HOLTEK

HT16515
1/4 to 1/12 Duty VFD Controller

Features

- Logic voltage: 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 (20mA max.)
- 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)
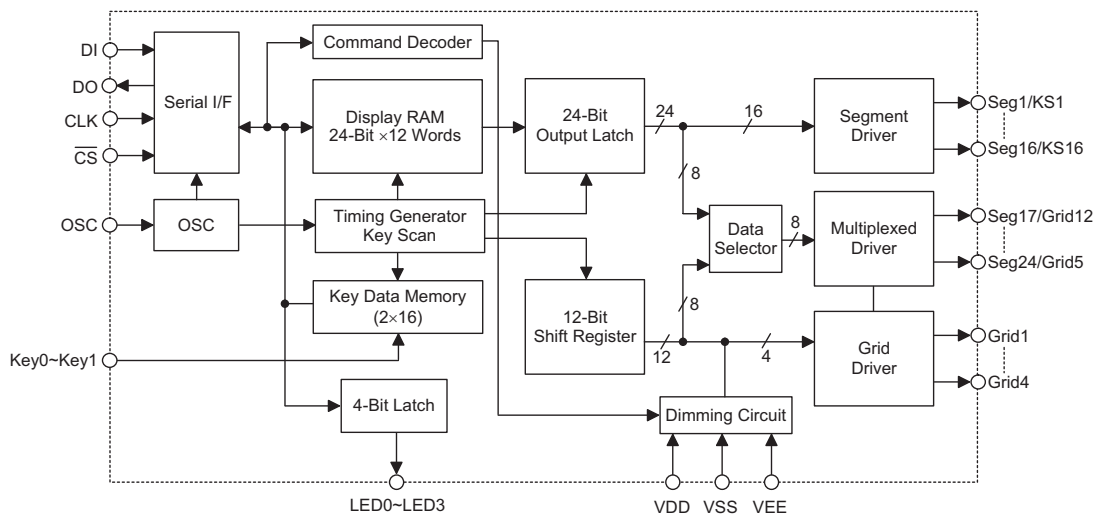- 44-pin QFP package

Applications

- Consumer products panel function control
- Industrial measuring instrument panel function control

- Other similar applications for panel function control
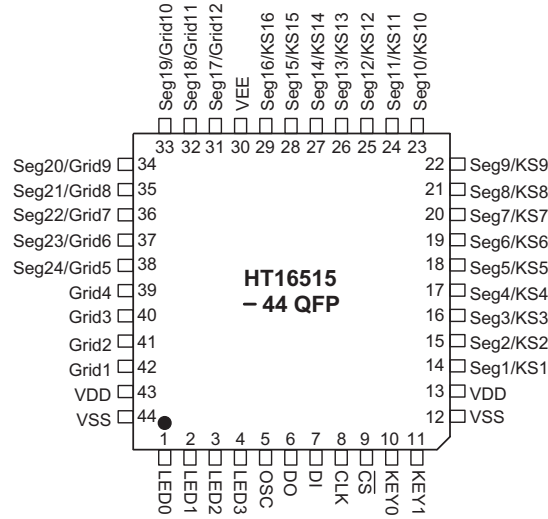
General Description

