected 1h = Fault detected
215	TEF	R	0h	Thermal error flag 0h = No fault detected 1h = Fault detected
214	PTW	R	0h	Pre-thermal warning flag 0h = No fault detected 1h = Fault detected
213–211	APS_FLAG[2:0]	R	0h	APS test flag fault 3h = APS test passes 6h = APS test fails
210	ISF	R	0h	ISF fault 0h = No fault detected 1h = Fault detected
209	IOF	R	0h	IOF fault 0h = No fault detected 1h = Fault detected
208– 206	LOD_LSD_FLAG[2:0]	R	0h	LOD_LSD self-test flag 3h = LOD_LSD self-test passes 6h = LOD_LSD self-test fails
205	NEG1	R	0h	Neg1 bit value
204	NEG0	R	0h	Neg0 bit value
203–192	RESERVED	R	0h	Reserved
191–184	OUTB_LSD2[7:0]	R	0h	LSD2 for OUTB7–OUTB0. For each channel: 0h = No fault detected 1h = Fault detected
183–176	RESERVED	R	0h	Reserved

Table 31. SID Register Field Descriptions (continued)

Bit	Field	Type	Default	Description
175–168	OUTR_LSD2[7:0]	R	0h	LSD2 for OUTR7–OUTR0. For each channel: 0h = No fault detected 1h = Fault detected
167–160	OUTB_LSD1[7:0]	R	0h	LSD1 for OUTB7– OUTB0. For each channel: 0h = No fault detected 1h = Fault detected
159–152	RESERVED	R	0h	Reserved
151–144	OUTR_LSD1[7:0]	R	0h	LSD1 for OUTR7–OUTR0. For each channel: 0h = No fault detected 1h = Fault detected
143–0	RESERVED	R	0h	Reserved

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

Below is a typical application for an automotive local dimming application.

8.2 Typical Application

In automotive LCD display applications such as a solid-state cluster or center information display, LED backlighting is one of the key parts of the display. Today most LED backlighting is the traditional edge-lit type, which means the backlighting is globally dimmed. This method consumes much power and causes light leakage from the liquid crystals in the black areas, because the backlighting is always turned on. Recently, local-dimming backlighting, a direct-lit type of backlighting, has been proposed to overcome this drawback. The lighting level of the backlighting follows the display contents. The lighting level is dynamically adjusted by the content of the image blocks for local-dimming control. When an image block is bright, the lighting level of the backlighting turns high also. Conversely, the backlighting level is adjusted to low in a black region. This arrangement reduces power dissipation and light leakage from the LCD and creates pure black, increasing the image contrast ratio.

Users can use the TLC6C5716-Q1 device to drive LED backlighting in such local dimming applications. Depending how many zones are in the display, users can connect different numbers of TLC6C5716-Q1s in a daisy chain to drive the LEDs.

