ABOV SEMICONDUCTOR
16 SEGMENT X 12 GRID VFD DRIVER WITH KEYSCAN

MC3401

Data Sheet (Ver. 1.4)

Version 1.4

Published by
FAE Team

REVISION HISTORY

VERSION 1.4 (2009. 07. 08) This Book
Modified the Command Data on page 19.

VERSION 1.31 (2009. 01. 06)
Modified the Format of Dout at Transmission (Data Read) on page 21.

VERSION 1.10 (2008. 09. 03)
Updated description for LED Setting Diagram on page 22.
Updated Serial communication timing diagram for initialization setting on page 22.
Updated Block Diagram on page 6.

VERSION 1.00 (2008. 08. 14)
The first Edition

DESCRIPTION

MC3401 is a Vacuum Fluorescent Display (VFD) Controller driven on a 1/4 to 1/12 duty factor. Sixteen segment output lines, 4 grid output lines, 8 segment/grid output drive lines, one display memory, control circuit, key scan circuit are all incorporated into a single chip to build a highly reliable peripheral device for a single chip micro computer. Serial data is fed to MC3401 via a three-line serial interface. It is housed in a 44-pin LQFP, MQFP

FEATURES

• CMOS Technology
• Low Power Consumption
• Key Scanning (16 x 2 matrix)
• Multiple Display Modes: (16 segments, 12 digits to 24 segments, 4 digits)
• 8-Step Dimming Circuitry
• LED Ports Provide (4 channels, 20mA max.)
• Serial Interface for Clock, Data Input, Data Output, Strobe Pins
• No External Resistors Needed for Driver Outputs
• Available in 44-pin LQFP, MQFP

