



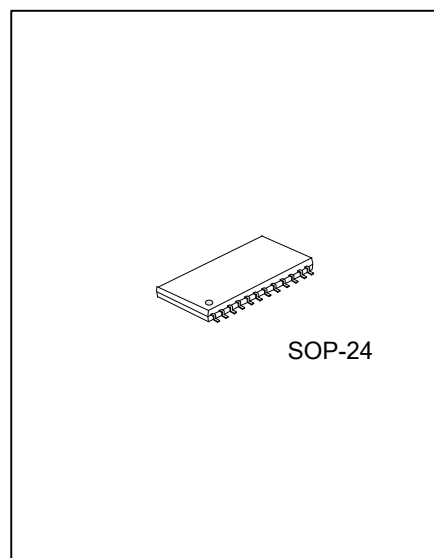
## UL316

## LINEAR INTEGRATED CIRCUIT

### SERIAL-INTERFACED 6-DIGIT LED CONTROLLER IC WITH KEYSKAN

#### DESCRIPTION

The **UL316** is a compact LED controller and driver that interface microprocessors to LED displays through a serial 3-wire interface. It drives LED connected in common anode configuration. The **UL316** drives up to 48 discrete LEDs in 8 segment/6 digit configuration while functioning from a supply voltage of 5.0V.



SOP-24

#### FEATURES

- \* LED driver with 14 outputs (8 segments/6 digits)×40 mA load current capability for each segment
- \* Output pins connected directly to the LEDs or can be open-drain
- \* Key-scanning (8 x 2 matrix)
- \* 3-wire serial bus interface (CLK, STB, DIN/DOUT)
- \* 8-step dimming circuit to control the overall display brightness

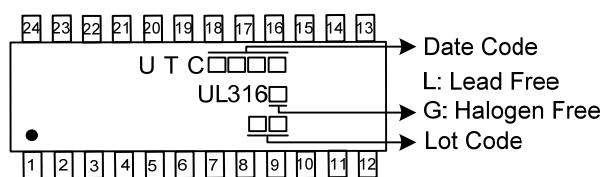
- \* Single external resistor for output current setting
- \* Inputs with Schmitt trigger give superior noise immunity
- \* A single LED digit output (DIG1\_LED) can be used to drive up to 8 discrete LEDs
- \* 8-step dimming circuit to control brightness of individual LEDs for LED digit
- \* 5.0 V (± 10%) for V<sub>CC</sub>
- \* Drives common-anode LED digits
- \* Built-in power on reset and soft-start circuits

#### ORDERING INFORMATION

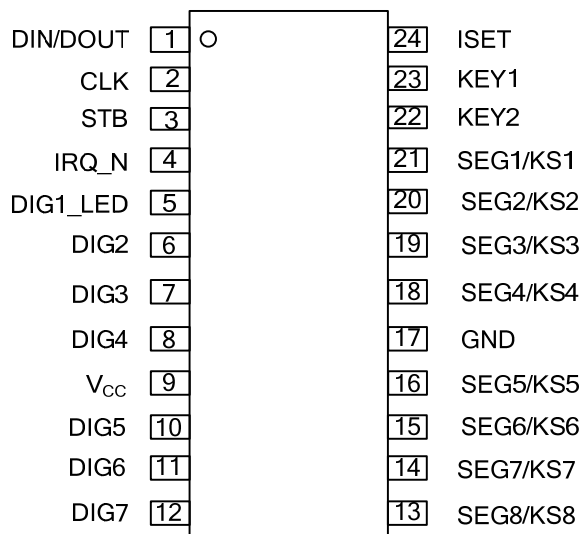
Ordering Number		Package	Packing
Lead Free	Halogen Free		
UL316L-S24-R	UL316G-S24-R	SOP-24	Tape Reel

<p>UL316G-S24-R</p> <p>(1)Packing Type</p> <p>(2)Package Type</p> <p>(3)Green Package</p>	<p>(1) R: Tape Reel</p> <p>(2) S24: SOP-24</p> <p>(3) G: Halogen Free and Lead Free, L: Lead Free</p>
---	---