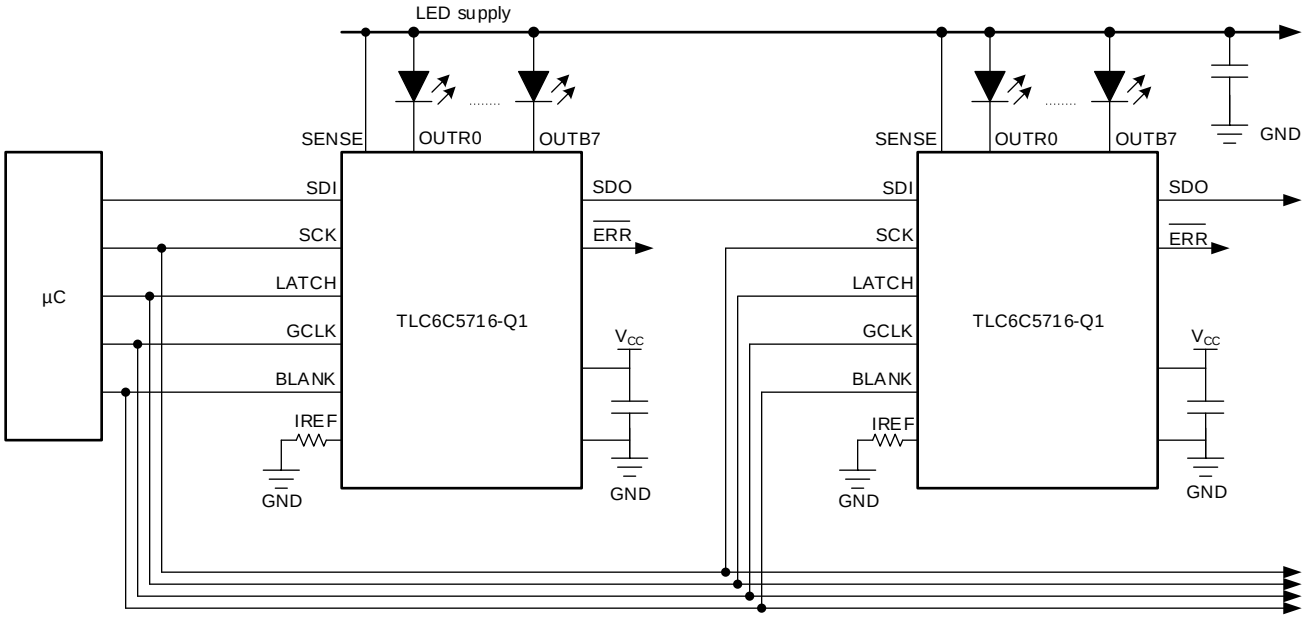


Figure 31. Typical Block Diagram for Local Dimming

Typical Application (continued)

8.2.1 Design Requirements

Table 32 shows the design requirements for the local dimming application.

Table 32. Design Requirements

PARAMETER	VALUE
LCD size	12.3 inches
Zones	128
Number of LEDs per string	1
LED current	50 mA

8.2.2 Detailed Design Procedure

As the backlighting includes 128 zones, each TLC6C5716-Q1 device can drive 16 zones, so a total of eight TLC6C5716-Q1 units are needed.

According to Maximum Constant-Sink-Current Setting, to realize 50-mA output current, users can choose a 0.96–kΩ reference resistor.

Users can use a daisy chain connection to control all of the eight TLC6C5716-Q1 devices through one serial interface, just as Figure 31 shows. Figure 32 shows how to send the data into cascaded devices, where M is the number of cascaded devices.

If more current is needed, users can parallel two outputs together to get more current.

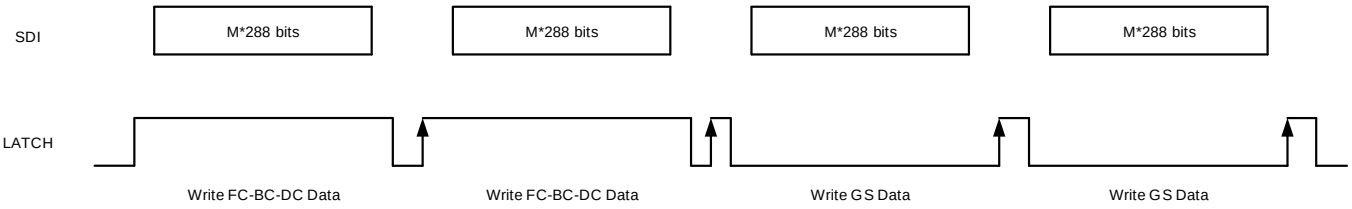


Figure 32. Cascading Data Write

8.2.3 Application Curves

Below are two test waveforms. Figure 33 shows different PWM duty cycles for different output channels, which can realize a local dimming feature. Figure 34 shows a data-write waveform typical for each write of M × 288 bits of data into the serial interface.