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.
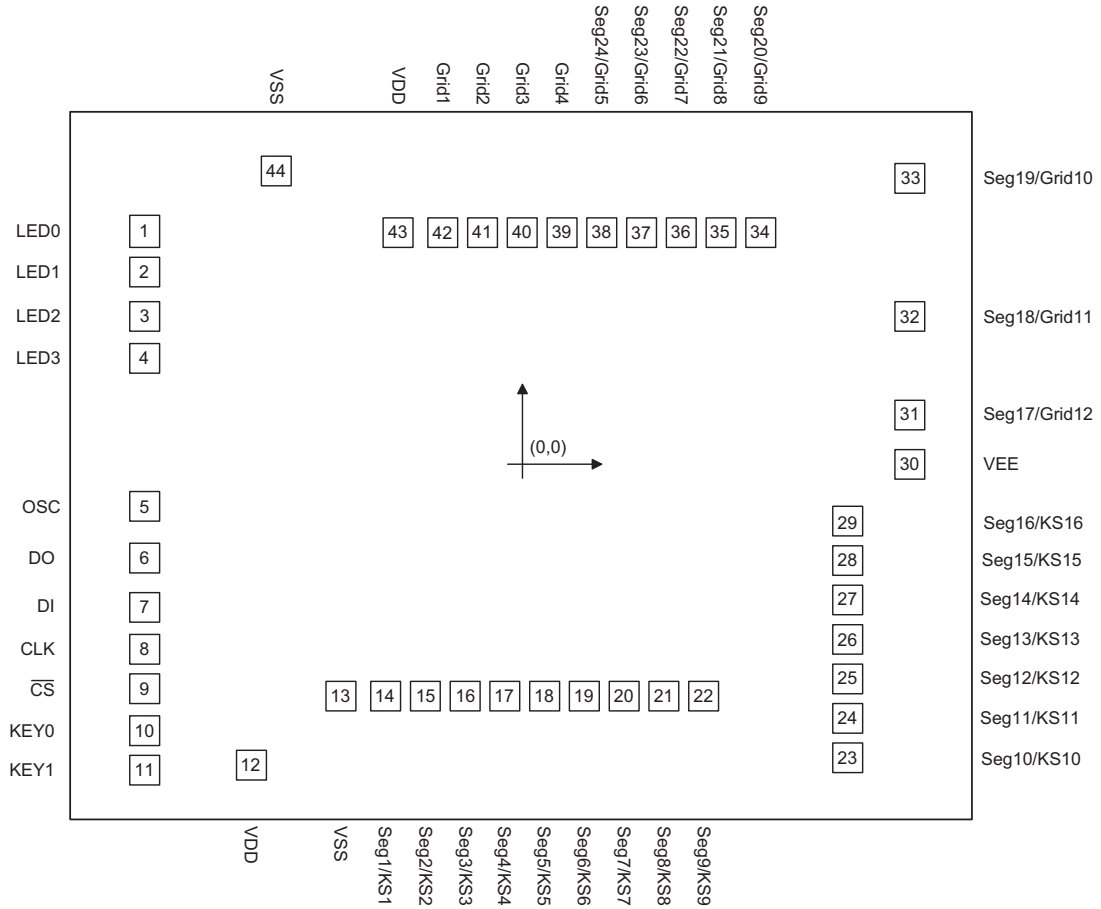
Block Diagram

Pin Assignment

HT16515
– 44 QFP

Top side pins (33–23, left to right): Seg19/Grid10, Seg18/Grid11, Seg17/Grid12, VEE, Seg16/KS16, Seg15/KS15, Seg14/KS14, Seg13/KS13, Seg12/KS12, Seg11/KS11, Seg10/KS10

Left side pins (34–44): Seg20/Grid9, Seg21/Grid8, Seg22/Grid7, Seg23/Grid6, Seg24/Grid5, Grid4, Grid3, Grid2, Grid1, VDD, VSS

Right side pins (22–12): Seg9/KS9, Seg8/KS8, Seg7/KS7, Seg6/KS6, Seg5/KS5, Seg4/KS4, Seg3/KS3, Seg2/KS2, Seg1/KS1, VDD, VSS

Bottom side pins (1–11): LED0, LED1, LED2, LED3, OSC, DO, DI, CLK, $\overline{CS}$, KEY0, KEY1

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
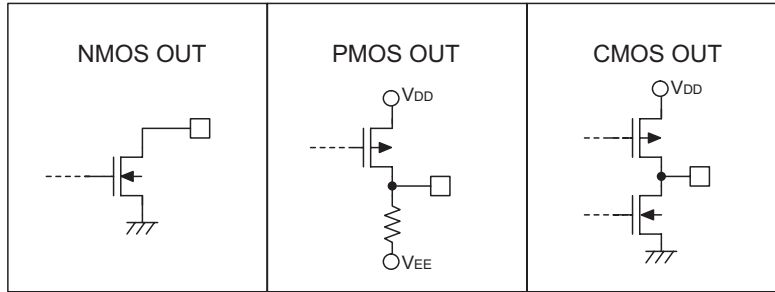
Absolute Maximum Ratings

