## 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

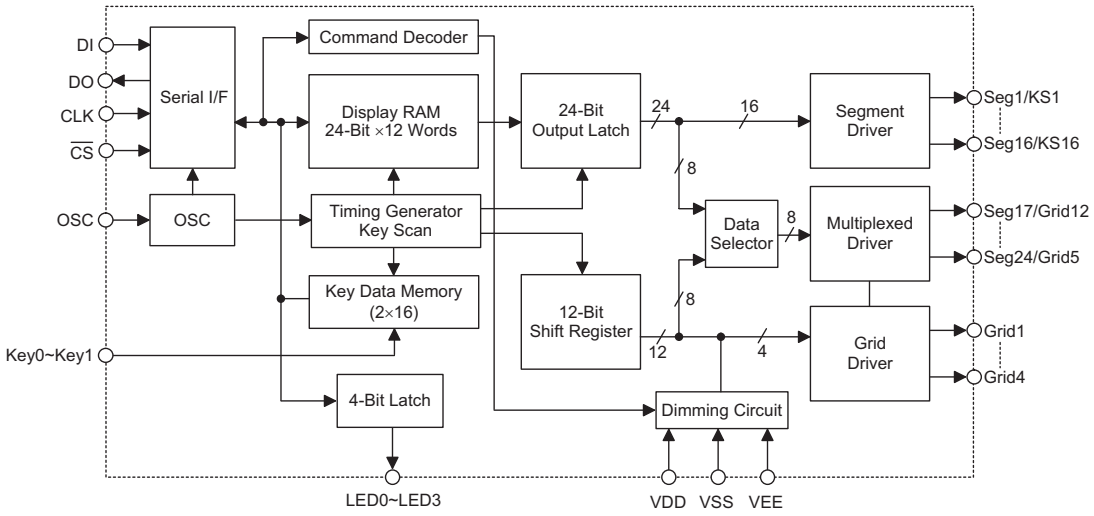
- Consumer products panel function control
- Industrial measuring instrument panel function control
- Other similar applications for panel function control

## General Description

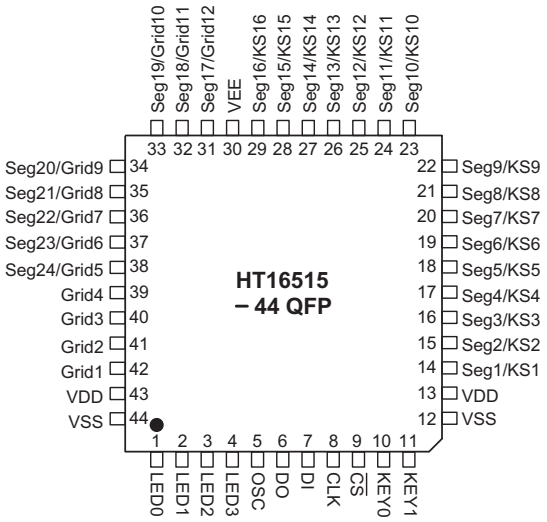
HT16515 is a VFD (Vacuum Fluorescent Display) controller/driver that is driven on a 1/4 to 1/12 duty factor. It consists of 16 segment output lines, 4 grid output lines, 8 segment/grid output drive lines, 4 LED output ports, a control circuit, a display memory, and a key scan circuit.

