HT16515
1/4 to 1/12 Duty VFD Controller

Features

- Logic voltage: 3.0V~5.5V
- High-voltage output: V_{DD}-35V max.
- Multiple display (16-segment & 12-digit to 24-segment & 4-digit)
- 16×2 matrix key scanning
- 8 steps dimmer circuit
- 4 LED output ports
- No external resistors necessary for driver output (provides PMOS open-drain and pull-low resistor output)
- Serial interface with MCU (CLK, $\overline{CS}$, DI, DO)
- 44-pin LQFP packages

Applications

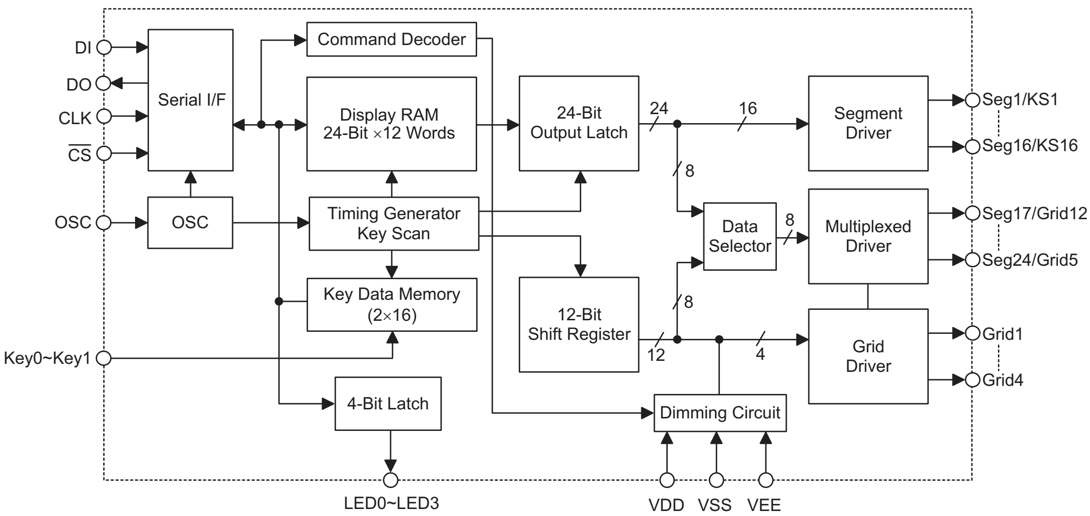
- Consumer products panel function control
- Industrial measuring instrument panel function control
- Other similar applications for panel function control

General Description

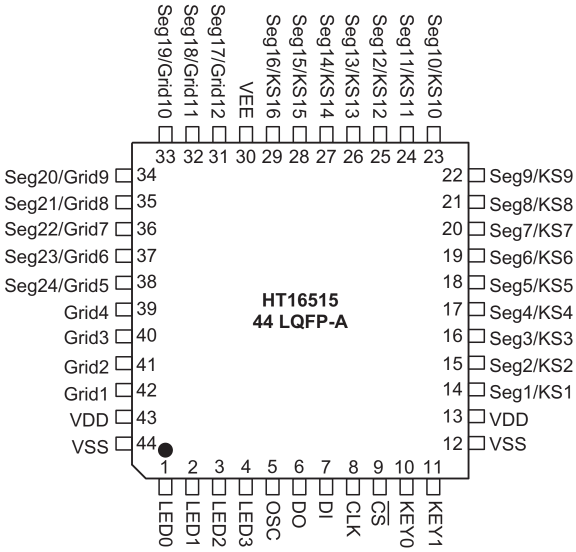
HT16515 is a VFD (Vacuum Fluorescent Display) controller/driver that is driven on a 1/4 to 1/12 duty factor. It consists of 16 segment output lines, 4 grid output lines, 8 segment/grid output drive lines, 4 LED output ports, a control circuit, a display memory, and a key scan circuit.

Serial data inputs to the HT16515 through a three-line serial interface. This VFD controller/driver is an ideal MCU peripheral device.