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

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V_{DD}	Conditions				
V_{DD}	Logic Supply Voltage	—	—	4.5	5	5.5	V
V_{EE}	VFD Supply Voltage	—	—	0	—	V_{DD}–35	V
f_{OSC}	Oscillation Frequency	5V	R_{OSC}=82kΩ	350	500	650	kHz
R_{PL}	Output Pull-low Resistor	5V	Driver output	40	65	120	kΩ
I_{DD}	Operating Current	5V	No load, VFD display off	—	—	5	mA
I_{OL}	Driver Leakage Current	5V	V_O=V_{DD}–30V, VFD driver off	—	—	–10	μA
I_{OL1}	LED Sink Current	5V	V_{OL}=1V, LED0~LED3	20	—	—	mA
I_{OH1}	LED Source Current	5V	V_{OH}=0.9V_{DD}, LED0~LED3	–3	—	—	mA
I_{OH21}	Segment 1~16 Source Current	5V	V_{OH}=V_{DD}–2V	–3	—	—	mA
I_{OH22}	Segment 17~24, Grid 1~4 Source Current	5V	V_{OH}=V_{DD}–2V	–15	—	—	mA
I_{OL3}	DO Sink Current	5V	V_{OL}=0.4V	4	—	—	mA
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	—	CLK, D_{IN}, $\overline{CS}$	—	0.35	—	V
V_{OH1}	High-level Output Voltage	5V	LED0~LED3, I_{OH1}=–3mA	0.9V_{DD}	—	V_{DD}	V
V_{OL1}	Low-level Output Voltage	5V	LED0~LED3, I_{OL1}=20mA	0	—	1	V
V_{OL2}	Low-level Output Voltage	5V	DO, I_{OL2}=4mA	0	—	0.4	V

A.C. Characteristics

Ta=25°C

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

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).
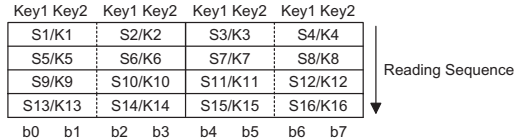
Key Matrix and Key-Input Data Storage RAM

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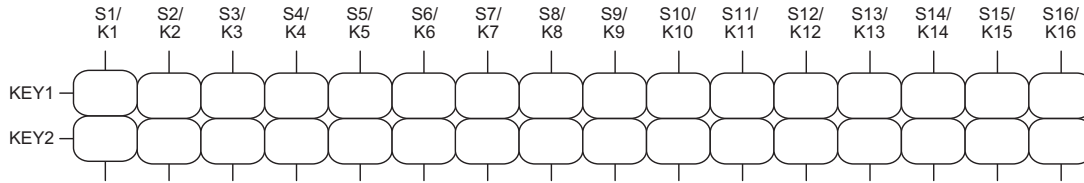
The data of each key is stored as illustrated below, and is read with the read command, starting from the least significant bit.

Key1 Key2	Key1 Key2	Key1 Key2	Key1 Key2	
S1/K1	S2/K2	S3/K3	S4/K4	
S5/K5	S6/K6	S7/K7	S8/K8	Reading Sequence
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.
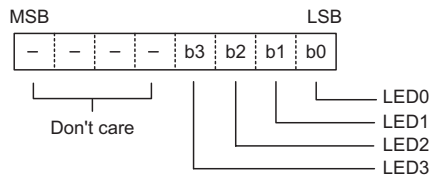
Commands

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.
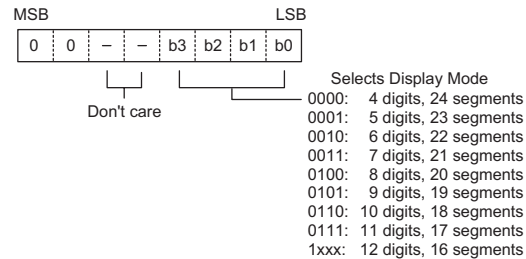
Note: Power-on status: 12-digit, 16 segment mode is selected.
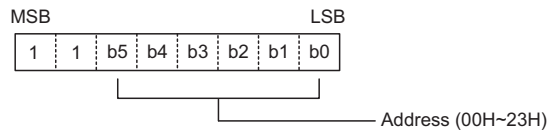
• Data setting commands

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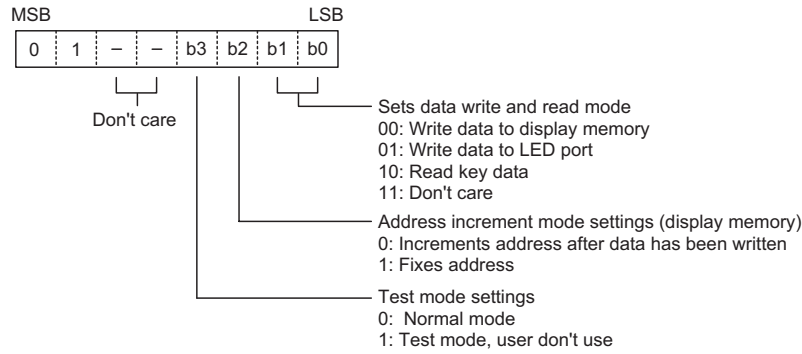
Note: power-on status: normal mode operation and address increment mode are set.