#### MARKING



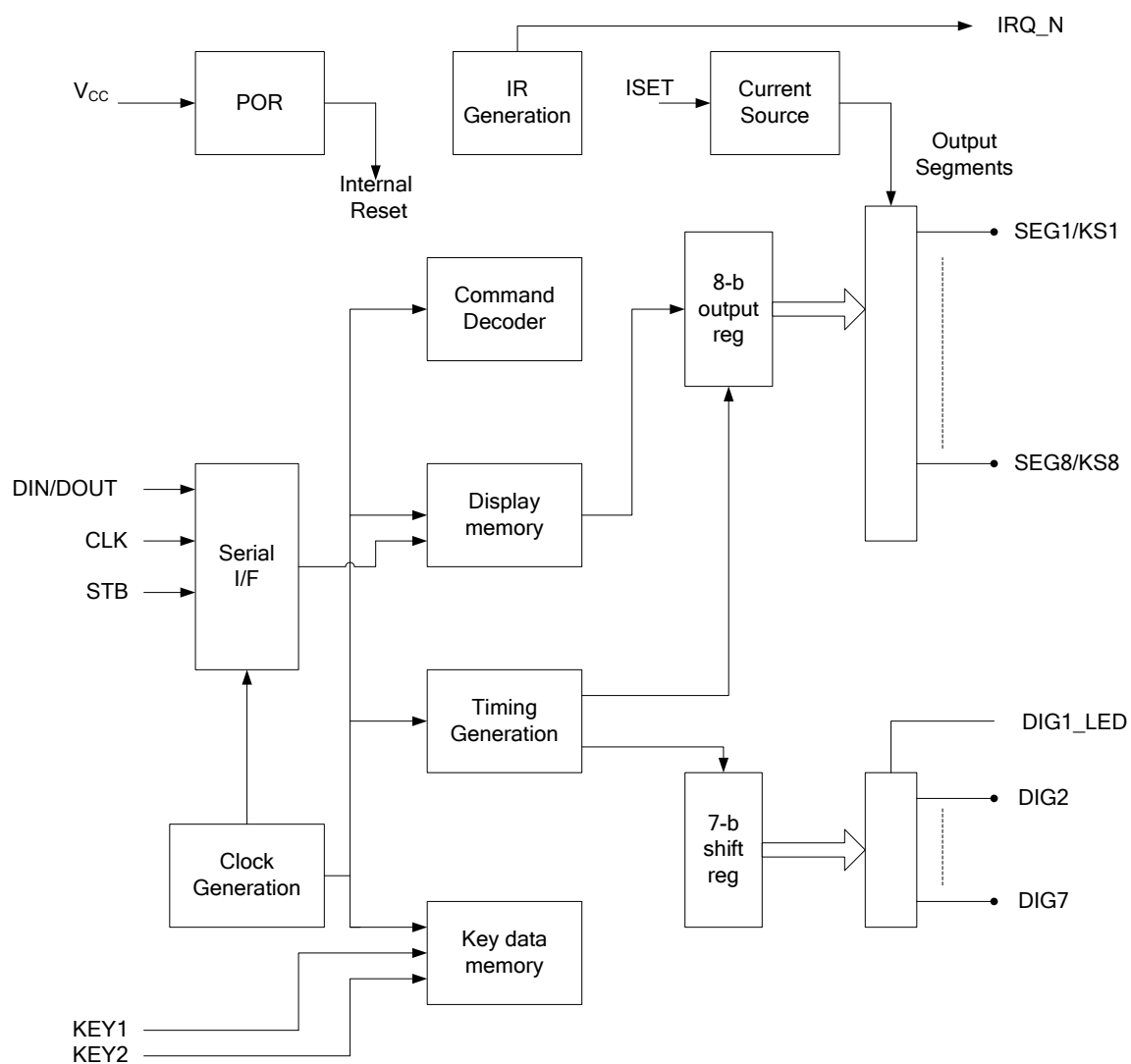
## ■ PIN CONFIGURATIONS



## ■ PIN CONFIGURATIONS

PIN NUMBER	SYMBOL	TYPE	NAME AND FUNCTION
1	DIN/DOUT	IN/OUT	Output serial data at falling edge of the shift clock, starting from lower bit. Input serial data is clocked in at rising edge of the shift clock, starting from lower bit.
2	CLK	IN	Reads serial data at rising edge, and outputs data at falling edge.
3	STB	IN	Initializes serial interface at rising or falling edge for reception of command. Data input after the falling edge of STB are processed as a command. While command data are processed, current processing is stopped, and the serial interface is initialized. While STB is high, instructions are ignored.
4	IRQ_N	OUT	Interrupt output (active low) to interrupt the MCU when there is a key press
5	DIG1_LED	OUT	Single output LED used together with the 8 segments to drive up to 8 discrete LEDs
6	DIG2	OUT	Digit output pin
7	DIG3	OUT	Digit output pin
8	DIG4	OUT	Digit output pin
9	V <sub>CC</sub>	PWR	5.0 V ± 10% Core main supply voltage. Bypass to GND through a 0.1 μF capacitor as close to the pin as possible
10	DIG5	OUT	Digit output pin
11	DIG6	OUT	Digit output pin