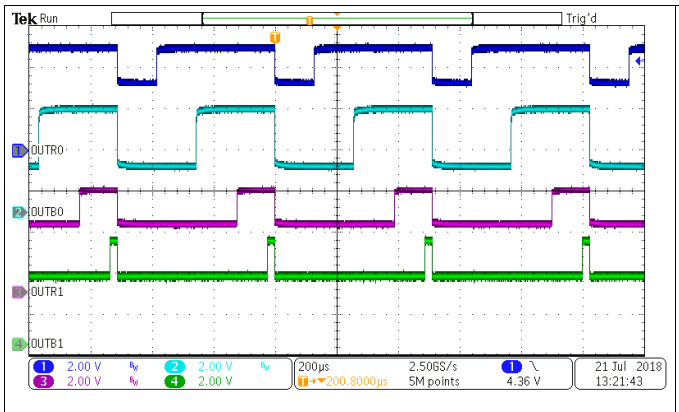


Figure 33. Individual PWM Dimming for Each Channel

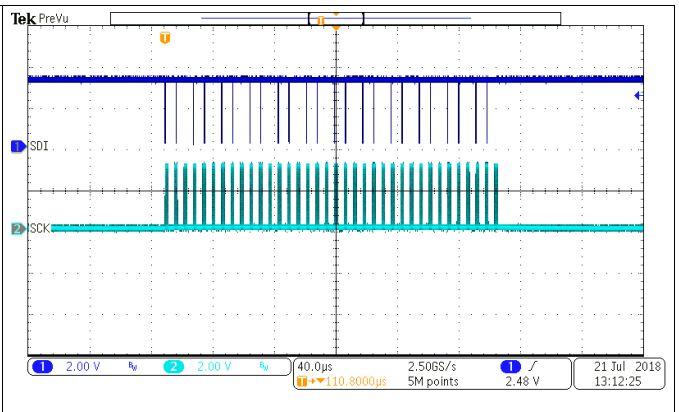


Figure 34. Data Write Through the Serial Interface

9 Power Supply Recommendations

The TLC6C5716-Q1 device requires two power supplies. One is V_{CC}, which can range from 3 V to 5.5 V. The other is V_{LED}, which can be up to 8 V. Users must add a capacitor on the V_{CC} power supply to filter noise. Place the capacitor as close to the V_{CC} pin and SENSE pin as possible.

10 Layout

10.1 Layout Guidelines

Figure 35 shows a layout example for the TLC6C5716-Q1 device. To improve the thermal performance, TI recommends to use the GND plane to dissipate the heat. To filter the supply noise, users can put the capacitor as close to the V_{CC} and SENSE pins as possible. The IREF resistor also should be connected as close to IREF pin as possible.