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

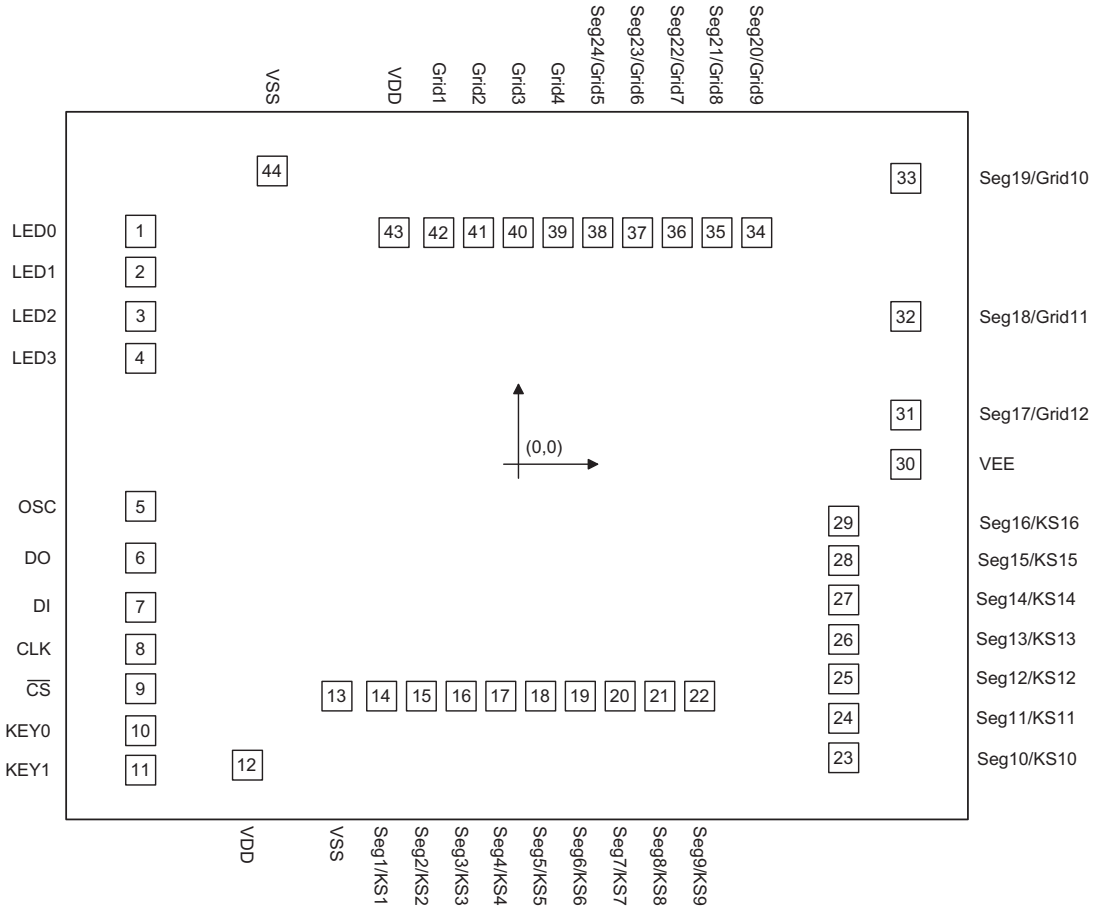
## Block Diagram



## Pin Assignment




## Pad Assignment




Chip Size:

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

## Pad Coordinates

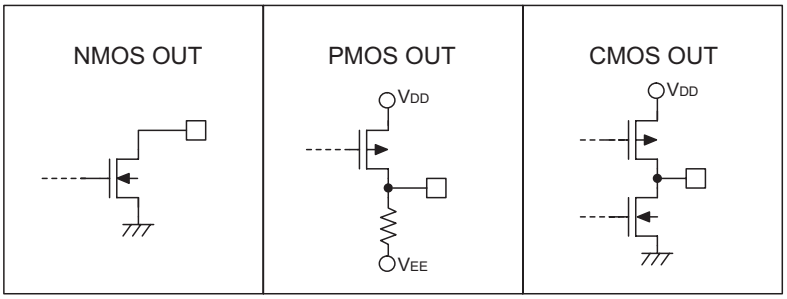
Unit: μm

| 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 | $V_{OH}$=0.9$V_{DD}$, 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 | — | — | 0.7$V_{DD}$ | — | $V_{DD}$ | V |
| $V_{IL}$ | "L" Input Voltage | — | — | 0 | — | 0.3$V_{DD}$ | 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 | 0.9$V_{DD}$ | — | $V_{DD}$ | 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<br>$C_L$=15pF, $R_L$=10kΩ | — | — | 300 | ns |
| $t_{PLH}$ | | 5V | | — | — | 300 | ns |
| $t_{r1}$ | Rise Time | 5V | $C_L$=300pF, S1~S16 | — | — | 2 | μs |
| $t_{r2}$ | | 5V | $C_L$=300pF, G1~G4<br>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