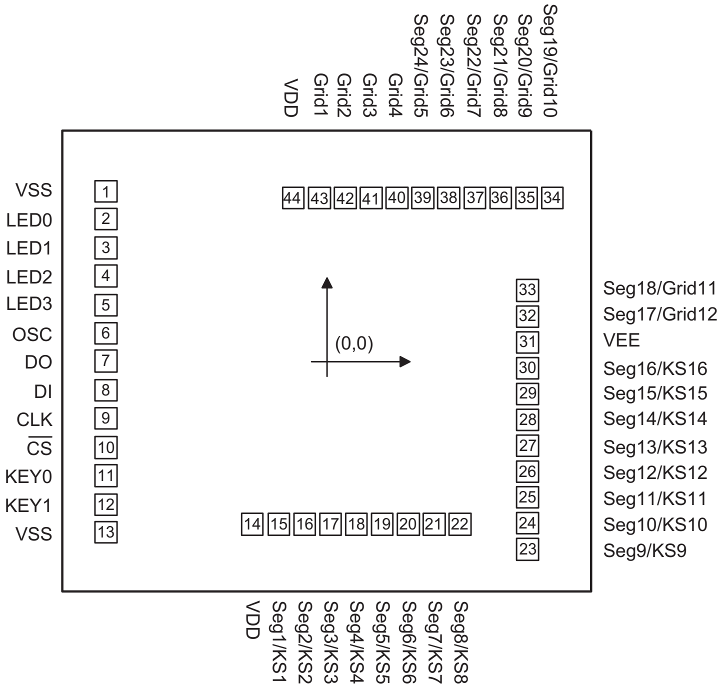
Block Diagram



Pin Assignment



Pad Assignment



Chip Size: 1778µm × 1530µm

* The IC substrate should be connected to VSS in the PCB layout artwork.

Pad Coordinates

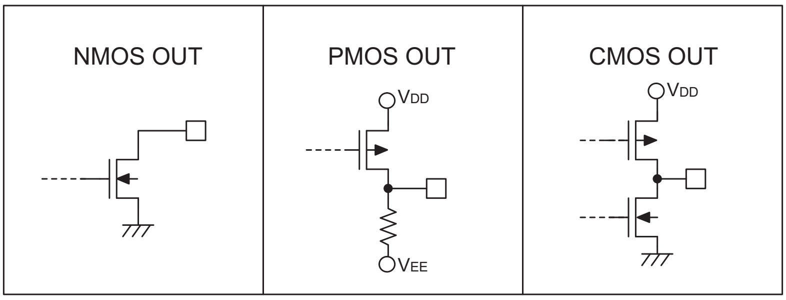
Unit: μm

Pad No.	X	Y	Pad No.	X	Y
1	-725.150	558.200	23	659.750	-617.800
2	-725.150	468.200	24	659.750	-532.800
3	-725.150	372.200	25	659.750	-447.800
4	-725.150	280.200	26	659.750	-362.800
5	-725.150	184.200	27	659.750	-277.800
6	-725.150	92.200	28	659.750	-192.800
7	-725.150	0.200	29	659.750	-107.800
8	-725.150	-95.800	30	659.750	-22.800
9	-725.150	-187.800	31	659.750	61.950
10	-725.150	-283.800	32	659.750	147.200
11	-725.150	-375.800	33	659.750	232.200
12	-725.150	-471.800	34	741.150	535.750
13	-725.150	-561.800	35	656.150	535.750
14	-244.300	-535.750	36	571.150	535.750
15	-157.300	-535.750	37	486.150	535.750
16	-72.300	-535.750	38	401.150	535.750
17	12.700	-535.750	39	316.150	535.750
18	97.700	-535.750	40	231.150	535.750
19	182.700	-535.750	41	146.150	535.750
20	267.700	-535.750	42	61.150	535.750
21	352.700	-535.750	43	-23.850	535.750
22	437.700	-535.750	44	-109.350	535.750