APPLICATION

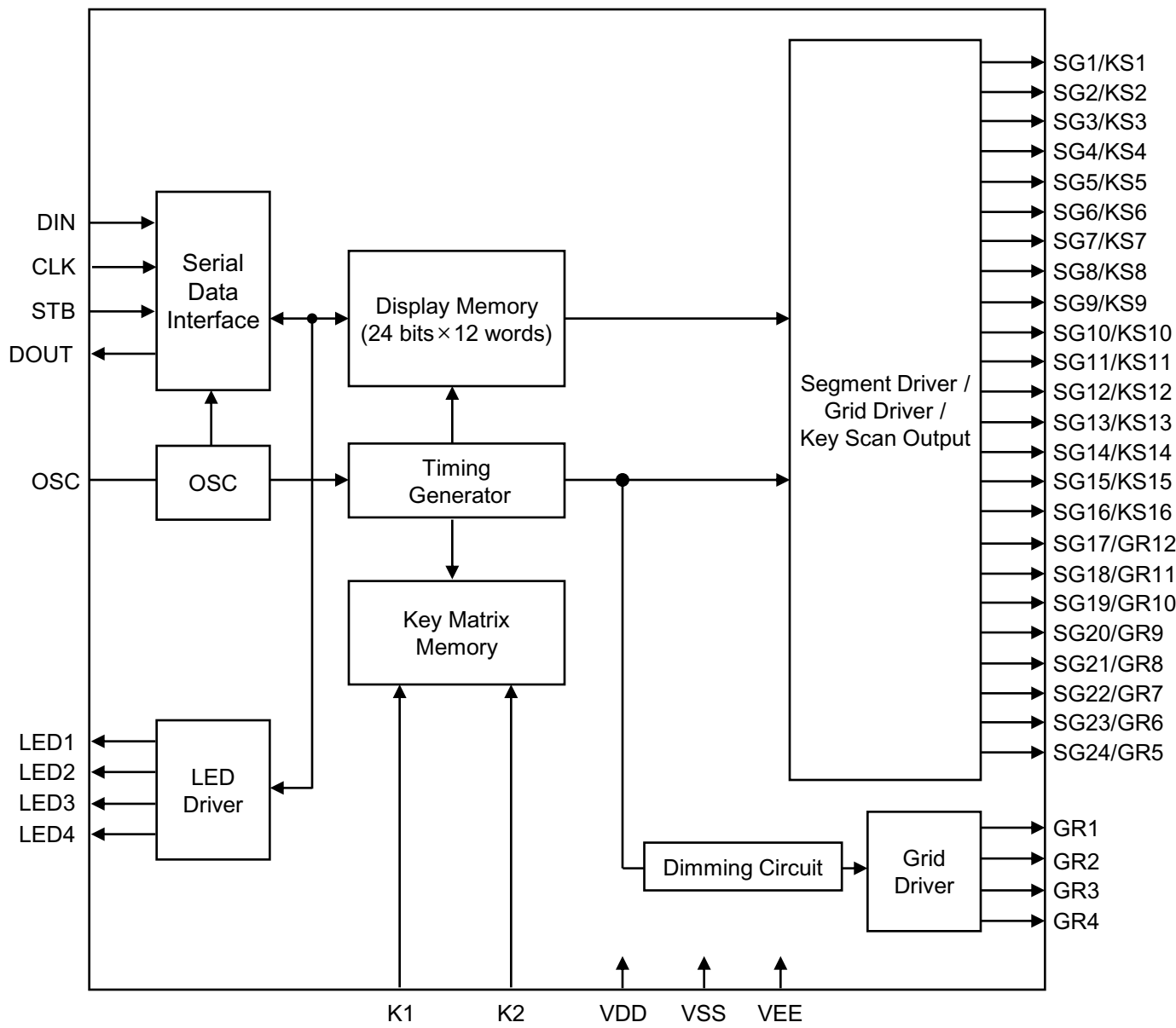• Microcomputer Peripheral Devices

ORDERING INFORMATION

Device name	Segment	Grid	Key Scanning	PKG TYPE
MC3401L	24 Segments	12 Grid	16 x 2 matrix	44LQFP
MC3401M	24 Segments	12 Grid	16 x 2 matrix	44MQFP

PIN DESCRIPTION

PIN NAME	I/O	DESCRIPTION	PIN No.
LED1 to LED4	O	LED Output Pin	1 to 4
OSC	I	Oscillator Input Pin A resistor is connected to this pin to determine the oscillation Frequency.	5
DOUT	O	Data Output Pin (N-Channel, Open-Drain) This pin outputs serial data at the falling edge of the shift clock (starting from the lower bit)	6
DIN (Schmitt Trigger)	I	Data Input Pin This pin inputs serial data at the rising edge of the shift clock (starting from the lower bit)	7
CLK (Schmitt Trigger)	I	Clock Input Pin This pin reads serial data at the rising edge and outputs data at the falling edge of the shift clock	8
STB (Schmitt Trigger)	I	Serial Interface Strobe Pin The data input after the STB has fallen is processed as a command. When this in is "HIGH", CLK is ignored.	9
K1 to K2	I	Key Data Input Pins The data inputted to these pins is latched at the end of the display cycle.	10, 11
VSS	-	Logic Ground Pin	12, 44
VDD	-	Logic Power Pin	13, 43
SG1/KS1 to SG16/KS16	O	High-Voltage Segment Output Pins Also acts as the Key Source.	14 to 29
VEE	-	Pull-Down Level	30
SG17/GR12 to SG24/GR5	O	High-Voltage Segment/Grid Output Pins	31 to 38
GR4 to GR1	O	High-Voltage Grid Output Pins	39 to 42

BLOCK DIAGRAM

PIN CONFIGURATION

VSS
VDD
GR1
GR2
GR3
GR4
SG24/GR5
SG23/GR6
SG22/GR7
SG21/GR8
SG20/GR9

44 43 42 41 40 39 38 37 36 35 34

MC3401

LED1 — 1	33 — SG19/GR10
LED2 — 2	32 — SG18/GR11
LED3 — 3	31 — SG17/GR12
LED4 — 4	30 — VEE
OSC — 5	29 — SG16/KS16
DOUT — 6	28 — SG15/KS15
DIN — 7	27 — SG14/KS14
CLK — 8	26 — SG13/KS13
STB — 9	25 — SG12/KS12
K1 — 10	24 — SG11/KS11
K2 — 11	23 — SG10/KS10