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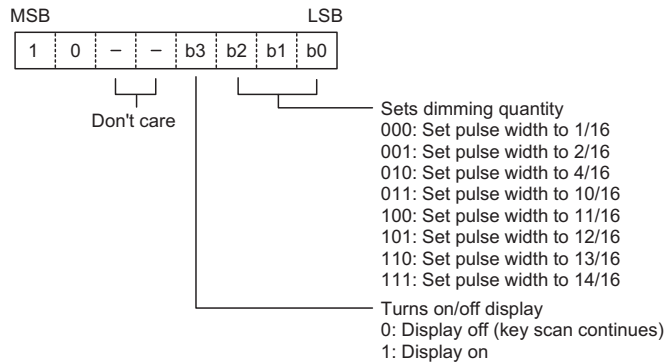
Note: power-on status: 1/16 pulse width is set and the display is turned off. Key scanning will be stopped during power-on status.

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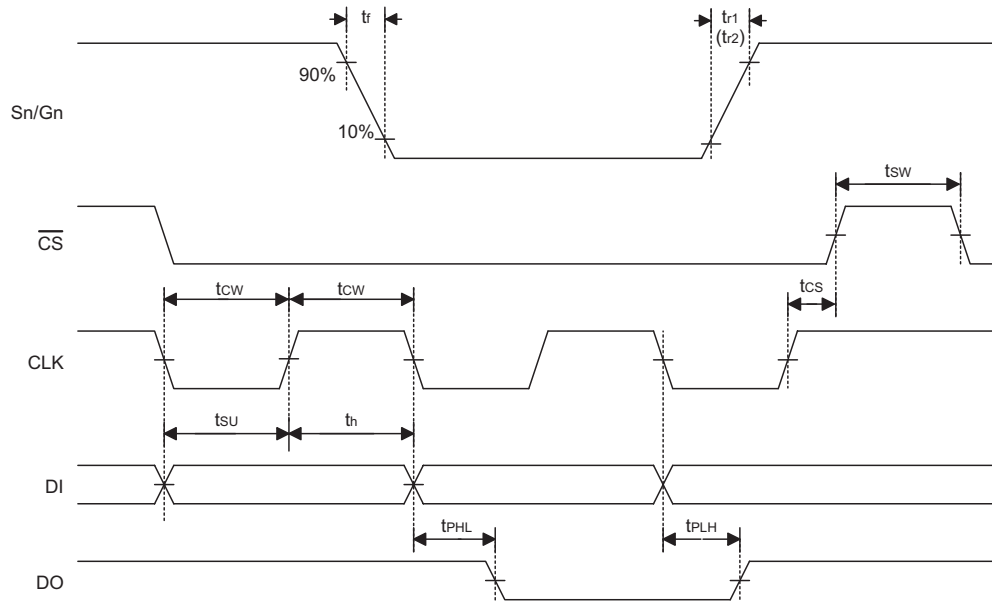
Key Scanning and Display Timing
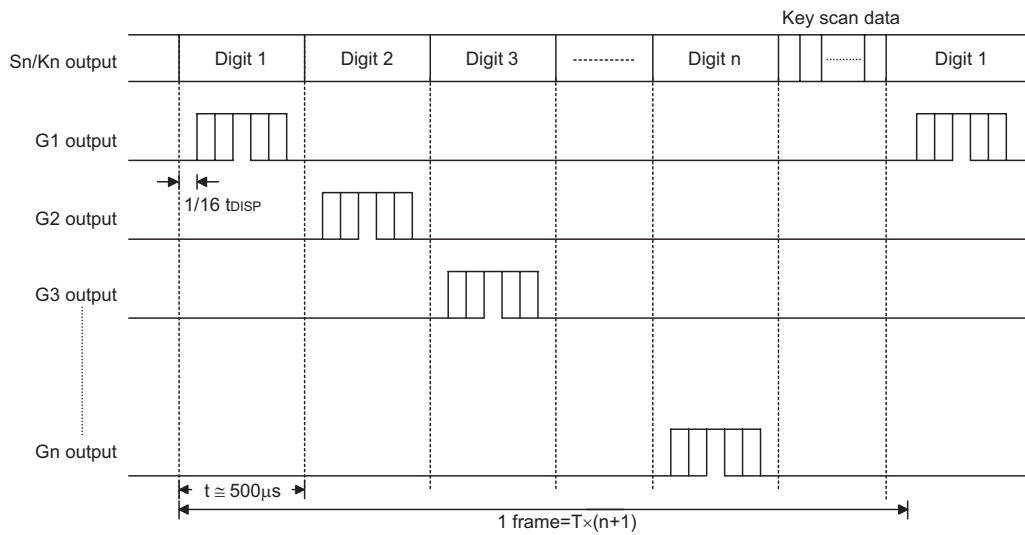
Note: One cycle of key scanning consists of two frames, and data of 16×2 matrixes is stored in the RAM.