12	DIG7	OUT	Digit output pin
13	SEG8/KS8	OUT	Segment output pin (dual function as key source)
14	SEG7/KS7	OUT	Segment output pin (dual function as key source)
15	SEG6/KS6	OUT	Segment output pin (dual function as key source)
16	SEG5/KS5	OUT	Segment output pin (dual function as key source)
17	GND	PWR	Connect this pin to system GND
18	SEG4/KS4	OUT	Segment output pin (dual function as key source)
19	SEG3/KS3	OUT	Segment output pin (dual function as key source)
20	SEG2/KS2	OUT	Segment output pin (dual function as key source)
21	SEG1/KS1	OUT	Segment output pin (dual function as key source)
22	KEY2	IN	Key 2 input
23	KEY1	IN	Key 1 input
24	ISSET	IN	Segment current setting. Connect to GND through a resistor to set the peak segment current.

## ■ BLOCK DIAGRAM



■ ABSOLUTE MAXIMUM RATINGS (all voltages are referenced to GND)

PARAMETER	SYMBOL	VALUES	UNIT
Supply Voltage to Ground	$V_{CC}$	-0.5 to +7	V
Logic Input Voltage	$V_{IN}$	-0.5 to $V_{CC}+0.5$ V	V
Power Dissipation	$P_D$	1200	mW
Operating Ambient Temperature	$T_A$	-40 ~ 85	°C
Junction Temperature	$T_J$	150	°C
Storage Temperature	$T_{STG}$	-65 to +150	°C

Note: De-rate at -9.6 mW/°C at  $T_A = 25^\circ\text{C}$  or higher.