12 13 14 15 16 17 18 19 20 21 22

VSS
VDD
SG1/KS1
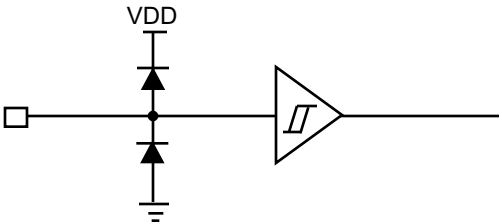SG2/KS2
SG3/KS3
SG4/KS4
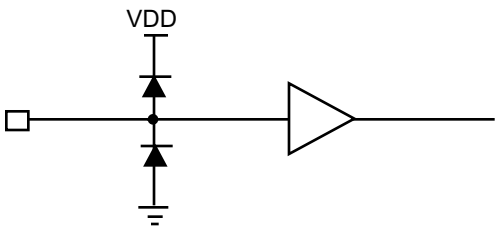SG5/KS5
SG6/KS6
SG7/KS7
SG8/KS8
SG9/KS9

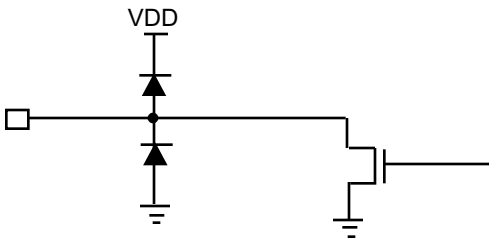# INPUT/OUTPUT PINS SCHEMATIC DIAGRAM
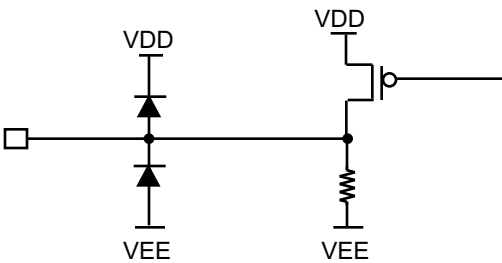
Input pins : CLK,STB,DIN

Input pins : K1,K2

Output pin : DOUT

Output pins : SGn, GRn

Output pins : LED1 to LED4
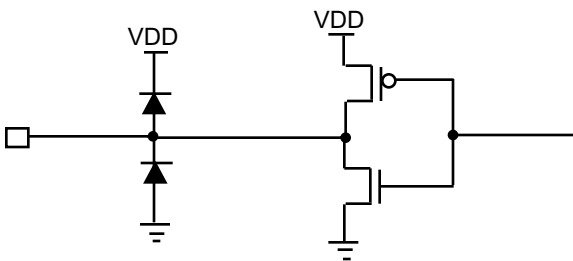
ABSOLUTE MAXIMUM RATINGS

(Unless otherwise stated, Ta=25℃, GND=0V)

Parameter	Symbol	Ratings	Unit
Logic Supply Voltage	VDD	-0.3 to +7	V
Driver Supply Voltage	VEE	VDD+0.3 to VDD-40	V
Logic Input Voltage	VI	-0.3 to VDD+0.3	V
VFD Driver Output Voltage	VO	VEE-0.3 to VDD+0.3	V
LED Driver Output Voltage	IOLED	±20	mA
VFD Drive Output Current	IOVFD	-40 (Grid) -15 (Segment)	mA
Operating Temperature	Topr	-40 to +85	℃
Storage Temperature	Tstg	-65 to +150	℃
VDD	-	Logic Power Pin	13, 43

RECOMMENDED OPERATING RANGE

(Unless otherwise stated, Ta= 25℃, GND=0V)

Parameter	Symbol	Ratings			Unit
		Min.	Typ.	Max.	
Logic Supply Voltage	VDD	3.0	5	5.5	V
High-Level Input Voltage	VIH	0.7VDD	-	VDD	V
Low-Level Input Voltage	VIL	0	-	0.3VDD	V
Driver Supply Voltage	VEE	VDD-35	-	0	V

