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 QFP package

Applications

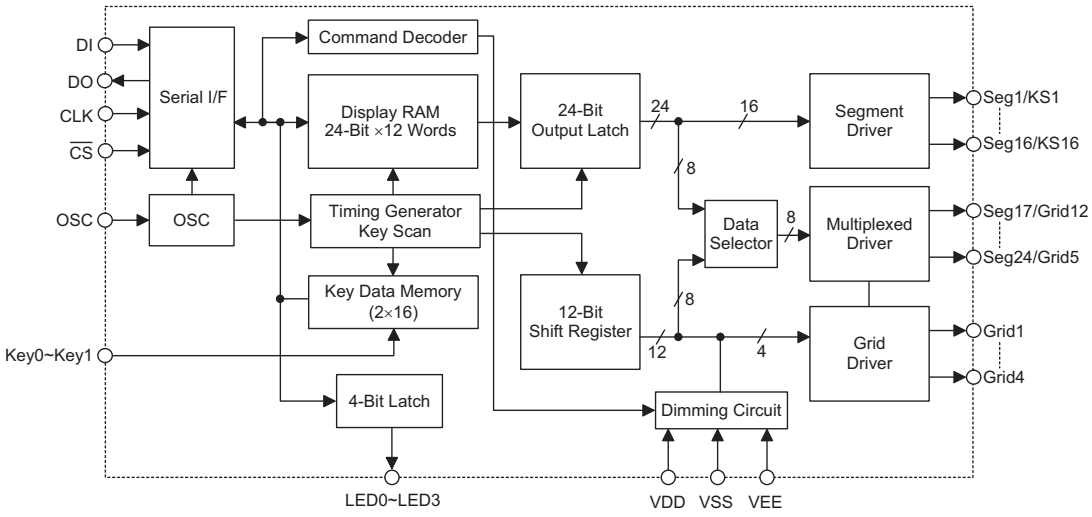
- Consumer products panel function control
- Industrial measuring instrument panel function control
- Other similar applications for panel function control

General Description

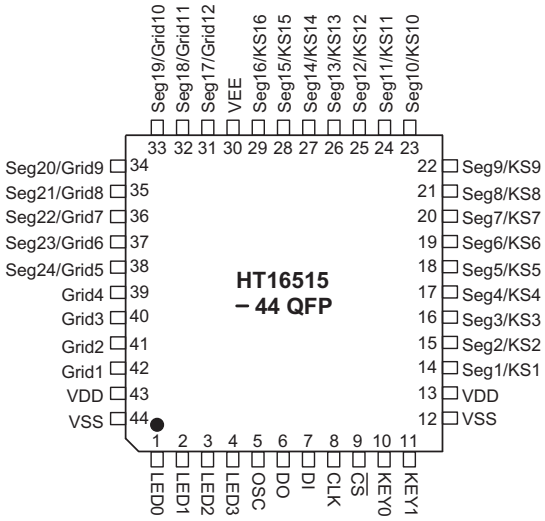
HT16515 is a VFD (Vacuum Fluorescent Display) controller/driver that is driven on a 1/4 to 1/12 duty factor. It consists of 16 segment output lines, 4 grid output lines, 8 segment/grid output drive lines, 4 LED output ports, a control circuit, a display memory, and a key scan circuit.