10.2 Layout Example

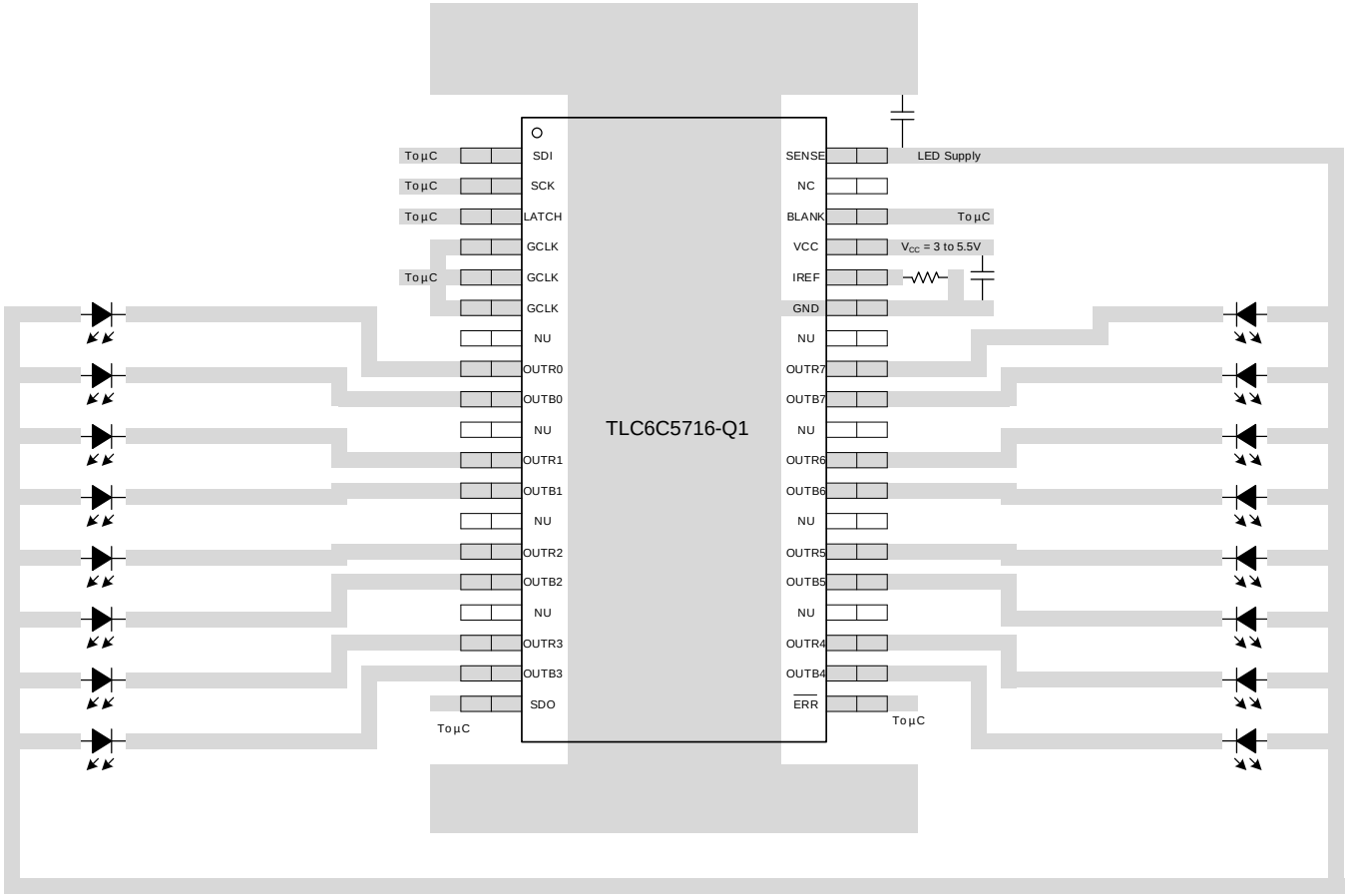


Figure 35. TLC6C5716-Q1 Example Layout Diagram

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

PowerPAD, E2E are trademarks of Texas Instruments.

11.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated device. This data is subject to change without notice and without revision of this document. For browser-based versions of this data sheet, see the left-hand navigation pane.

12.1 Package Option Addendum

12.1.1 Packaging Information

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (3)	MSL Peak Temp (4)	Op Temp (°C)	Device Marking (5) (6)
TLC6C5716QDAPRQ1	ACTIVE	HTSSOP	DAP	38	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	–40 to 125	TLC6C5716Q

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PRE_PROD Unannounced device, not in production, not available for mass market, nor on the web, samples not available.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

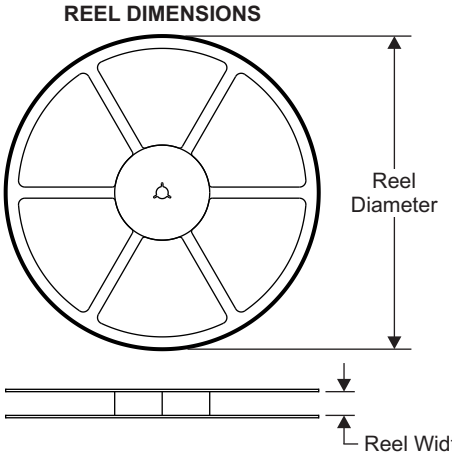
(3) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

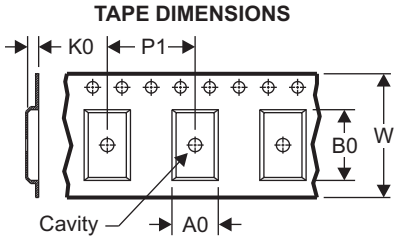
(4) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(5) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device

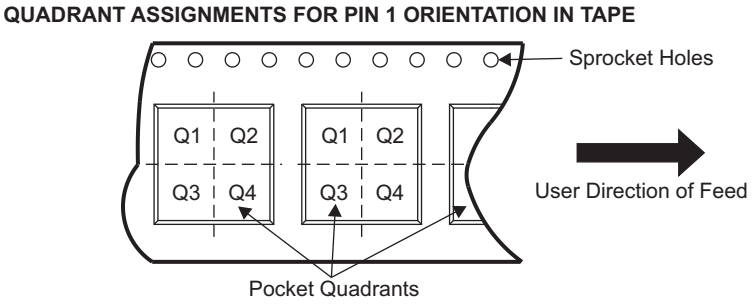
(6) Multiple Device markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