ELECTRICAL CHARACTERISTICS

(Unless otherwise stated, VDD=5V, GND=0V, VEE=VDD-35V, Ta=25℃)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
High-Level Output Voltage	VOHLED	IOHLED = -12mA LED1 to LED4	VDD-1	-	-	V
Low-Level Output Voltage	VOLLED	IOLLED = +15mA LED1 to LED4	-	-	1	V
Low-Level Output Voltage	VOLDOUT	IOLDOUT = 4mA DOUT	-	-	0.4	V
High-Level Output Current	IOHSG	VO = VDD – 2V SG1/KS1 to SG16/KS16	-3	-	-	mA
High-Level Output Current	IOHGR	VO = VDD – 2V GR1 to GR8, SG17/GR12 to SG24/GR5	-15	-	-	mA
Oscillation Frequency	fosc	R=82KΩ	350	500	650	KHz
Schmitt-Trigger Transfer Voltage (+)	VT+	VDD = 5V DIN, CLK, STB	2.7	3	3.3	V
Schmitt-Trigger Transfer Voltage (-)	VT-	VDD = 5V DIN, CLK, STB	0.7	1.0	1.3	V
Hysteresis Voltage	Vhys	VDD = 5V DIN, CLK, STB	1.4	2.0	-	V
Input Current	II	VI = VDD or VSS	-	-	±1	uA
Dynamic Current Consumption	IDDdyn	Under no load Display Off	-	-	5	mA

Note : The frequency value is for MC3401 test condition : fosc = 224/T (see page 13 for detailed data)

ELECTRICAL CHARACTERISTICS

(Unless otherwise stated, VDD=3.3V, GND=0V, VEE=VDD-35V, Ta=25℃)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
High-Level Output Voltage	VOHLED	IOHLED = -6mA LED1 to LED4	VDD-1	-	-	V
Low-Level Output Voltage	VOLLED	IOLLED = +15mA LED1 to LED4	-	-	1	V
Low-Level Output Voltage	VOLDOUT	IOLDOUT = 4mA DOUT	-	-	0.4	V
High-Level Output Current	IOHSG	VO = VDD – 2V SG1/KS1 to SG16/KS16	-1.5	-	-	V
High-Level Output Current	IOHGR	VO = VDD – 2V GR1 to GR8, SG17/GR12 to SG24/GR5	-6	-	-	mA
Oscillation Frequency	fosc	R=100KΩ	350	500	650	KHz
Schmitt-Trigger Transfer Voltage (+)	VT+	VDD = 5V DIN, CLK, STB	1.8	2.0	2.2	V
Schmitt-Trigger Transfer Voltage (-)	VT-	VDD = 5V DIN, CLK, STB	0.2	0.4	0.6	V
Hysteresis Voltage	Vhys	VDD = 5V DIN, CLK, STB	1.0	1.6	-	V
Input Current	II	VI = VDD or VSS	-	-	±1	uA
Dynamic Current Consumption	IDDdyn	Under no load Display Off	-	-	3	mA

Note : The frequency value is for MC3401 test condition : fosc = 224/T (see page 13 for detailed data)