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

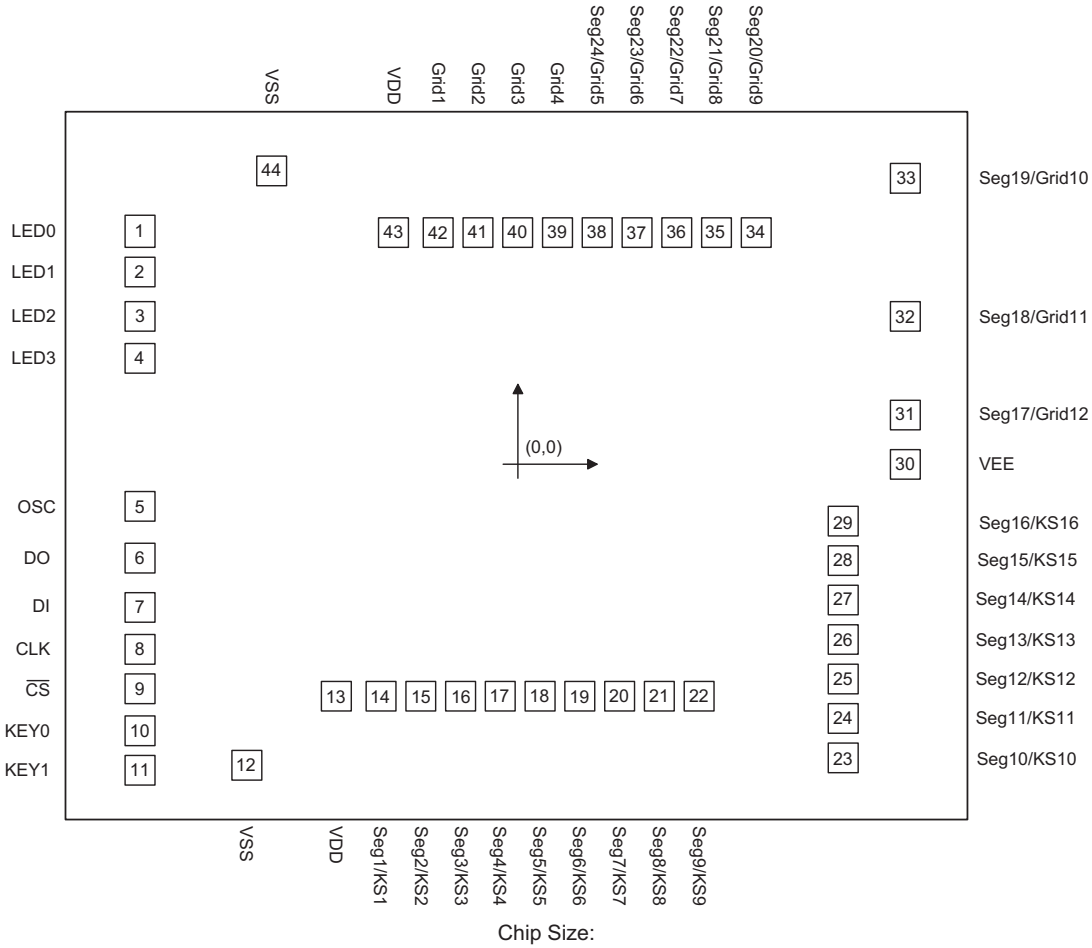
Block Diagram



Pin Assignment



Pad Assignment



Chip Size:

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

Pad Coordinates

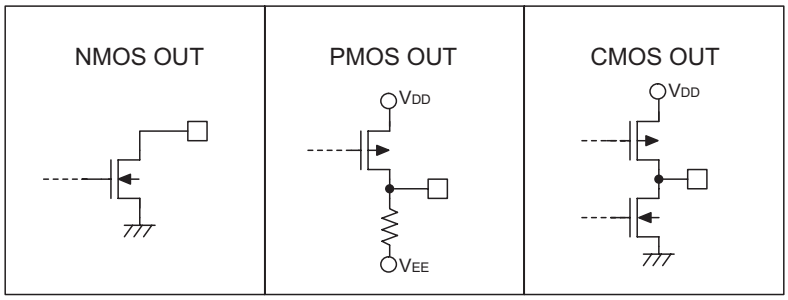
Unit: μm

Pad No.	X	Y	Pad No.	X	Y
1	–962.50	600.00	23	834.10	–754.00
2	–962.50	495.00	24	834.10	–652.60
3	–962.50	380.20	25	834.10	–551.20
4	–962.50	275.20	26	834.10	–449.80
5	–962.50	–107.20	27	834.10	–348.40
6	–962.50	–235.60	28	834.10	–247.00
7	–962.50	–366.00	29	834.10	–145.60
8	–962.50	–471.00	30	987.30	0.50
9	–962.50	–576.00	31	987.30	130.50
10	–962.50	–681.00	32	987.30	382.05
11	–962.50	–786.00	33	987.30	734.05
12	–689.60	–772.45	34	610.30	594.40
13	–460.45	–595.30	35	508.90	594.40
14	–344.25	–595.30	36	407.50	594.40
15	–242.85	–595.30	37	306.10	594.40
16	–141.45	–595.30	38	204.70	594.40
17	–40.05	–595.30	39	103.30	594.40
18	61.35	–595.30	40	1.90	594.40
19	162.75	–595.30	41	–99.50	594.40
20	264.15	–595.30	42	–200.90	594.40
21	365.55	–595.30	43	–317.10	594.40
22	466.95	–595.30	44	–624.50	756.80

Pin Description

Pin No.	Pin Name	I/O	Description
1~4	LED3~LED0	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	350	500	650	kHz
		5V					
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	—	5	μA
		5V		–10	—	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	—	—	
V_{IH}	"H" Input Voltage	—	—	0.7V_{DD}	—	V_{DD}	V

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
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	
t_{max}	Maximum Clock Frequency	3.3V	Duty=50%	0.5	—	—	MHz
		5V		1	—	—	
C_i	Input Capacitance	3.3V	—	—	—	15	pF
		5V					
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	
00HL	00HU	01HL	01HU	02HL	02HU		DIG1
03HL	03HU	04HL	04HU	05HL	05HU		DIG2
06HL	06HU	07HL	07HU	08HL	08HU		DIG3
09HL	09HU	0AHL	0AHU	0BHL	0BHU		DIG4
0CHL	0CHU	0DHL	0DHU	0EHL	0EHU		DIG5
0FHL	0FHU	10HL	10HU	11HL	11HU		DIG6
12HL	12HU	13HL	13HU	14HL	14HU		DIG7
15HL	15HU	16HL	16HU	17HL	17HU		DIG8
18HL	18HU	19HL	19HU	1AHL	1AHU		DIG9
1BHL	1BHU	1CHL	1CHU	1DHL	1DHU		DIG10
1EHL	1EHU	1FHL	1FHU	20HL	20HU		DIG11
21HL	21HU	22HL	22HU	23HL	23HU		DIG12

b0 b3	b4 b7
XXHL	XXHU
Lower 4 bits	Higher 4 bits

Dimming Control

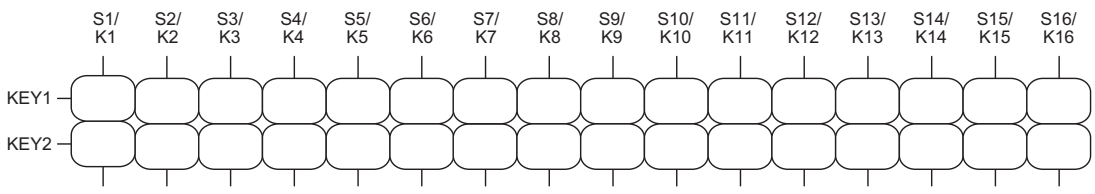
HT16515 provides an 8-step dimmer function on display by controlling the 3-bit binary command code. The full pulse width of grid signal is divided into 16 uniform sections by PWM (pulse width modulation) technology.

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.