12.1.2 Tape and Reel Information



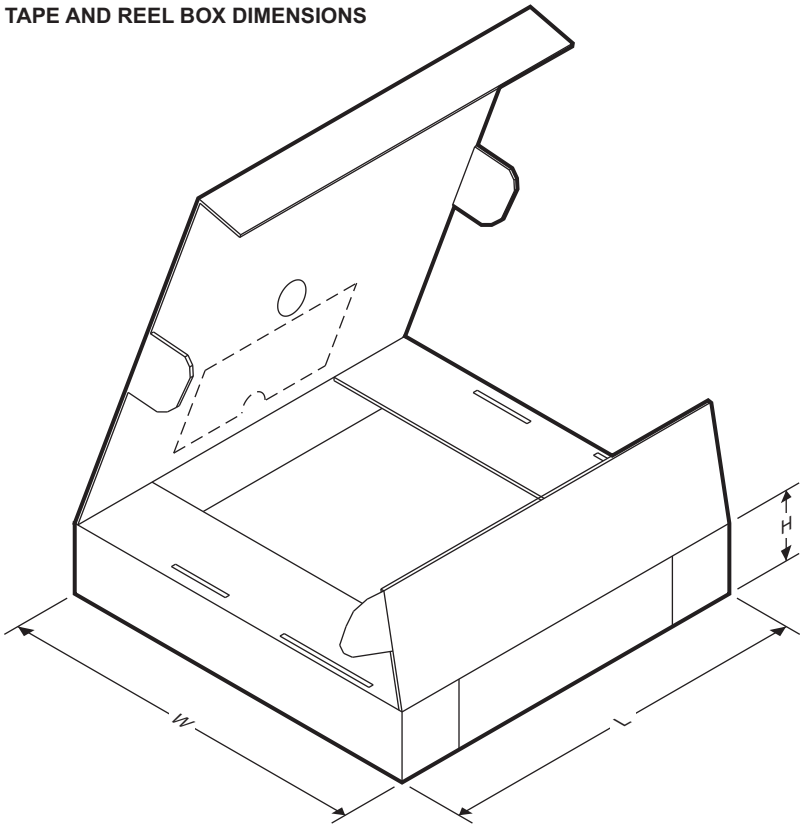


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLC6C5716QDAPRQ1	HTSSOP	DAP	38	2000	330.0	24.4	8.6	13.0	1.8	12.0	24.0	Q1

TAPE AND REEL BOX DIMENSIONS



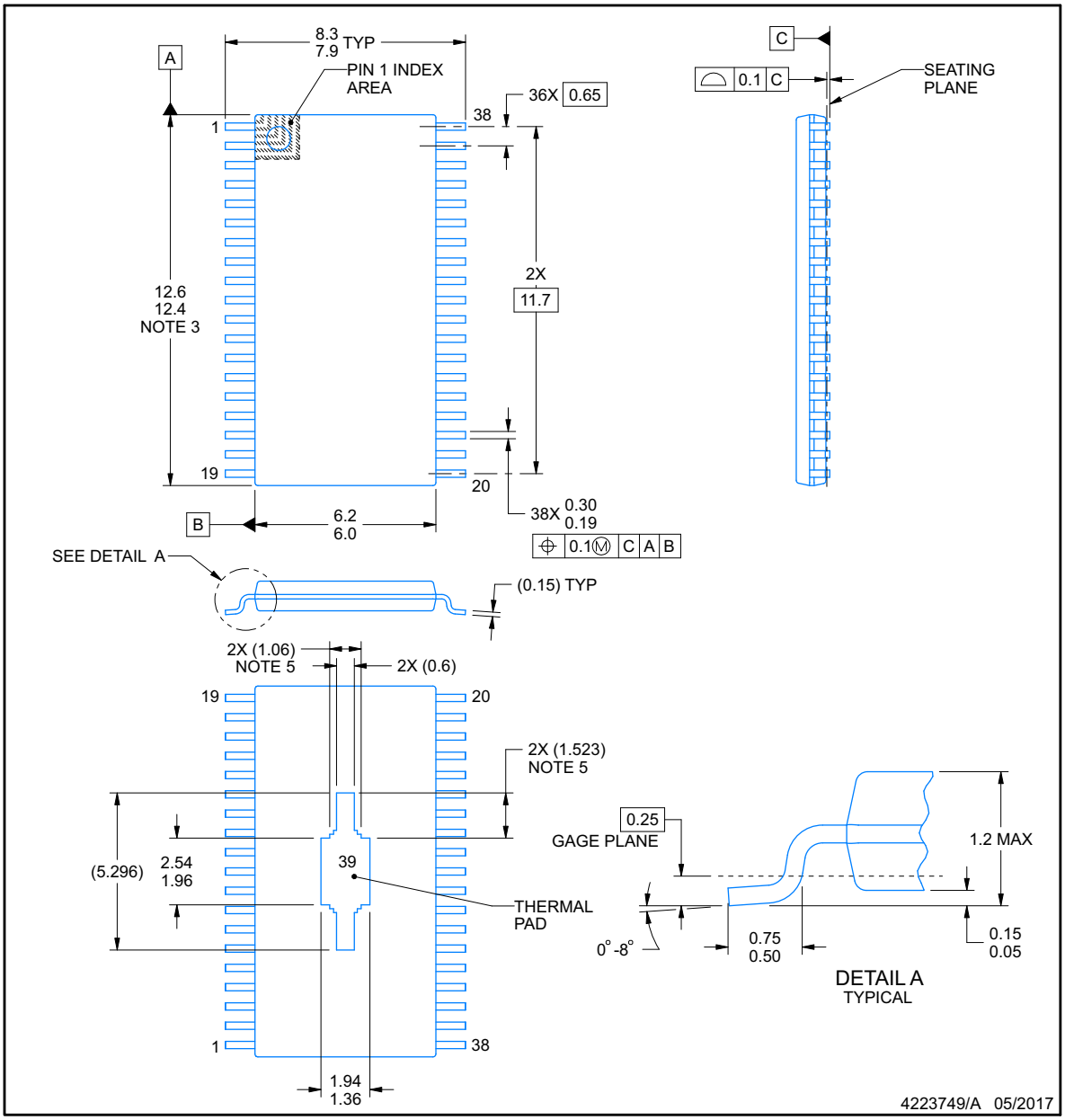
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLC6C5716QDAPRQ1	HTSSOP	DAP	38	2000	350.0	350.0	43.0