■ THERMAL DATA

PARAMETER	SYMBOL	VALUES	UNIT
Junction to Case	$\theta_{JC}$	75	°C/W

■ DC ELECTRICAL CHARACTERISTICS

DC electrical characteristics ( $T_A = -40$  to  $+85^\circ\text{C}$ ,  $V_{CC} = 5.0\text{ V} \pm 10\%$ , GND = 0 V)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Logic Supply Voltage	$V_{CC}$		4.5	5.0	5.5	V
High Level Input Voltage	$V_{IH}$	High Level Guaranteed Digital Pins	$0.7 \times V_{CC}$		$V_{CC}$	V
Low Level Input Voltage	$V_{IL}$	Low Level Guaranteed Digital Pins	0		$0.3 \times V_{CC}$	V
Input Current	$I_{IH}, I_{IL}$	$V_{IN} = V_{CC}$ or GND	-2		2	$\mu\text{A}$
Hysteresis Voltage (DIN, CLK, STB pins)	$V_{HYS}$			1.05		V
Low Level Output Voltage	$V_{OL(DOUT)}$	$D_{OUT}, I_{OL2}=4\text{mA}$			0.4	V
Segment Drive LED Sink Current	$I_{SEG}$	$V_{LED}=2.5\text{V}, V_{DIGIT}=V_{CC}-1.0$	-30	-40	-50	mA
Digit Drive LED Source Current	$I_{DIG}$	$V_{DIGIT}=V_{CC}-1.0$	240	320	400	mA
Segment Drive Current Matching	$I_{TOLSEG}$	$V_{CC}=5.0\text{V}, T_A=25^\circ\text{C}, V_{LED}=2.5\text{V}$		3		%
External Current Setting Reference Resistor (Precision = $\pm 1\%$ Tolerance)	$R_{SET}$	$I_{SEG}=40\text{mA}$		360		$\Omega$

■ POWER SUPPLY CHARACTERISTICS ( $T_A = -40$  to  $+85^\circ\text{C}$ , unless otherwise specified)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Quiescent Power Supply Current	$I_{STBY}$	$V_{CC}=5.5\text{V}$ , All Inputs= $V_{CC}$ or GND		50		$\mu\text{A}$
Operating Power Supply Current (display ON)	$I_{CC}$	All Segments ON, All Digits Scanned, Intensity Set to Full, Internal Oscillator, No Display Load Connected		10		mA

■ TIMING CHARACTERISTICS

( $T_A = -40 \sim +85^\circ\text{C}$ ,  $V_{CC}=5.0\text{V} \pm 10\%$ , Typical values are at  $25^\circ\text{C}$ , unless otherwise specified)

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Clock Pulse Width	$PW_{CLK}$		400			ns
Strobe Pulse Width	$PW_{STB}$		1			$\mu\text{s}$
Clock-Strobe Time	$t_{CLK-STB}$	CLK Rising Edge to STB Rising Edge	1			$\mu\text{s}$

## ■ COMMANDS

Command sets the display mode and the status of the LED driver. The first byte input to the UL316 through the DIN input after the STB goes low is regarded as a command. If STB is set high while commands/data are transmitted, serial communication is initialized, and the commands/data being transmitted are invalid (however, the commands/data already transmitted remain valid).

### 1. Write command

MSB8	MSB7	MSB6	MSB5	MSB4	MSB3	MSB2	MSB1
------	------	------	------	------	------	------	------

Description: LSB 3 -1 → address of the memory

MSB5 and LSB4 → address of memory bank (page)

MSB 6 → '0' auto increment address

'1' fixed address

MSB 7 → '0' Write command

'1' Read command

MSB 8 → 'X' Unused

The following bytes are either configuration data or display data.

During the write command, the control flag display on and auto increment address are latched into the internal control flag register. The default value is '0' for display on control register implying that the display is off. The user must turn on the display to view the display memory. Similarly the auto increment address mode is enabled by default. If the user desires to read from a particular address location, the user can fix the address pointer.

Display ON:

MSB8	MSB7	MSB6	MSB5	MSB4	MSB3	MSB2	MSB1
X	0	X	0	1	1	0	1

Display OFF:

MSB8	MSB7	MSB6	MSB5	MSB4	MSB3	MSB2	MSB1
X	0	X	0	1	1	1	0

Use these two commands to turn the display 'ON' and 'OFF'.

### 2. Read command

MSB8	MSB7	MSB6	MSB5	MSB4	MSB3	MSB2	MSB1
------	------	------	------	------	------	------	------

Description: LSB 3 -1 → address of the memory

MSB5 and LSB4 → address of the memory bank (page)

MSB 6 → '0' auto increment address

'1' fixed address

MSB 7 → '0' Write command

'1' Read command

MSB 8 → 'X' Unused

Use the page 0x01 to read the LED data and key data.