SWITCHING CHARACTERISTIC WAVEFORM

MC3401 Switching Characteristics Waveform is given below.
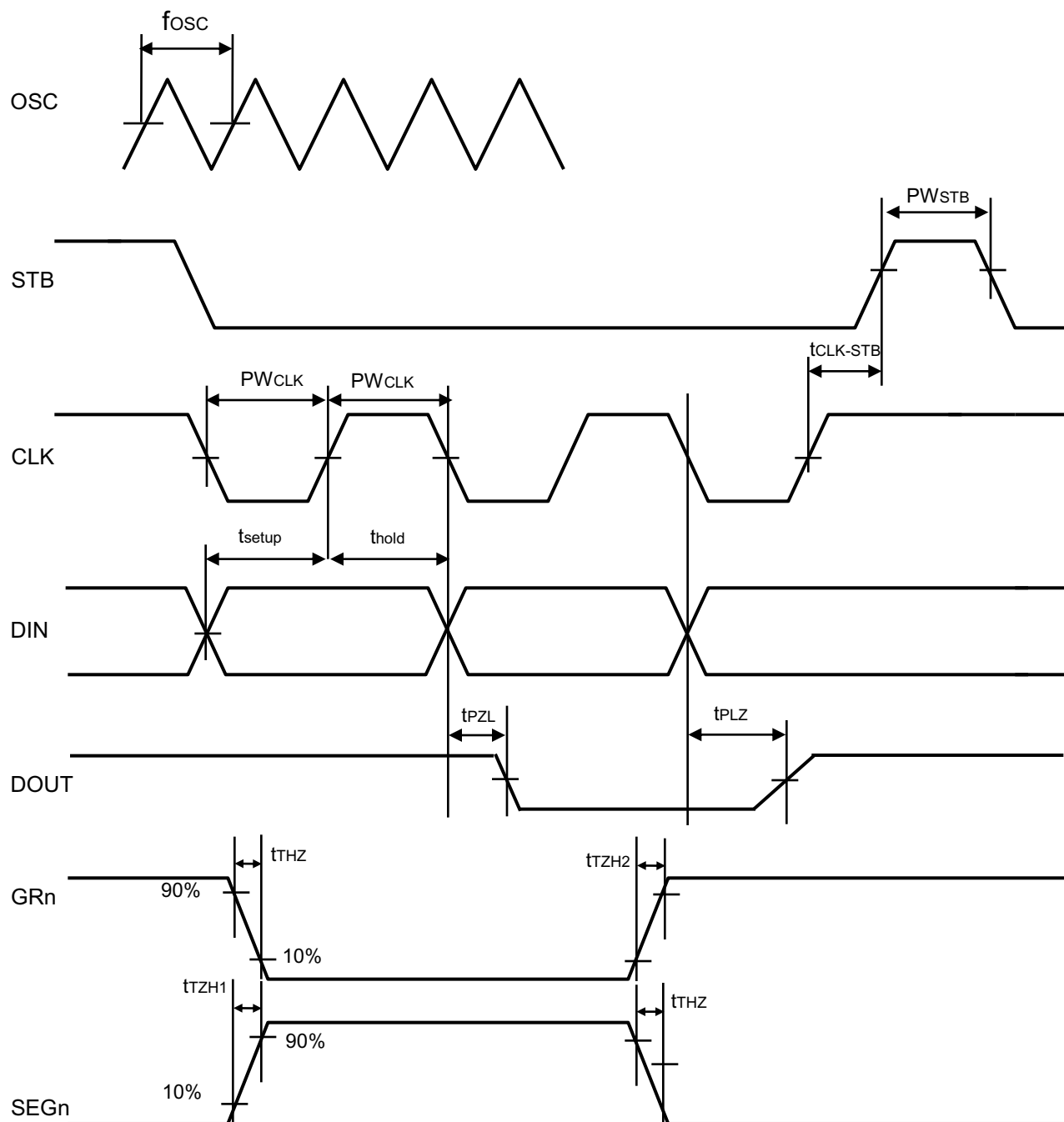
PW $_{CLK}$ (Clock Pulse Width) ≥400ns
t setup (Data Setup Time) ≥ 100ns
t $_{CLK-STB}$ (Clock - Strobe Time) ≥ 1μs
t $_{TZH2}$ (Grid Rise Time) ≤ 0.5μs (VDD=5V)
t $_{TZH2}$ (Grid Rise Time) ≤ 1.2μs (VDD=3.3V)
t $_{TZH1}$ (Segment Rise Time) < 2.0μs (VDD=5V)
t $_{TZH1}$ (Segment Rise Time) < 4.0μs (VDD=3.3V)