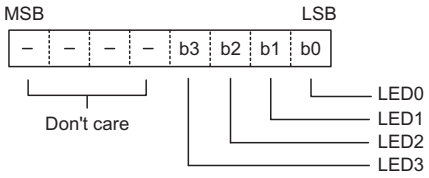
Key1 Key2	Key1 Key2	Key1 Key2	Key1 Key2
S1/K1	S2/K2	S3/K3	S4/K4
S5/K5	S6/K6	S7/K7	S8/K8
S9/K9	S10/K10	S11/K11	S12/K12
S13/K13	S14/K14	S15/K15	S16/K16
b0 b1	b2 b3	b4 b5	b6 b7

Reading Sequence

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.

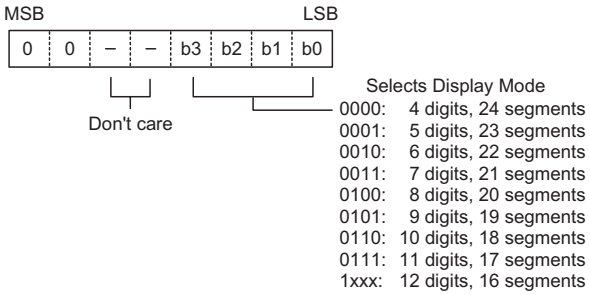


Commands

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).

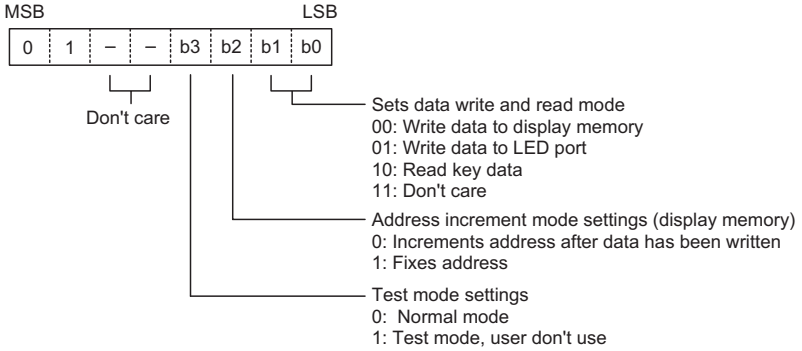
- Display mode setting commands
  These commands initialize the HT16515 and select the number of segments and the number of grids (1/4~1/12 duty, 16 to 24 segments).
  When these commands are executed, the display is forcibly turned off, and key scanning is also stopped. To resume display, the display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



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

- Data setting commands

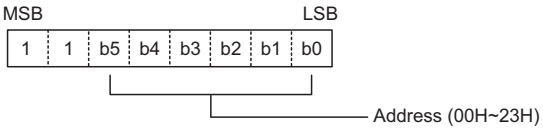
  These commands set the data write and data read modes.



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

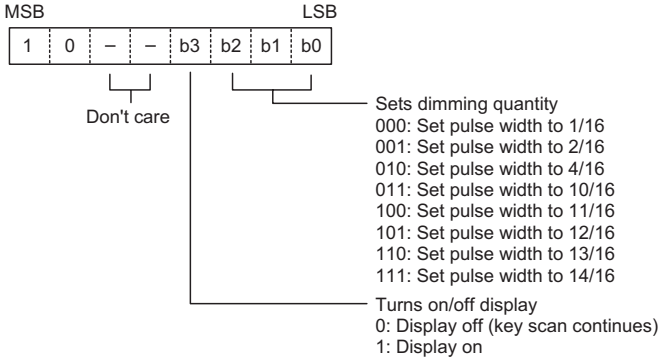
- Address setting commands

  These commands set the address of the display memory.