Serial Communication Format

- Reception (command/data write)

- Transmission (data read)
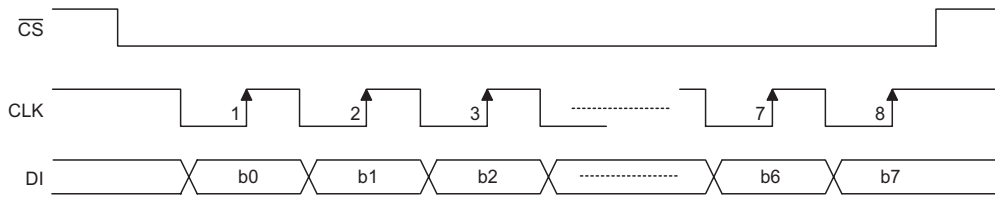
A data read command is set   Data is read
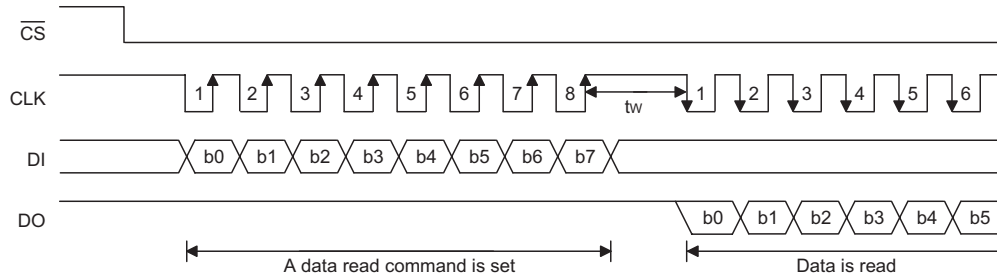
Be sure to connect an external pull-high resistor to this pin ($1k\Omega$ to $10k\Omega$).

Note: When data is read, a wait time "t_W" of $1\mu s$ is necessary.

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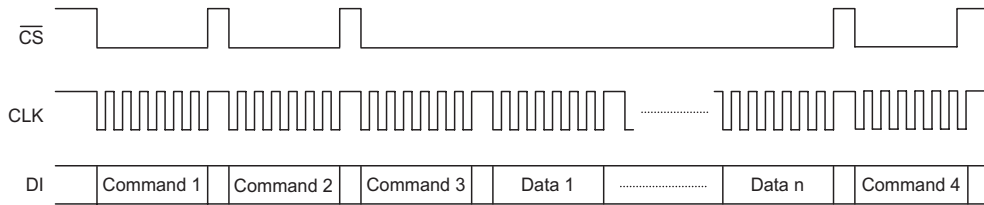
Note: Command 1: sets display mode
　　　Command 2: sets data
　　　Command 3: sets address
　　　Data 1 to n: transfers display data (36 bytes max.)
　　　Command 4: controls display

- Updating specific addresses
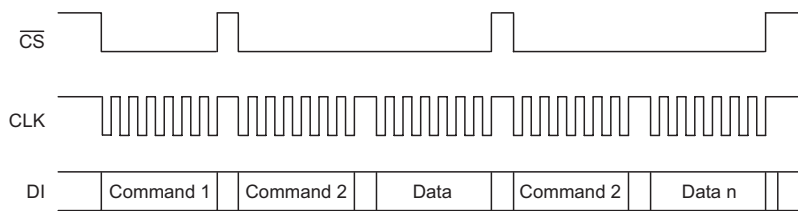
Note: Command 1: sets data
　　　Command 2: sets address
　　　Data: display data