Table 1. Read command

ADDRESS	FUNCTION
00	LED data (optional)
01	Key data byte1
02	Key data byte2

Set flag for key1 and key2 to ensure that the user reads from the particular key. When reading the key data from the memory, the IRQ\_N will be automatically cleared signifying that the end of the 8 bit was transmitted correctly. If the IRQ\_N is asserted by the last eight keys, then the user reads the key data (one byte only by reading the first byte). In this case, the IRQ\_N will remain active until the second byte is read. When the user uses the read key to read the LED and key data, first the user must choose the address (default address location is 0x00) after which the address will increment only by 3 addresses (maximum).

## ■ COMMANDS (Cont.)

### 3. Device configuration

This section describes how to program and read the configuration of the device.

Configuration data comprises of the display setting, dimming setting, display on/off and fixed. address/auto increment. The address pointer will indicate the configuration location and write signal writes the configuration data into the respective location.

The memory block is split into two page locations. One is for the 7-segment brightness configuration memory and the other is for the LED (discrete) configuration memory. The configuration memory address starts from 0x00 to 0x07. The configuration page address is "10" and "11".

Initial Value:

Table 2. Memory page mapping

MEMORY PAGE	ADDRESS	VALUE
10	00	0 × FB
10	01	0 × 00
10	02	0 × 00
10	03	0 × 00
11	00	0 × 00
11	01	0 × 00
11	02	0 × 00
11	03	0 × 00

Description:

Address 0x00; page 0x10

LSB 0 – 2 → indicates the number of digits in the display

LSB3 MSB 4 → '11' is for constant brightness control for the display

→ '00' is for variable brightness control for the display

→ '01' is reserved

→ '10' is reserved

MSB 5 – 7 → indicates constant brightness control value for all including the LED (discrete)

Default is constant brightness control with 14/16 pulse width (for maximum brightness).

Page 0x10 - address 0x01 to 0x03 is for the variable brightness control value for 7 segments:

Table 3. Memory page mapping

ADDRESS	MSB	LSB
0 × 01	Digit 2	Digit 1
0 × 02	Digit 4	Digit 3
0 × 03	Digit 6	Digit 5

Default is constant brightness control with 14/16 pulse width.

Page 0x11 - address 0x00 to 0x03 is for the variable brightness control value for LED (discrete).

Table 4. LED address mapping

ADDRESS	MSB	LSB
0 × 00	LED / Seg 2	LED / Seg 1
0 × 01	LED / Seg 4	LED / Seg 3
0 × 02	LED / Seg 6	LED / Seg 5
0 × 03	LED / Seg 8	LED / Seg 7

Default is constant brightness control with 14/16 pulse width.

During normal operation, the user defined value will be stored in the respective location.

## ■ COMMANDS (Cont.)

### 甲、 Display setting (maximum number of digits):

The 3-bit values corresponding to selection of number of digits of display are shown below:

- 000: 1 digit 8 segments
- 001: 2 digits 8 segments
- 010: 3 digits 8 segments
- 011: 4 digits 8 segments
- 100: 5 digits 8 segments
- 101: 6 digits 8 segments

Select the number of digits by writing the value in page 0x10 and the address 0x00 in LSB2 to LSB0.

### 乙、 Dimming setting (brightness levels):

The 4-bit values corresponding to different brightness levels are shown below:

- 0000: pulse width is 1/16
- 0001: pulse width is 2/16
- 0010: pulse width is 4/16
- 0011: pulse width is 10/16
- 0100: pulse width is 11/16
- 0101: pulse width is 12/16
- 0110: pulse width is 13/16
- 0111: pulse width is 14/16

Set the dimming timing (write into respective address location from 0x00 to 0x03; page 0x10 & 0x11).

## 4. Display memory

The address pointer, memory page and write signal indicates to this block the location to write the data.

This block will manage the address pointer. When the user writes a first byte, the address increments by one if in auto-increment mode, else the address pointer remains in the same location. The initial address is latched during the write/read command into the address pointer. The display memory (7-segment/LED) is directly mapped into the display segments. The user can access only one bank at a time in both the read and write modes.