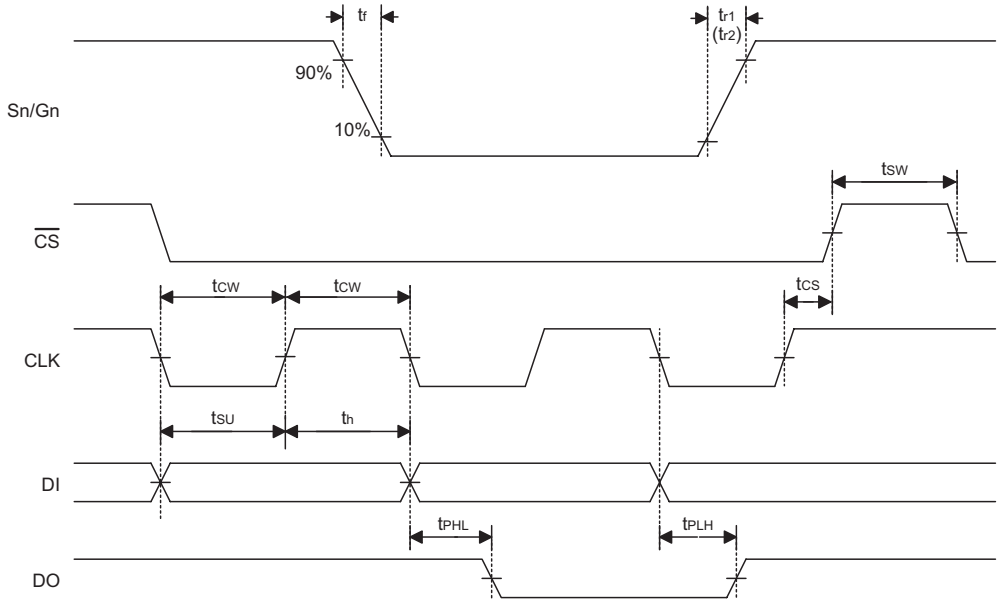
  If address 24H or higher is set, data is ignored until a valid address is set.
  Note: power-on status: the address is set to 00H.

- Display control commands

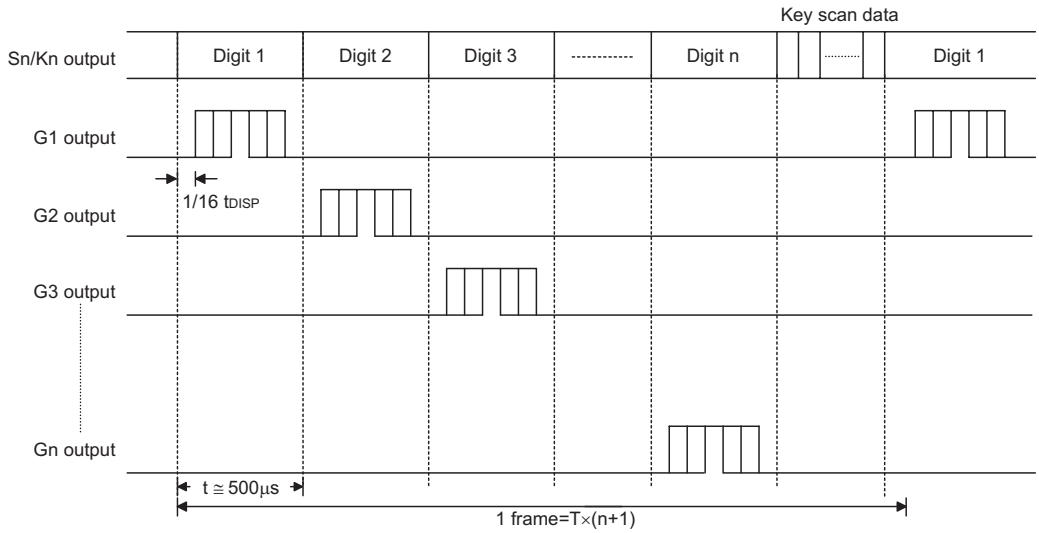


  Note: power-on status: 1/16 pulse width is set and the display is turned off. Key scanning will be stopped during power-on status.