PW$_{STB}$ (Strobe Pulse Width) ≥ 1μs
thold (Data Hold Time) ≥ 100ns
t $_{THZ}$ (Fall Time) ≤ 150μs
t $_{PZL}$ (Propagation Delay Time) ≤ 100ns
t $_{PLZ}$ (Propagation Delay Time) ≤ 400ns (VDD=5V)
t $_{PLZ}$ (Propagation Delay Time) ≤ 400ns (VDD=3.3V)
fosc = Oscillation Frequency
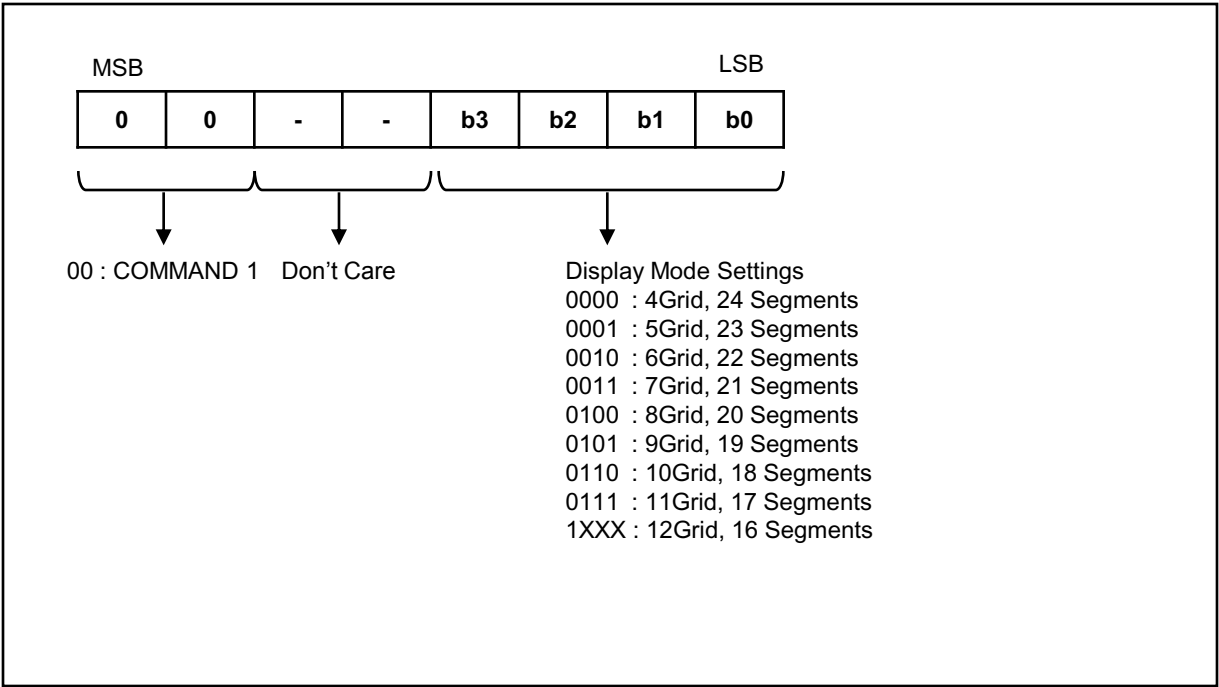
FUNCTIONAL DESCRIPTION

COMMANDS

Commands determine the display mode and status of MC3401. A command is the first byte (b0 to b7) inputted to MC3401 via the DIN Pin after STB Pin has changed from "HIGH" to "LOW" State. If for some reason the STB Pin is set to "HIGH" while data or commands are being transmitted, the serial communication is initialized, and the data/commands being transmitted are considered invalid.

COMMAND 1 : DISPLAY MODE SETTING COMMAND

MC3401 provides 8 display mode settings as shown in the diagram below: As stated earlier a command is the first one byte (b0 to b7) transmitted to MC3401 via the DIN Pin when STB is "LOW". However, for these commands, the bits 5 to 6 (b4 to b5) are ignored, bits 7 & 8 (b6 to b7) are given a value of "0".

The Display Mode Setting Commands determine the number of segments and grids to be used (1/4 to1/12 duty, 16 to 24 segments). When these commands are executed, the display is forcibly turned off, the key scanning stops. A display command "ON" must be executed in order to resume display. If the same mode setting is selected, no command execution is take place, therefore, nothing happens.

When Power is turned "ON", the 12-digit, 16-segment modes is selected.

```
  MSB                                    LSB

  0    0    -    -    b3   b2   b1   b0


00 : COMMAND 1   Don't Care        Display Mode Settings
                                   0000 : 4Grid, 24 Segments
                                   0001 : 5Grid, 23 Segments
                                   0010 : 6Grid, 22 Segments
                                   0011 : 7Grid, 21 Segments
                                   0100 : 8Grid, 20 Segments
                                   0101 : 9Grid, 19 Segments
                                   0110 : 10Grid, 18 Segments
                                   0111 : 11Grid, 17 Segments
                                   1XXX : 12Grid, 16 Segments
```

Display Mode and RAM Address

Data transmitted from an external device to MC3401 via the serial interface are stored in the Display RAM and are assigned addresses. The RAM Addresses of MC3401 are given below in 8bits unit.

SG1 — SG4	SG5 — SG8	SG9 — SG12	SG13 — SG16	SG17 — SG20	SG21 — SG24	
$00H_L$	$00H_U$	$01H_L$	$01H_U$	$02H_L$	$02H_U$	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 4bits	Higher 4bits
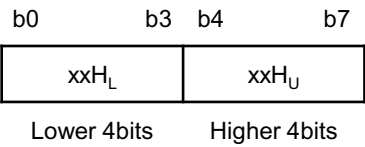
COMMAND 2 : DATA SETTING COMMAND

The Data Setting Commands executes the Data Write or Data Read Modes for MC3401. The data Setting Command, the bits 5 and 6 (b4, b5) are ignored, bit 7 (b6) is given the value of "1" while bit 8 (b7) is given the value of "0". Please refer to the diagram below.