PACKAGE OUTLINE

DAP0038E

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



PowerPAD is a trademark of Texas Instruments.

NOTES:

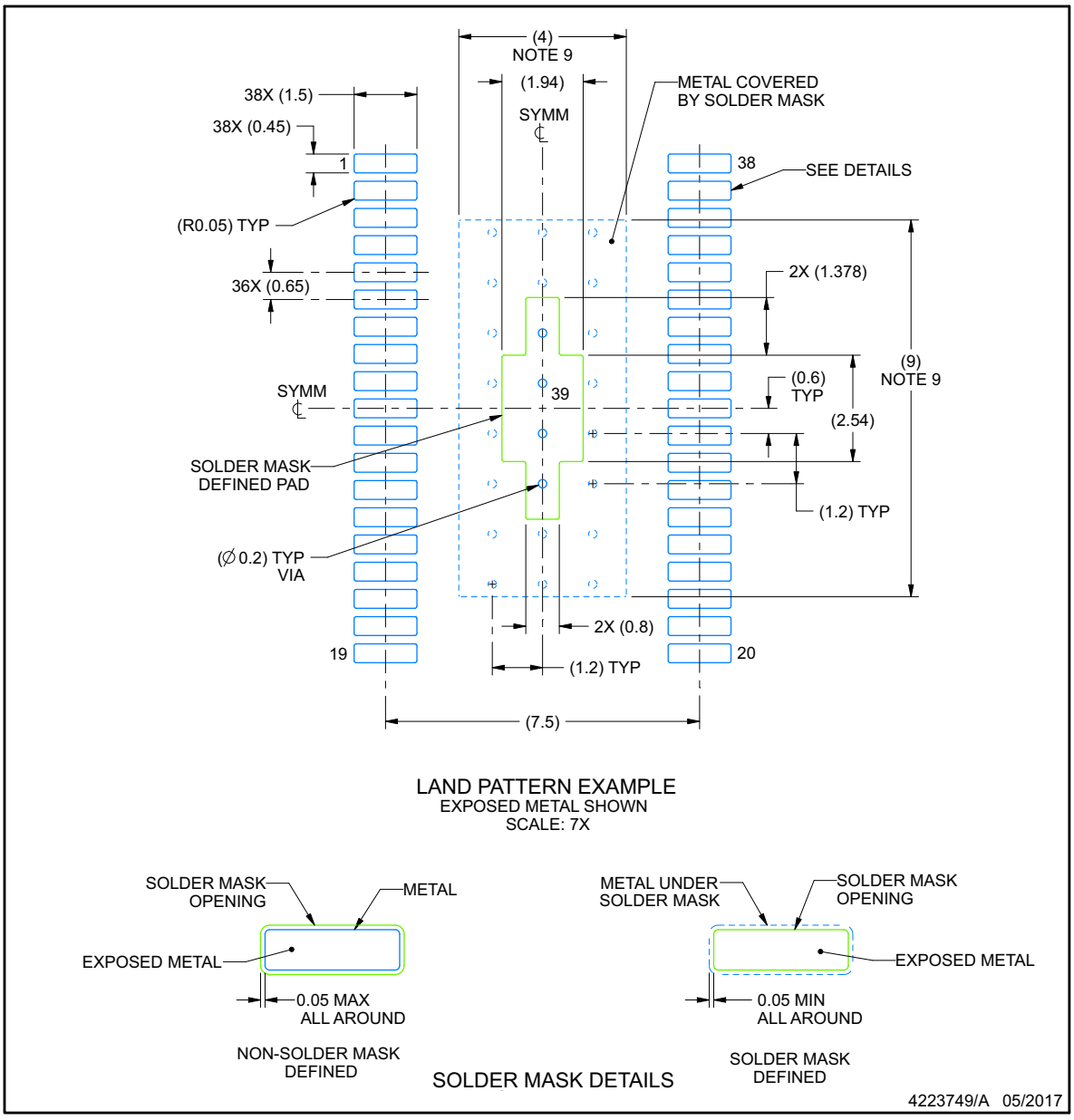
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-153.
5. Features may differ or may not be present.