The memory block is split into 4 pages.

Table 5. Memory page address

Page 1 7 segment memory	Page 2 LED Display	Page 3 7 segment brightness setting	Page 4 LED brightness setting
Addr 0x00 to 0x05 (40 bit)	Addr 0x00 (8 bit)	Addr 0x00 to 0x03 (32bit)	Addr 0x00 to 0x03 (32bit)

7-segment display memory page 0x00:

Table 6. 7-segment display address

ADDRESS	VALUE
0 × 00	0 × 00
0 × 01	0 × 00
0 × 02	0 × 00
0 × 03	0 × 00
0 × 04	0 × 00
0 × 05	0 × 00

LED display memory page 0x01:

# ■ COMMANDS (Cont.)

Table 7. 7-segment display address

ADDRESS	DATA
0 × 00h	0 × 00h

Initial memory:

Default memory value is "00" in all locations.

During operation:

User defined value in these locations.

When the user wants to read the data from a particular location, the user sends the address page through read command and chooses the mode of the address pointer (fixed or auto).

In this case, the user can access the whole memory area in that particular page (maximum 0 × 05).

The display RAM stores the data transmitted from an external device to the UL316 through the serial interface; addresses are as follows, in 8-bits unit:

Seg 1	Seg 4	Seg 8
00 H <sub>L</sub>	00 H <sub>U</sub>	DIG 2
01 H <sub>L</sub>	01 H <sub>U</sub>	DIG 3
02 H <sub>L</sub>	02 H <sub>U</sub>	DIG 4
03 H <sub>L</sub>	03 H <sub>U</sub>	DIG 5
04 H <sub>L</sub>	04 H <sub>U</sub>	DIG 6
05 H <sub>L</sub>	05 H <sub>U</sub>	DIG 7

b0	b3	b4	b7
XX H <sub>L</sub>		XX H <sub>U</sub>	

"0" in memory means GND on output; "1" in memory means V<sub>CC</sub> on output.



## ■ KEY-SCANNING AND DISPLAY TIMING

During the first cycle, the 16 channels are used for the keyscan. The keyscan duration is made up of 64  $\mu\text{s}$ . The second cycle is used for the display of the LED (discrete). The maximum time is 512 $\mu\text{s}$  and the 3<sup>rd</sup>-8<sup>th</sup> cycles are used for the 7-segment display. The number of cycles will increase or decrease depending upon the user configuration.

By default, the configuration is made up of 4 cycles. If any data is written to the discrete LED, only then the 2<sup>nd</sup> cycle is valid. Otherwise the 7-segment moves from 2<sup>nd</sup> -7<sup>th</sup> cycle. This is a continuous operation. During the normal operation, the user cannot control or stop the timing generation.

One cycle of key scanning consists of one frame, and data of 8 x 2 matrices are stored in the RAM.

### 1. SERIAL COMMUNICATION FORMAT (RECEPTION)

The figure below shows the "reception" by UL316 for command/data write sequence.

The STB must be low for 1  $\mu\text{s}$  before the first and last clock rise. The minimum time the STB must remain low is 9  $\mu\text{s}$ .

The maximum clock frequency is 1 MHz with a duty cycle of 50%. Data set-up and hold time must be 100 ns.