Pin Description

Pin No.	Pin Name	I/O	Description
1~4	LED0~LED3	O	LED driver output ports. This is a CMOS output pin and maximum driving current up to +20mA.
5	OSC	I	Connected to an external resistor or an RC oscillator circuit.
6	DO	O	Data output pin, output serial data at falling edge of shift clock, starting from the lower bit. This is N-ch open-drain output pin.
7	DI	I	Data input pin, input serial data at rising edge of shift clock, starting from the lower bit.
8	CLK	I	Clock input pin. Reads serial data at the rising edge, and outputs data at the falling edge.
9	$\overline{CS}$	I	Initializes serial interface at the rising or falling edge of the HT16515. Then it waits to receive a command. Data input after $\overline{CS}$ has fallen is processed, current processing is stopped, and the serial interface is initialized. While $\overline{CS}$ is high, CLK is ignored.
10, 11	Key0, Key1	I	Key-in data input to these pins are latched at the end of the display cycle.
12, 44	VSS	—	Negative power supply, ground
13, 43	VDD	—	Positive power supply
14~29	Seg1/KS1~Seg16/KS16	O	High voltage output, segment output pins, dual function as key source. This is PMOS open-drain and pull-low resistor output.
30	VEE	—	VFD power supply
31~38	Seg17/Grid12~ Seg24/Grid5	O	High voltage output, these pins are selectable for segment or grid output. This is PMOS open-drain and pull-low resistor output.
39~42	Grid4~Grid1	O	High voltage output, grids output pin. This is PMOS open-drain and pull-low resistor output.

Approximate Internal Connections



Absolute Maximum Ratings

Supply Voltage ....V_{SS}–0.3V to V_{SS}+6.0V

Input Voltage..............................V_{SS}–0.3V to V_{DD}+0.3V

Operating Temperature...........................–25°C to 75°C

Storage Temperature ....–50°C to 125°C

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the device. Functional operation of this device at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

D.C. Characteristics

Ta=25°C, V_{EE}=V_{DD}–35V

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Logic Supply Voltage	3.3V	—	3	3.3	3.6	V
		5V		4.5	5	5.5	V
V_{EE}	VFD Supply Voltage	—	—	0	—	V_{DD}–35	V
f_{OSC}	Oscillation Frequency	3.3V	R_{OSC}=82kΩ	520	610	710	kHz
		5V		470	535	610	kHz
R_{PL}	Output Pull-low Resistor	3.3V	Driver output	40	65	120	kΩ
		5V					
I_{DD}	Operating Current	3.3V	No load, VFD display off, data output =00H	—	—	3	mA
		5V		—	—	5	
I_{OL}	Driver Leakage Current	3.3V	V_O=V_{DD}–35V, VFD driver off	—	—	–5	μA
		5V		—	—	–10	
I_{OL1}	LED Sink Current	3.3V	V_{OL}=1V, LED0~LED3	10	—	—	mA
		5V		20	—	—	
I_{OH1}	LED Source Current	3.3V	V_{OH}=0.9V_{DD}, LED0~LED3	—	—	–1.5	mA
		5V		—	—	–3	
I_{OH21}	Segment 1~16 Source Current	3.3V	V_{OH}=V_{DD}–2V	—	—	–1.5	mA
		5V		—	—	–3	
I_{OH22}	Segment 17~24, Grid 1~4 Source Current	3.3V	V_{OH}=V_{DD}–2V	—	—	–7.5	mA
		5V		—	—	–15	
I_{OL3}	DO Sink Current	3.3V	V_{OL}=0.4V	2	—	—	mA
		5V		4	—	—	

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{IH}	"H" Input Voltage	—	—	$0.7V_{DD}$	—	V_{DD}	V
V_{IL}	"L" Input Voltage	—	—	0	—	$0.3V_{DD}$	V
V_H	Hysteresis Voltage	3.3V	CLK, D_{IN}, $\overline{CS}$	—	0.17	—	V
		5V		—	0.35	—	
V_{OH1}	High-level Output Voltage	3.3V	LED0~LED3, I_{OH1}=–1.5mA	$0.9V_{DD}$	—	V_{DD}	V
		5V	LED0~LED3, I_{OH1}=–3mA				
V_{OL1}	Low-level Output Voltage	3.3V	LED0~LED3, I_{OL1}=10mA	0	—	1	V
		5V	LED0~LED3, I_{OL1}=20mA				
V_{OL2}	Low-level Output Voltage	3.3V	DO, I_{OL2}=2mA	0	—	0.4	V
		5V	DO, I_{OL2}=4mA				