Timing Diagrams



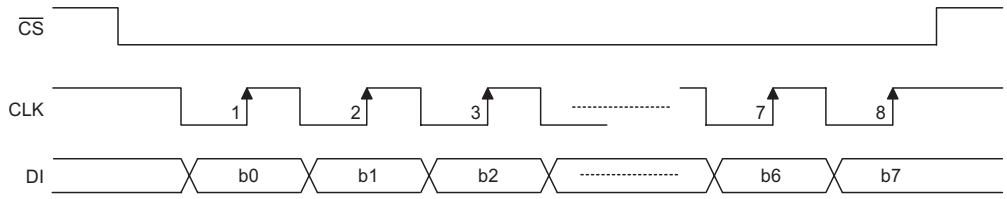
Key Scanning and Display Timing



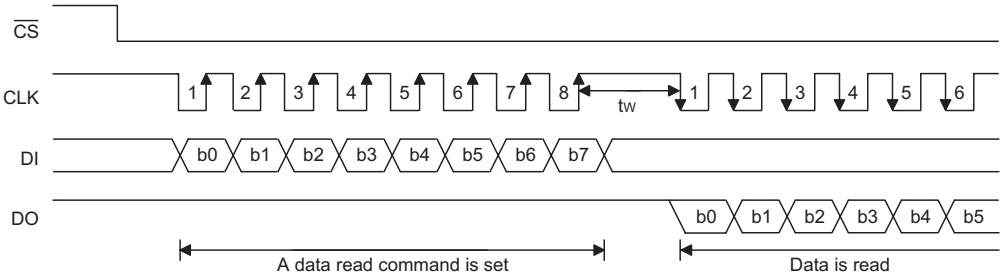
Note: One cycle of key scanning consists of two frames, and data of 16×2 matrixes is stored in the RAM.

Serial Communication Format

- Reception (command/data write)



- Transmission (data read)

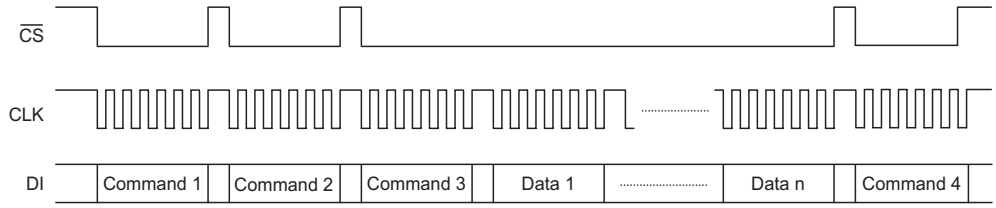


Be sure to connect an external pull-high resistor to this pin (1kΩ to 10kΩ).

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

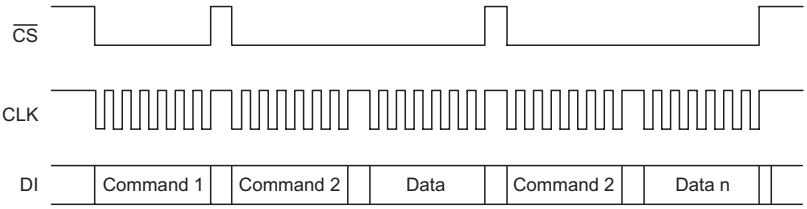
Command 2: sets data

Command 3: sets address

Data 1 to n: transfers display data (36 bytes max.)