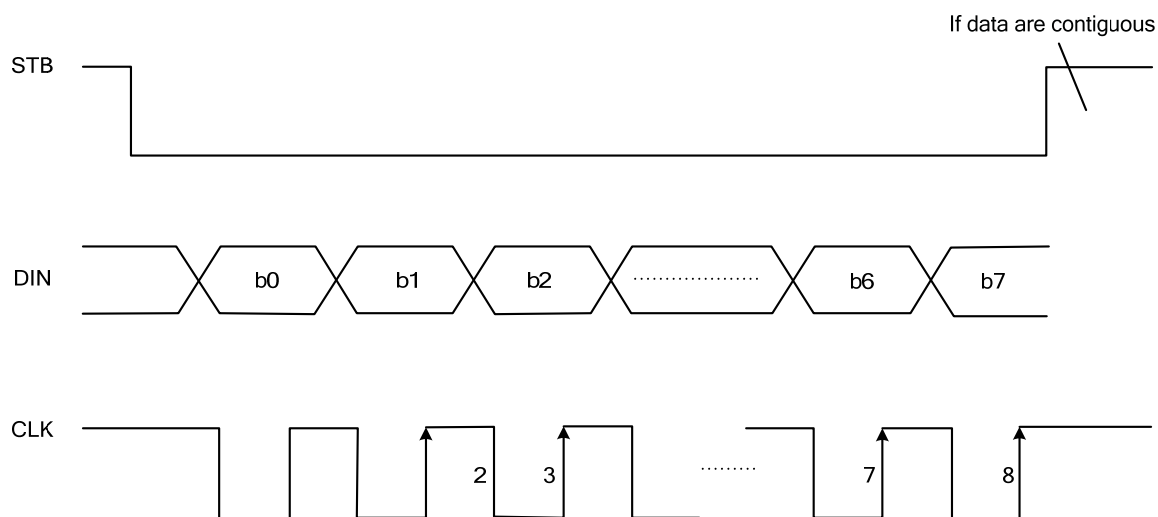


Fig 1. Serial communication format (reception)

## ■ KEY-SCANNING AND DISPLAY TIMING (Cont.)

### 2. SERIAL COMMUNICATION FORMAT (TRANSMISSION)

The figure below shows the “ transmission” from UL316 for data read sequence.