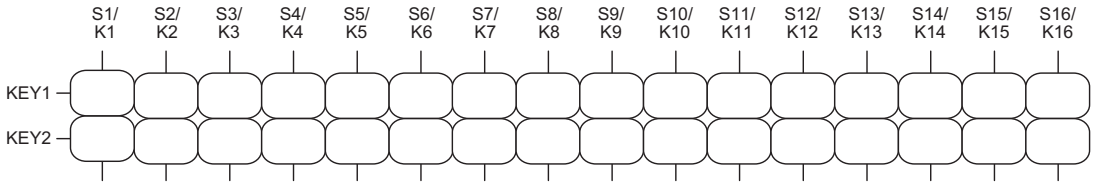
HT16515 provides an 8-step dimmer function on display by controlling the 3-bit binary command code. The full pulse width of grid signal is divided into 16 uniform sections by PWM (pulse width modulation) technology.

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.

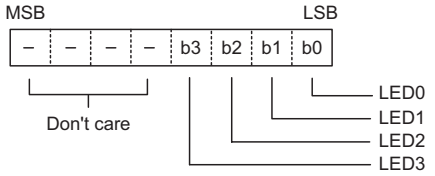
| Key1 Key2 | Key1 Key2 | Key1 Key2 | Key1 Key2 |
|---|---|---|---|
| S1/K1 | S2/K2 | S3/K3 | S4/K4 |
| S5/K5 | S6/K6 | S7/K7 | S8/K8 |
| S9/K9 | S10/K10 | S11/K11 | S12/K12 |
| S13/K13 | S14/K14 | S15/K15 | S16/K16 |
| b0 b1 | b2 b3 | b4 b5 | b6 b7 |

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.

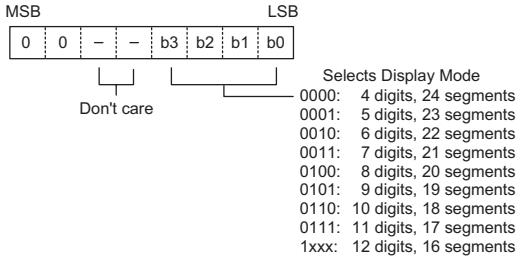



**Commands**

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).

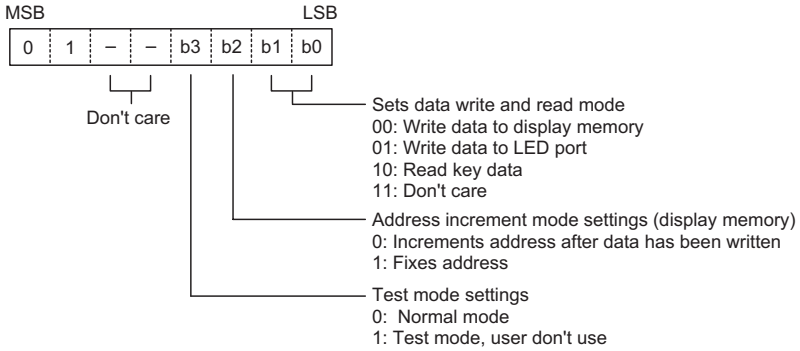
- Display mode setting commands
  These commands initialize the HT16515 and select the number of segments and the number of grids (1/4~1/12 duty, 16 to 24 segments).
  When these commands are executed, the display is forcibly turned off, and key scanning is also stopped.
  To resume display, the display 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

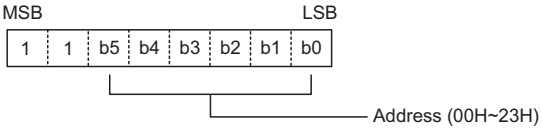
  These commands set the data write and data read modes.