A.C. Characteristics

Ta=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
t_{PHL}	Logic Supply Voltage	3.3V	CLK→DO C_L=15pF, R_L=10kΩ	—	—	600	ns
		5V		—	—	300	
t_{PLH}		3.3V		—	—	600	
		5V		—	—	300	
t_{r1}	Rise Time	3.3V	C_L=300pF, S1~S16	—	—	4	µs
		5V		—	—	2	
t_{r2}		3.3V	C_L=300pF, G1~G4 S17/G12~S24/G5	—	—	1	
		5V		—	—	0.5	
t_f	Fall Time	3.3V	C_L=300pF, Sn, Gn	—	—	240	µs
		5V		—	—	120	
f	Clock Frequency	3.3V	Duty=50%	—	—	0.5	MHz
		5V		—	—	1.0	
C_i	Input Capacitance	3.3V 5V	—	—	—	15	pF
t_{CW}	Clock Pulse Width	3.3V	—	800	—	—	ns
		5V		400	—	—	
t_{SW}	Strobe Pulse Width	3.3V	—	2	—	—	us
		5V		1	—	—	
t_{SU}	Data Setup Time	3.3V	—	200	—	—	ns
		5V		100	—	—	
t_h	Data Hold Time	3.3V	—	200	—	—	ns
		5V		100	—	—	
t_{CS}	Clock-Strobe Time	3.3V	CLK rising edge to $\overline{CS}$ rising edge	2	—	—	µs
		5V		1	—	—	
t_W	Wait Time	3.3V	CLK rising edge to CLK falling edge	2	—	—	µs
		5V		1	—	—	

Functional Description

Display RAM and Display Mode

The static display RAM stores the data transmitted from an external device to the HT16515 through a serial interface. The contents of the RAM are directly mapped to the contents of the VFD driver. Data in the RAM can be accessed through the data setting, address setting and display control commands. It is assigned as addresses in 8-bit unit as follows:

SEG1	SEG4	SEG8	SEG12	SEG16	SEG20	SEG24
$00H_L$	$00H_U$	$01H_L$	$01H_U$	$02H_L$	$02H_U$	DIG1
$03H_L$	$03H_U$	$04H_L$	$04H_U$	$05H_L$	$05H_U$	DIG2
$06H_L$	$06H_U$	$07H_L$	$07H_U$	$08H_L$	$08H_U$	DIG3
$09H_L$	$09H_U$	$0AH_L$	$0AH_U$	$0BH_L$	$0BH_U$	DIG4
$0CH_L$	$0CH_U$	$0DH_L$	$0DH_U$	$0EH_L$	$0EH_U$	DIG5
$0FH_L$	$0FH_U$	$10H_L$	$10H_U$	$11H_L$	$11H_U$	DIG6
$12H_L$	$12H_U$	$13H_L$	$13H_U$	$14H_L$	$14H_U$	DIG7
$15H_L$	$15H_U$	$16H_L$	$16H_U$	$17H_L$	$17H_U$	DIG8
$18H_L$	$18H_U$	$19H_L$	$19H_U$	$1AH_L$	$1AH_U$	DIG9
$1BH_L$	$1BH_U$	$1CH_L$	$1CH_U$	$1DH_L$	$1DH_U$	DIG10
$1EH_L$	$1EH_U$	$1FH_L$	$1FH_U$	$20H_L$	$20H_U$	DIG11
$21H_L$	$21H_U$	$22H_L$	$22H_U$	$23H_L$	$23H_U$	DIG12

b0 b3	b4 b7
XXH_L	XXH_U
Lower 4 bits	Higher 4 bits

Dimming Control

HT16515 provides an 8-step dimmer function on display by controlling the 3-bit binary command code. The full pulse width of grid signal is divided into 16 uniform sections by PWM (pulse width modulation) technology.

The 16 uniform sections available form an 8-step dimmer via 3-bit binary code. The 8-step dimmer includes 1/16, 2/16, 4/16, 10/16, 11/16, 12/16, 13/16 and 14/16. The 1/16 pulse width indicates minimum lightness. The 14/16 pulse width represents maximum lightness (Refer to the display control command).

Key Matrix and Key-Input Data Storage RAM

The key matrix scans the series key states at each level of the key strobe signal (Seg1/K1~Seg16/K16) output of the HT16515. The key strobe signal outputs are time-multiplexed signals from Seg1/K1~Seg16/K16. The states of inputs K0 and K1 are sampled by strobe signal Seg1/K1~Seg16/K16 and latched into the register.

The key matrix is made up of a 16×2 matrix, as shown below.