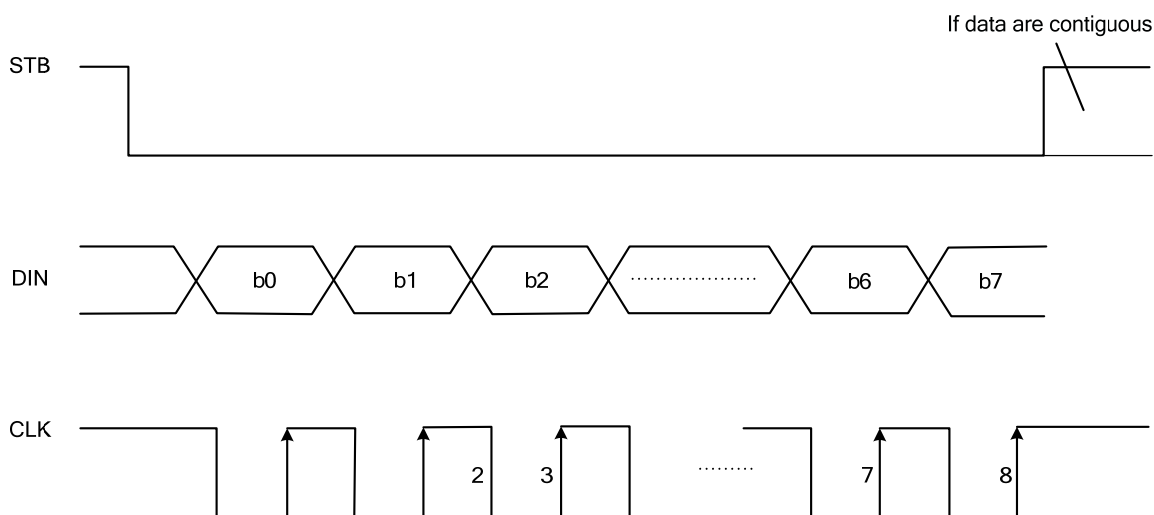
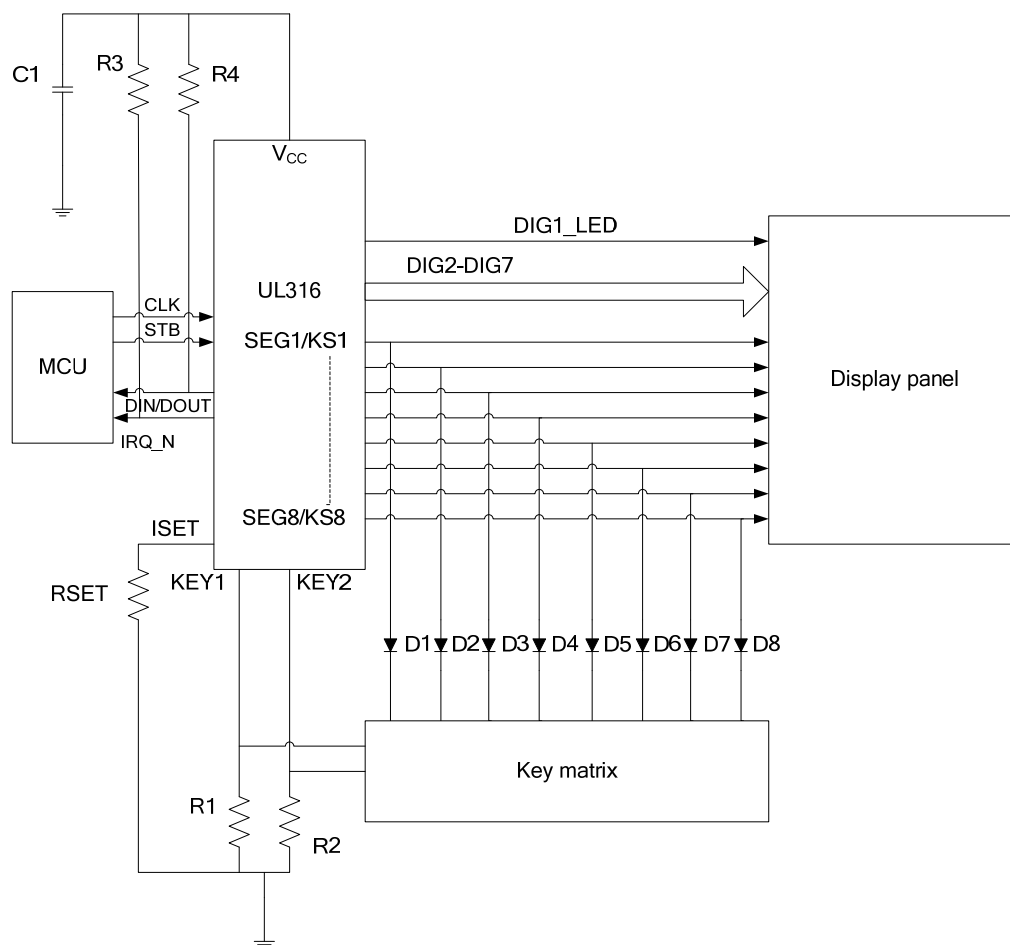


Fig 2. Serial communication format (transmission)

Because the DIN/DOUT pin in a bi-directional pin, it is recommended to connect an external pull-up resistor to this pin (1 K $\Omega$  to 10 K $\Omega$ ).

Note: No minimum wait time is needed to read the data from the device. The UL316 will output the data about 250 ns after the 8<sup>th</sup> clock pulse's falling edge. It is therefore suggested that the host must release the bus within 100ns after clocking the last bit on the 8<sup>th</sup> clock pulse. The UL316 is able to clock out the valid data on the immediate falling edge of the CLK without missing any clock cycle.

### ■ TYPICAL APPLICATION CIRCUIT



UTC assumes no responsibility for equipment failures that result from using products at values that exceed, even momentarily, rated values (such as maximum ratings, operating condition ranges, or other parameters) listed in products specifications of any and all UTC products described or contained herein. UTC products are not designed for use in life support appliances, devices or systems where malfunction of these products can be reasonably expected to result in personal injury. Reproduction in whole or in part is prohibited without the prior written consent of the copyright owner. UTC reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.