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

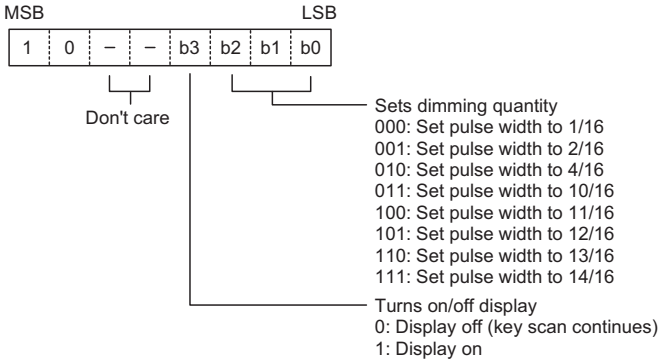
- Address setting commands

  These commands set the address of the display memory.



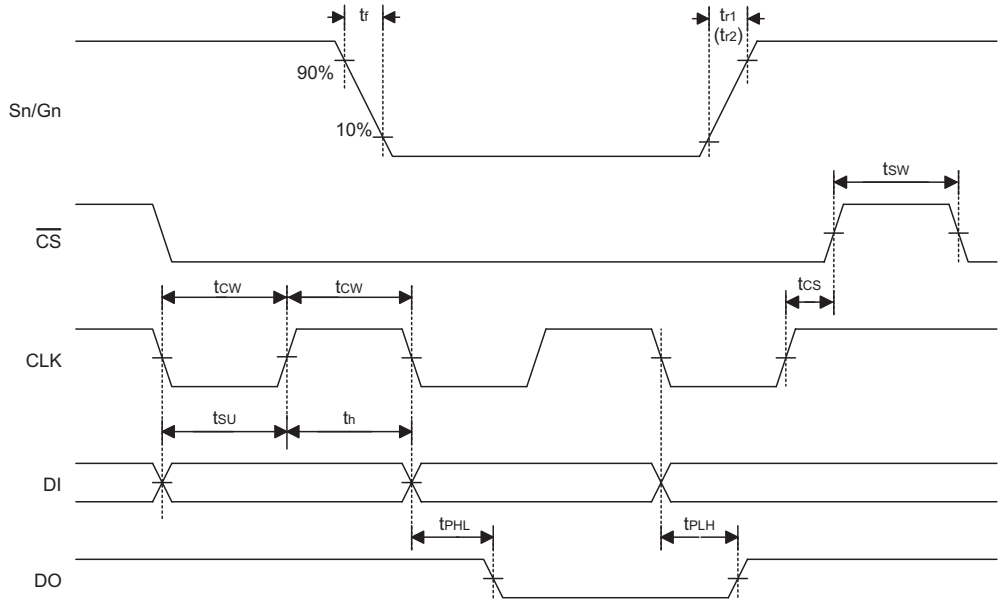

  If address 24H or higher is set, data is ignored until a valid address is set.
  Note: power-on status: the address is set to 00H.