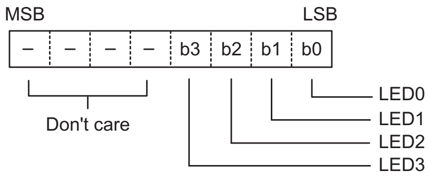
The data of each key is stored as illustrated below, and is read with the read command, starting from the least significant bit.

Key1 Key2	Key1 Key2	Key1 Key2	Key1 Key2	
S1/K1	S2/K2	S3/K3	S4/K4	Reading Sequence
S5/K5	S6/K6	S7/K7	S8/K8	
S9/K9	S10/K10	S11/K11	S12/K12	
S13/K13	S14/K14	S15/K15	S16/K16	
b0 b1	b2 b3	b4 b5	b6 b7	

LED Port

The LED port is of the CMOS output configuration.

Data is written to the LED port with the write command, starting from the least significant bit. In our application (see application circuits), the user adopts an internal NMOS device to a driver LED component by connecting VDD. When a bit of this port is 0, the corresponding LED lights up; when the bit is 1, the LED turns off. The data of bits 4 through 7 are ignored.

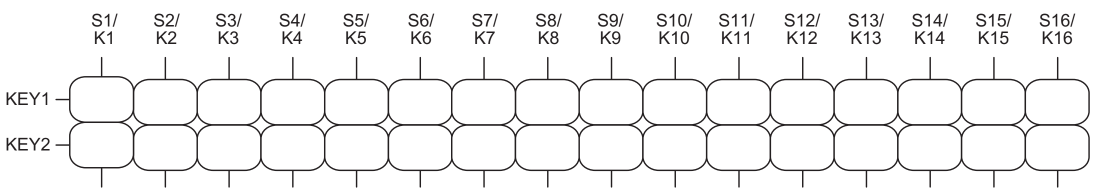


Commands

Commands set the display mode and status of the VFD driver.

The first 1 byte input to the HT16515 through the DI pin after the $\overline{CS}$ pin has fallen, is regarded as a command. If $\overline{CS}$ is set high while commands/data are transmitted, serial communication is initialized, and the commands/ data being transmitted are not valid (however, the commands/data previously transmitted remains valid).

- Display mode setting commands
  These commands initialize the HT16515 and select the number of segments and the number of grids (1/4~1/12 duty, 16 to 24 segments).
  When these commands are executed, the display is forcibly turned off, and key scanning is also stopped. To resume display, the display command ″ON″ must be executed. If the same mode is selected, nothing happens.



MSB							LSB
0	0	–	–	b3	b2	b1	b0

Don't care

Selects Display Mode
0000: 4 digits, 24 segments
0001: 5 digits, 23 segments
0010: 6 digits, 22 segments
0011: 7 digits, 21 segments
0100: 8 digits, 20 segments
0101: 9 digits, 19 segments
0110: 10 digits, 18 segments
0111: 11 digits, 17 segments
1xxx: 12 digits, 16 segments

Note: Power-on status: 12-digit, 16 segment mode is selected.

• Data setting commands

These commands set the data write and data read modes.

MSB							LSB
0	1	–	–	b3	b2	b1	b0

Don't care

Sets data write and read mode
00: Write data to display memory
01: Write data to LED port
10: Read key data
11: Don't care

Address increment mode settings (display memory)
0: Increments address after data has been written
1: Fixes address

Test mode settings
0: Normal mode
1: Test mode, user don't use

Note: power-on status: normal mode operation and address increment mode are set.

• Address setting commands

These commands set the address of the display memory.

MSB							LSB
1	1	b5	b4	b3	b2	b1	b0

Address (00H~23H)

If address 24H or higher is set, data is ignored until a valid address is set.
Note: power-on status: the address is set to 00H.