Command 4: controls display

- Updating specific addresses

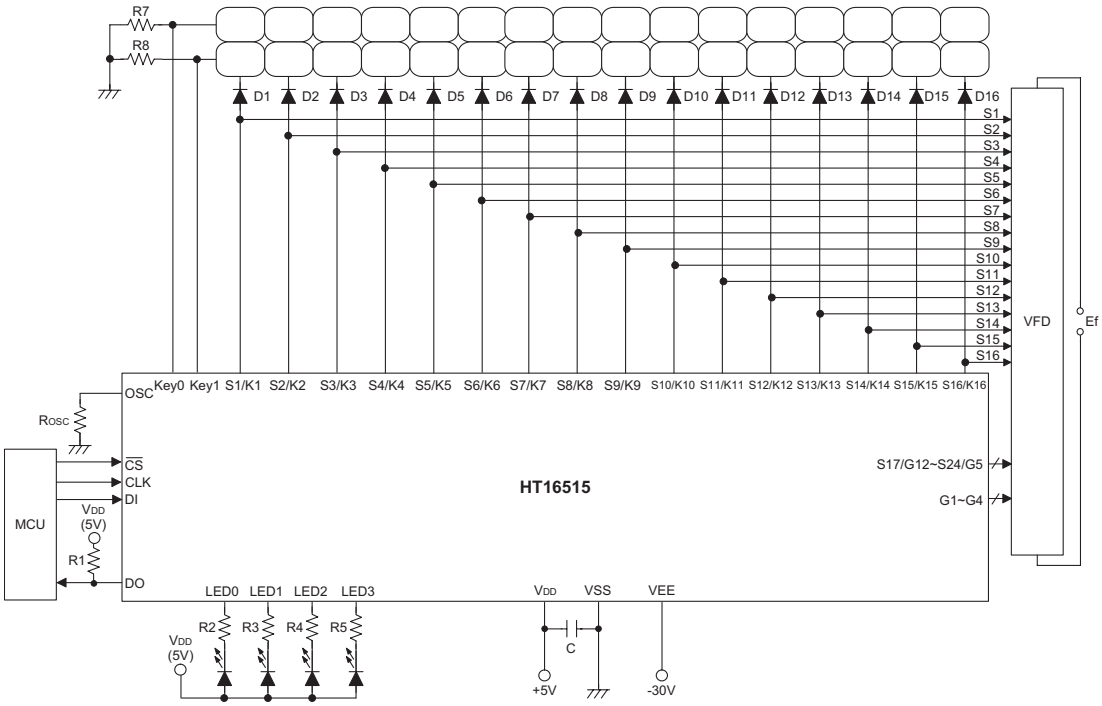


Note: Command 1: sets data

Command 2: sets address

Data: display data

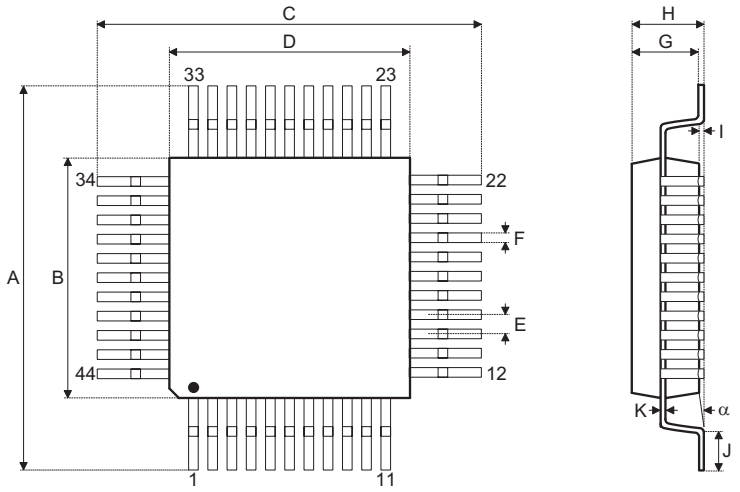
Application Circuits



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~D6=1N4001
Ef=Filament voltage for VFD
C=0.1μF~1.0μF

Package Information

44-pin QFP (10×10) Outline Dimensions



Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	13	—	13.40
B	9.90	—	10.10
C	13	—	13.40
D	9.90	—	10.10
E	—	0.80	—
F	—	0.30	—
G	1.90	—	2.20
H	—	—	2.70
I	—	0.10	—
J	0.73	—	0.93
K	0.10	—	0.20
α	0°	—	7°

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