- Display control commands

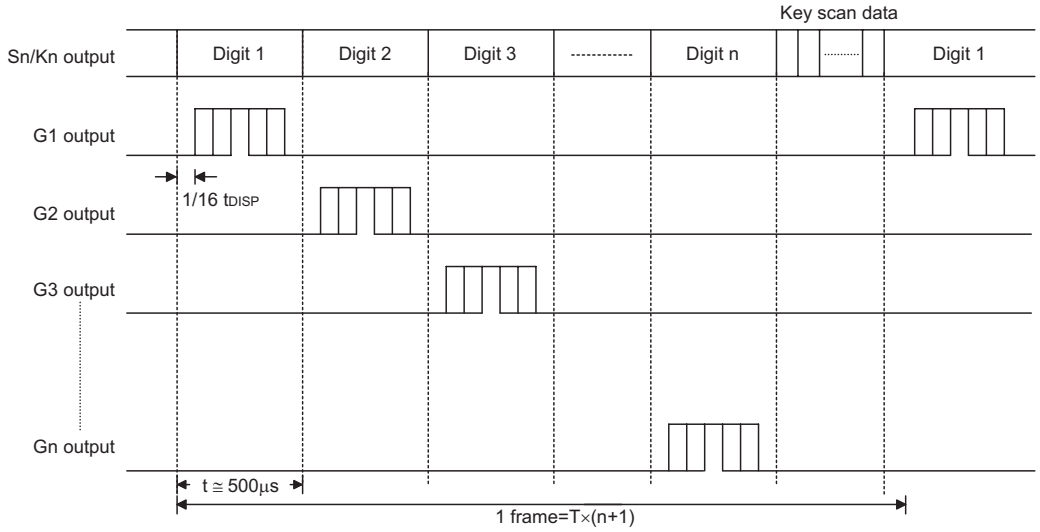



  Note: power-on status: 1/16 pulse width is set and the display is turned off. Key scanning will be stopped during power-on status.

## Timing Diagrams



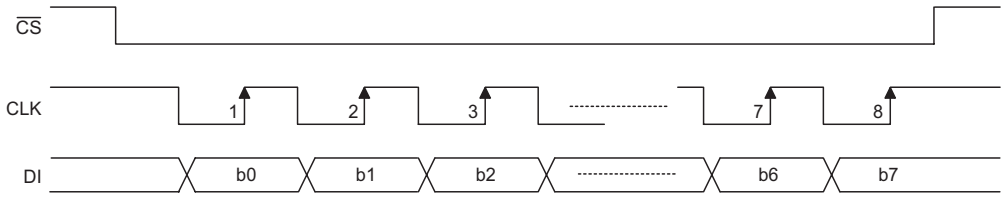

### Key Scanning and Display Timing



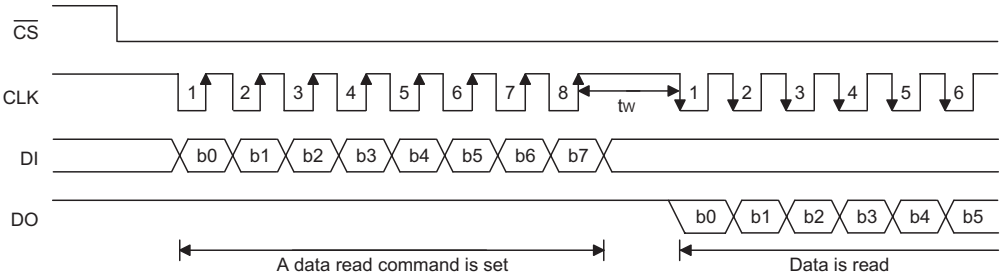

Note: One cycle of key scanning consists of two frames, and data of 16×2 matrixes is stored in the RAM.

**Serial Communication Format**

- Reception (command/data write)

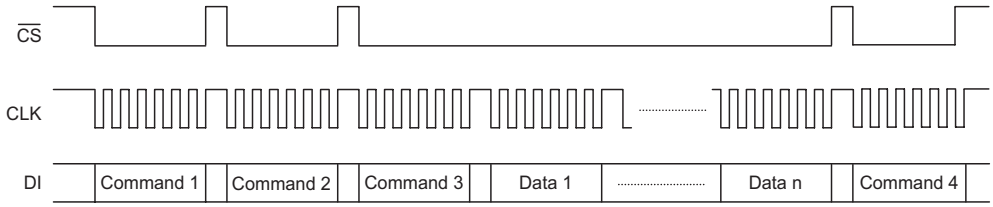



- Transmission (data read)



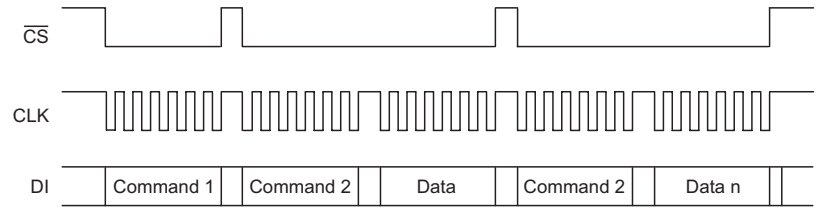

Be sure to connect an external pull-high resistor to this pin (1kΩ to 10kΩ).
Note: When data is read, a wait time "$t_W$" of 1μs is necessary.