• Display control commands

MSB							LSB
1	0	–	–	b3	b2	b1	b0

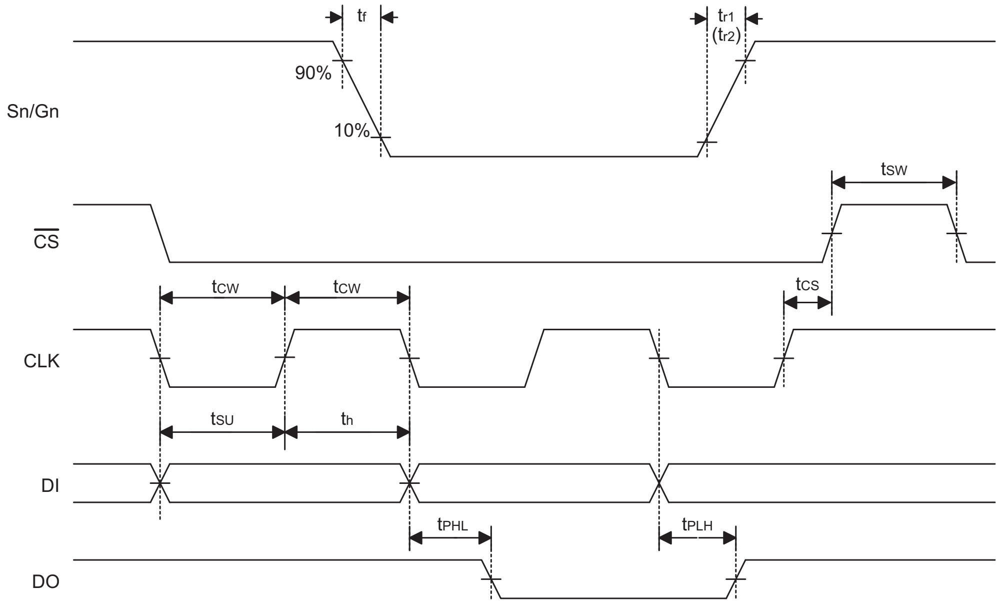
Don't care

Sets dimming quantity
000: Set pulse width to 1/16
001: Set pulse width to 2/16
010: Set pulse width to 4/16
011: Set pulse width to 10/16
100: Set pulse width to 11/16
101: Set pulse width to 12/16
110: Set pulse width to 13/16
111: Set pulse width to 14/16

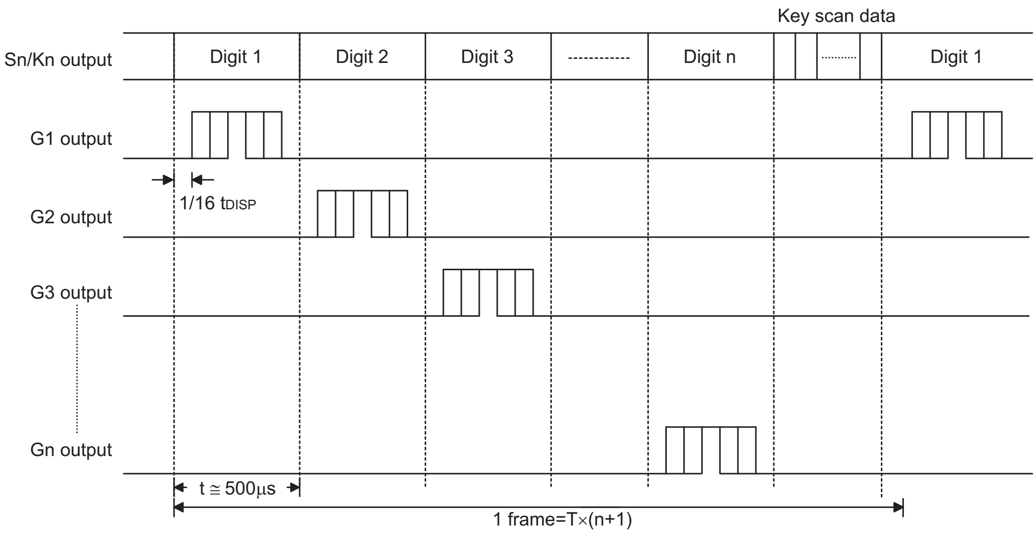
Turns on/off display
0: Display off (key scan continues)
1: Display on

Note: power-on status: 1/16 pulse width is set and the display is turned off. Key scanning will be stopped during power-on status.