EXAMPLE BOARD LAYOUT

DAP0038E

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES: (continued)

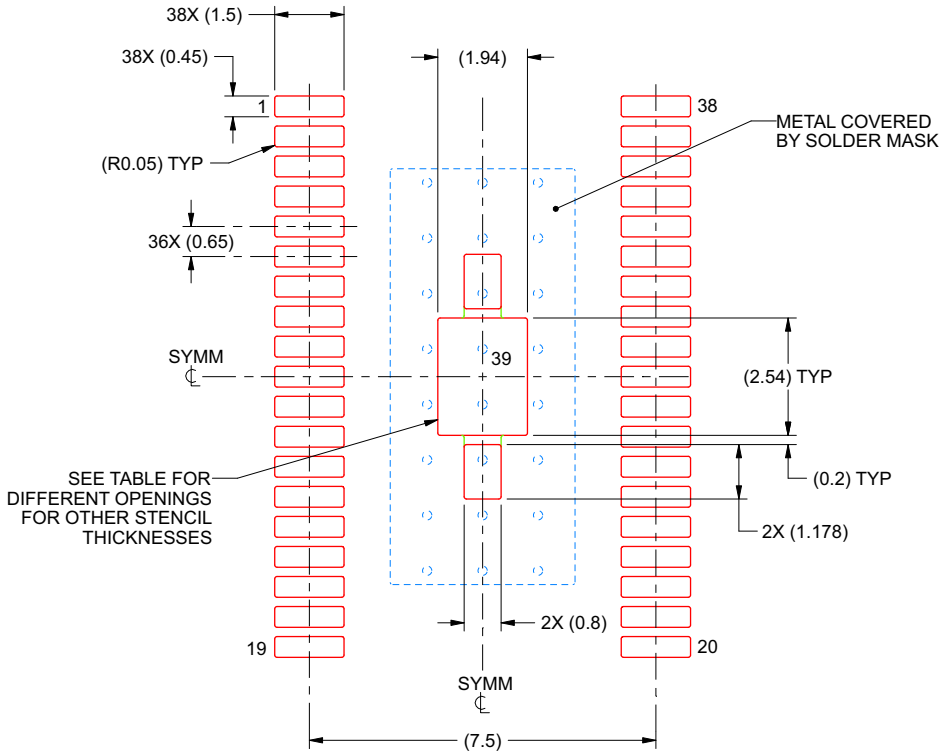
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature numbers SLMA002 (www.ti.com/lit/slma002) and SLMA004 (www.ti.com/lit/slma004).
9. Size of metal pad may vary due to creepage requirement.
10. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