- Updating display memory by incrementing address



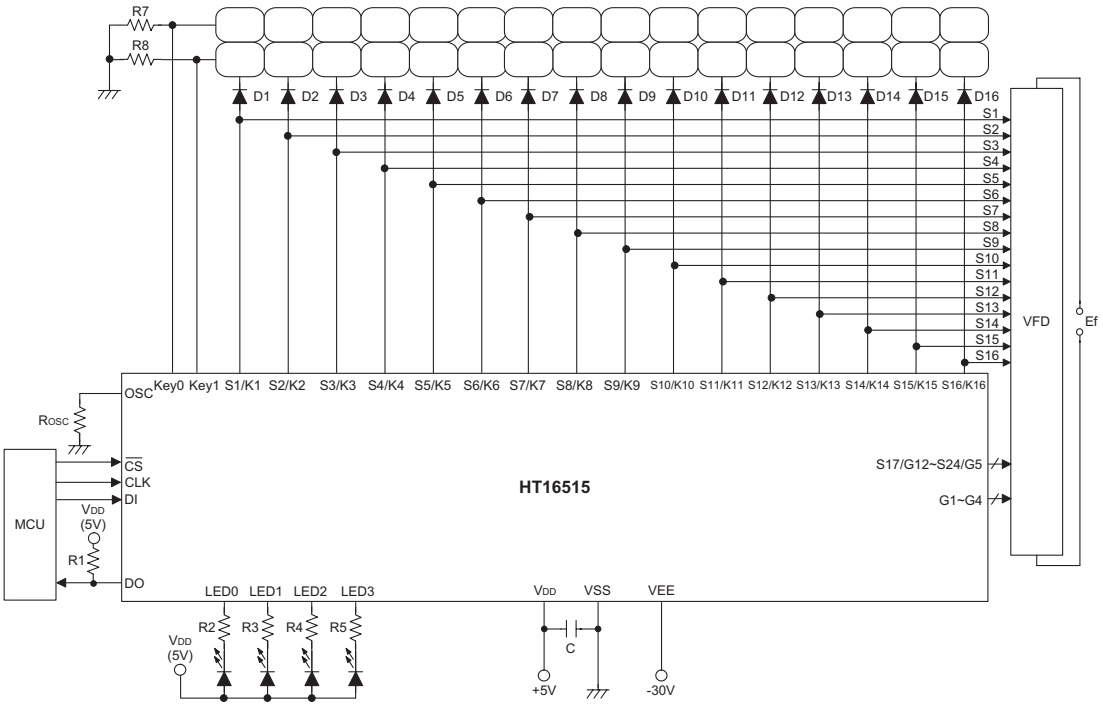

Note: Command 1: sets display mode
Command 2: sets data
Command 3: sets address
Data 1 to n: transfers display data (36 bytes max.)
Command 4: controls display

- Updating specific addresses




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

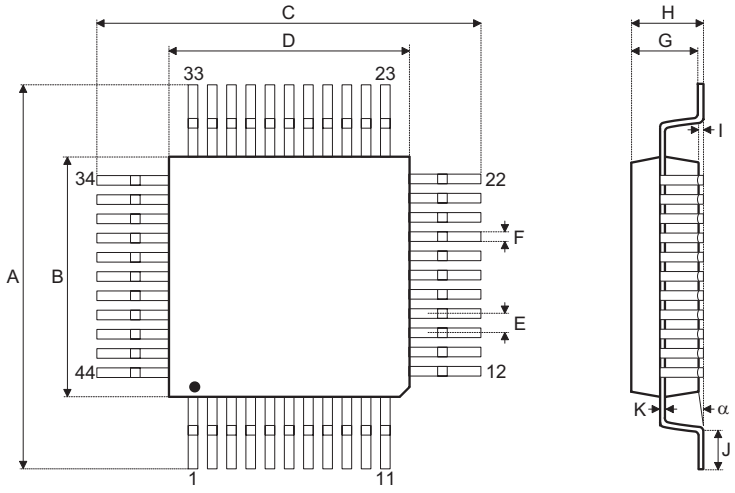
## Application Circuits




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° |

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