Timing Diagrams



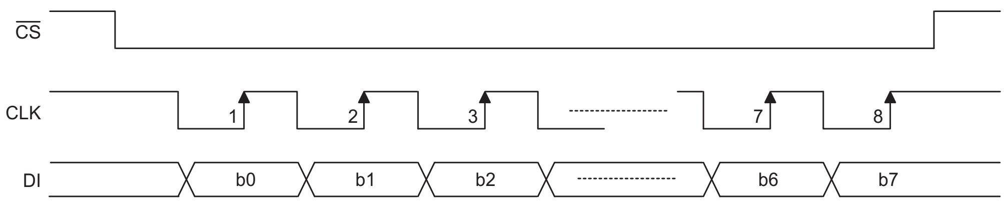
Key Scanning and Display Timing



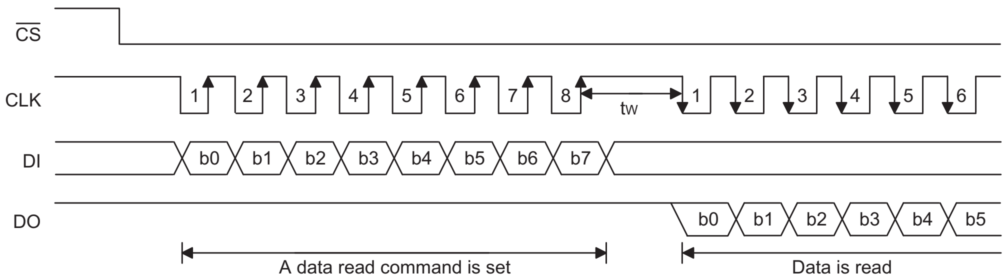
Note: One cycle of key scanning consists of two frames, and data of 16×2 matrixes is stored in the RAM.

Serial Communication Format

- Reception (command/data write)

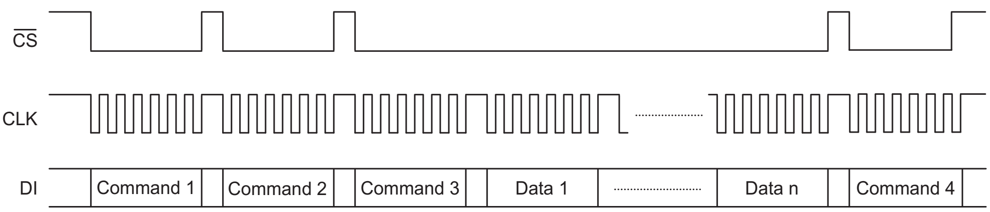


- Transmission (data read)



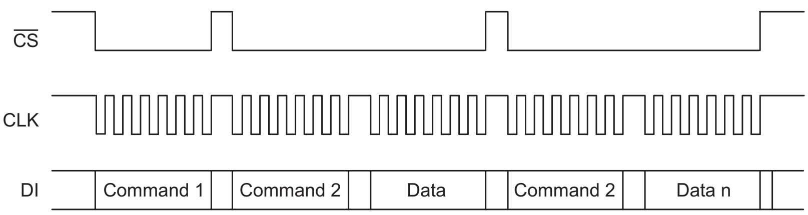
Be sure to connect an external pull-high resistor to this pin (1kΩ to 10kΩ).
Note: 1. When data is read, a wait time "t_W" of 1μs is necessary at 5V.
2. When data is read, a wait time "t_W" of 2μs is necessary at 3V.