DAP0038E

PowerPAD™ TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 7X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	2.17 X 2.84
0.125	1.94 X 2.54 (SHOWN)
0.15	1.77 X 2.32
0.175	1.64 X 2.15

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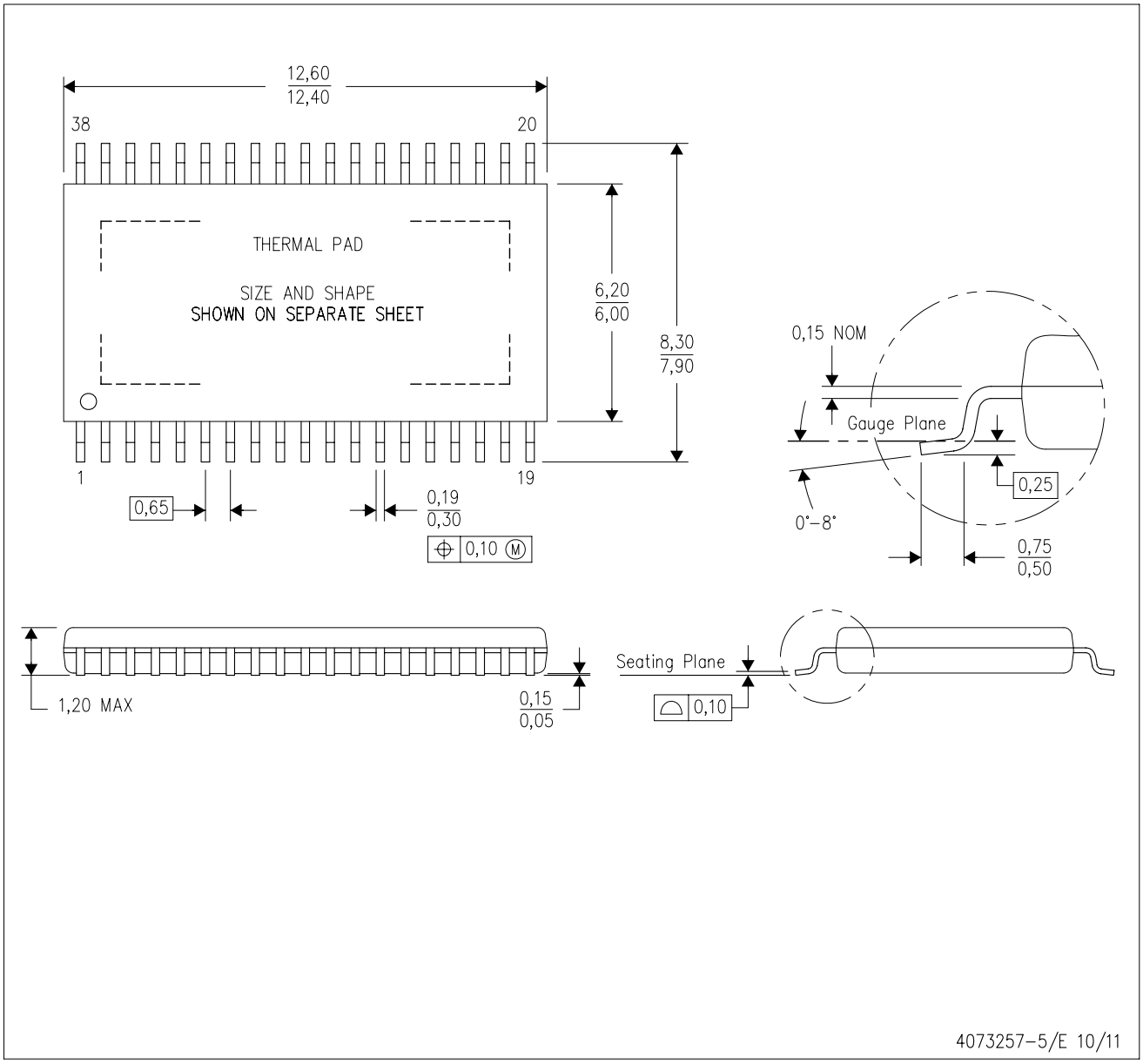
NOTES: (continued)

11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

DAP (R–PDSO–G38) PowerPAD™ PLASTIC SMALL–OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at www.ti.com <http://www.ti.com>.
E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
F. Falls within JEDEC MO–153 Variation DDT–1.

PowerPAD is a trademark of Texas Instruments.

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