Application Circuits
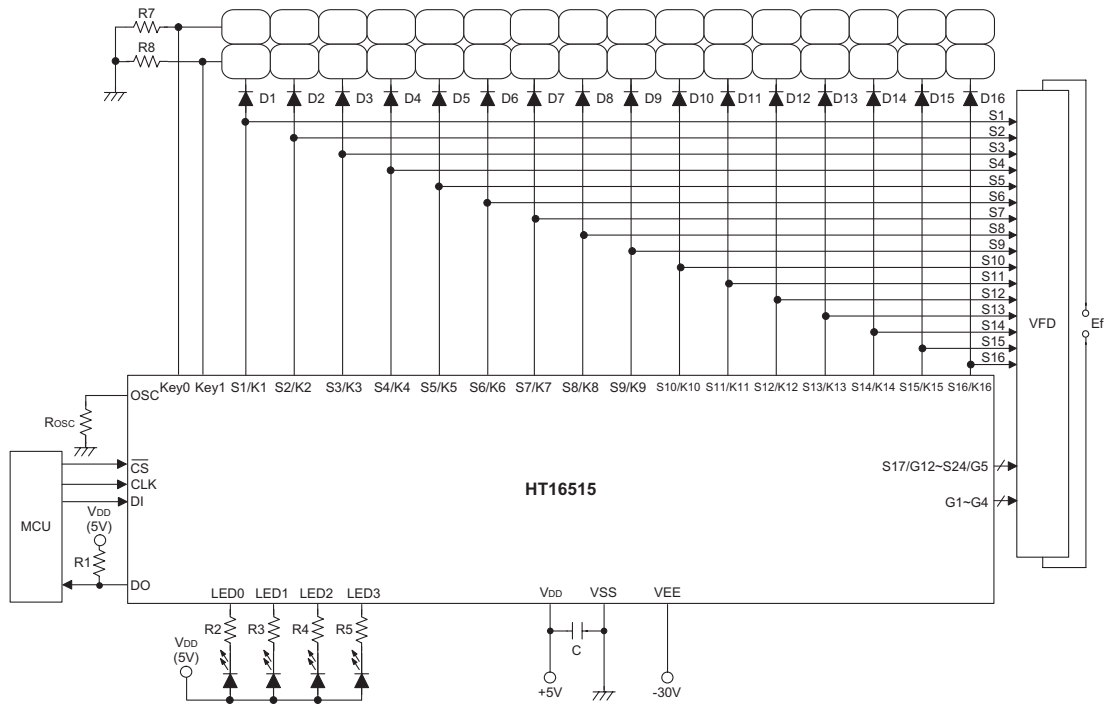
Note: R$_{OSC}$=82kΩ for oscillator resistor
R1=1~10kΩ for external pull-high resistor
R2~R6=750Ω~1.2kΩ
R7~R8=10kΩ for external pull-low resistor
D1~D6=1N4001
Ef=Filament voltage for VFD
C=0.1μF~1.0μF

Package Information

44-pin QFP (10×10) Outline Dimensions
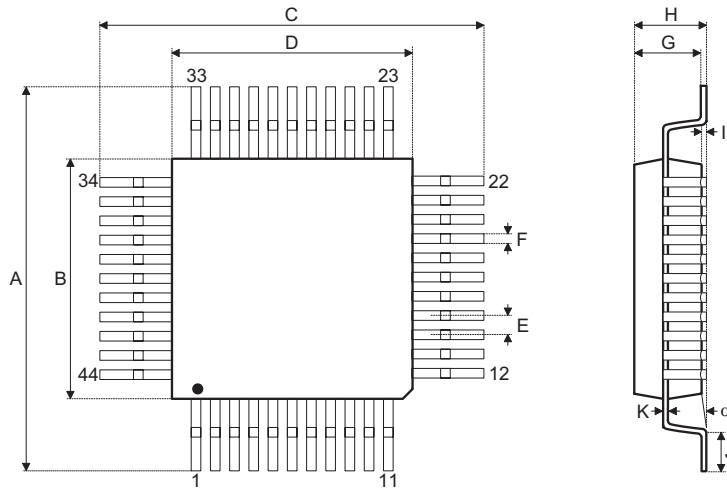
Symbol	Dimensions in mm		
	Min.	**Nom.**	**Max.**
A	13	—	13.40
B	9.90	—	10.10
C	13	—	13.40
D	9.90	—	10.10
E	—	0.80	—
F	—	0.30	—
G	1.90	—	2.20
H	—	—	2.70
I	—	0.10	—
J	0.73	—	0.93
K	0.10	—	0.20
α	0°	—	7°