- Updating display memory by incrementing address



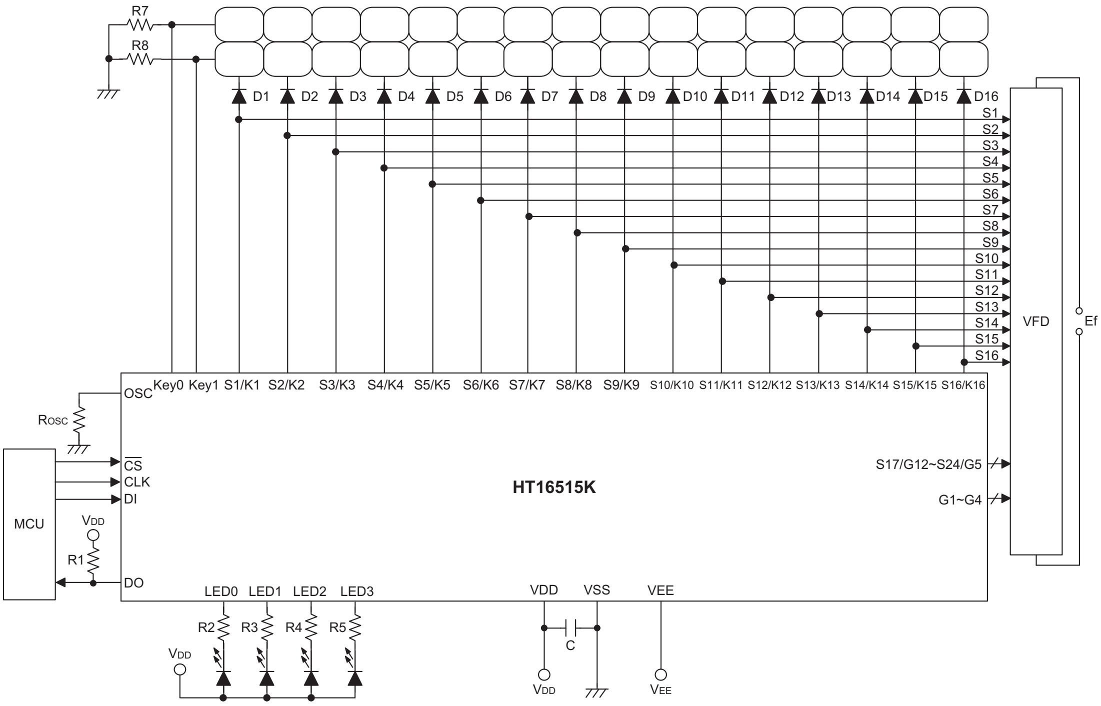
Note: Command 1: sets display mode
Command 2: sets data
Command 3: sets address
Data 1 to n: transfers display data (36 bytes max.)
Command 4: controls display

- Updating specific addresses



Note: Command 1: sets data
Command 2: sets address
Data: display data

Application Circuits



Note: R_{OSC}=82kΩ for oscillator resistor
R1=1~10kΩ for external pull-high resistor
R2~R6=750Ω~1.2kΩ
R7~R8=10kΩ for external pull-low resistor
D1~D16=1N4001
Ef=Filament voltage for VFD
C=0.1μF

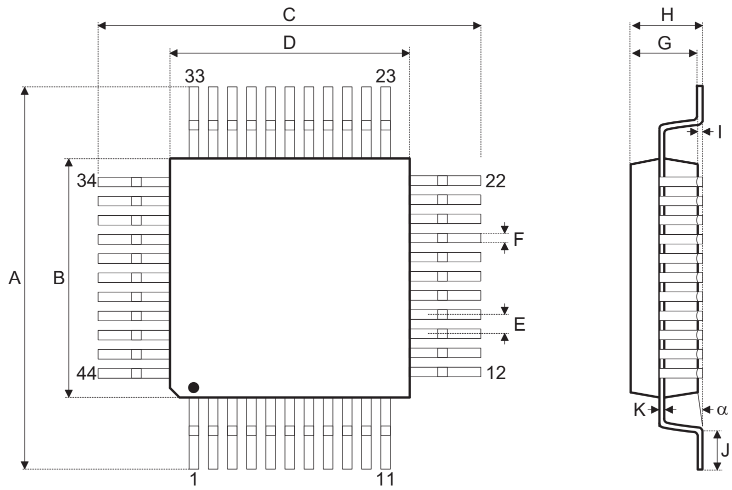
Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the Holtek website for the latest version of the Package/Carton Information.

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Further Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- Packing Meterials Information
- Carton information

44-pin LQFP (10mm×10mm) (FP2.0mm) Outline Dimensions



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.472 BSC	—
B	—	0.394 BSC	—
C	—	0.472 BSC	—
D	—	0.394 BSC	—
E	—	0.032 BSC	—
F	0.012	0.015	0.018
G	0.053	0.055	0.057
H	—	—	0.063
I	0.002	—	0.006
J	0.018	0.024	0.030
K	0.004	—	0.008
α	0°	—	7°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	12.00 BSC	—
B	—	10.00 BSC	—
C	—	12.00 BSC	—
D	—	10.00 BSC	—
E	—	0.80 BSC	—
F	0.30	0.37	0.45
G	1.35	1.40	1.45
H	—	—	1.60
I	0.05	—	0.15
J	0.45	0.60	0.75
K	0.09	—	0.20
α	0°	—	7°