When power is turned ON, the bit 4 to bit 1 (b3 to b0) are given the value of "0".
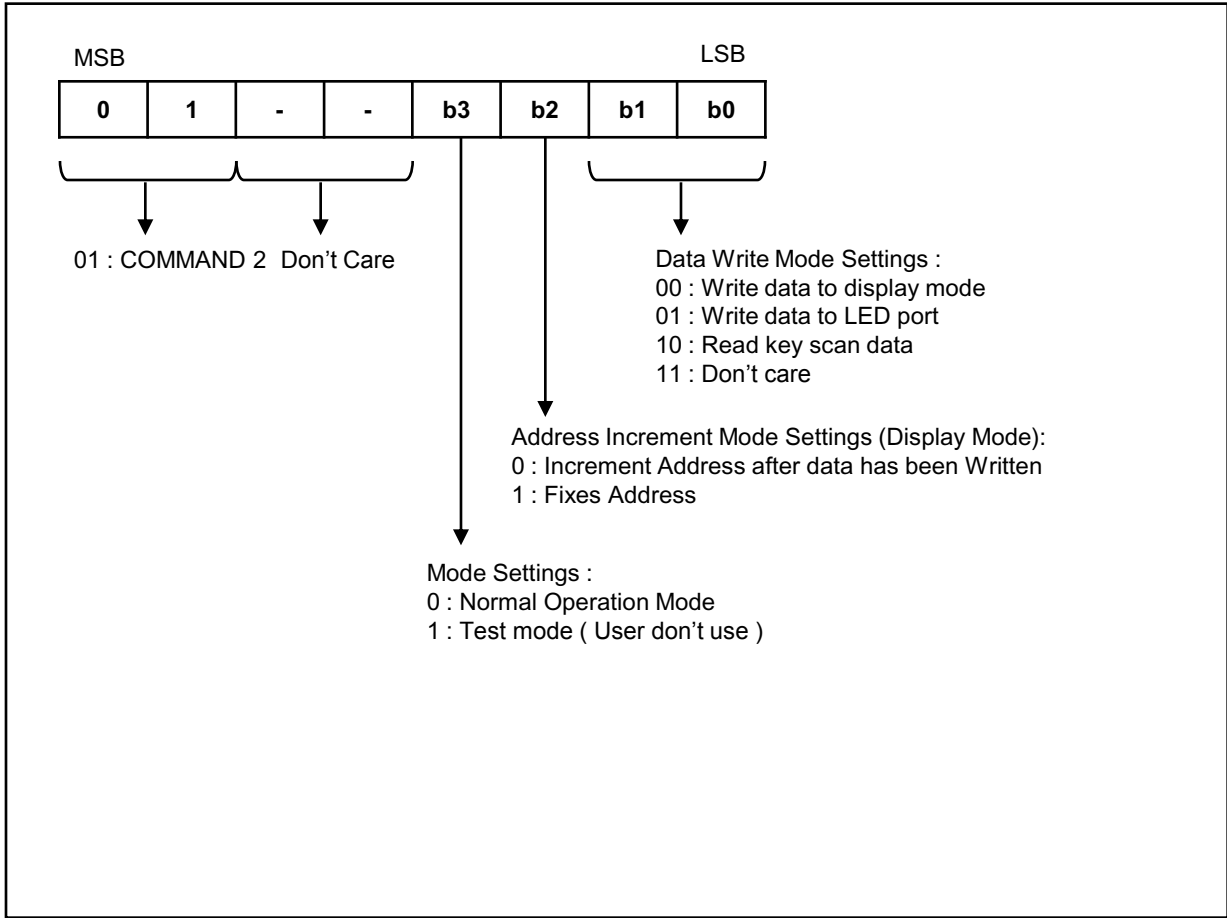
MC3401 Key Matrix & Key Input Data Storage RAM

MC3401 key matrix consists of 16×2 array as shown bellows.
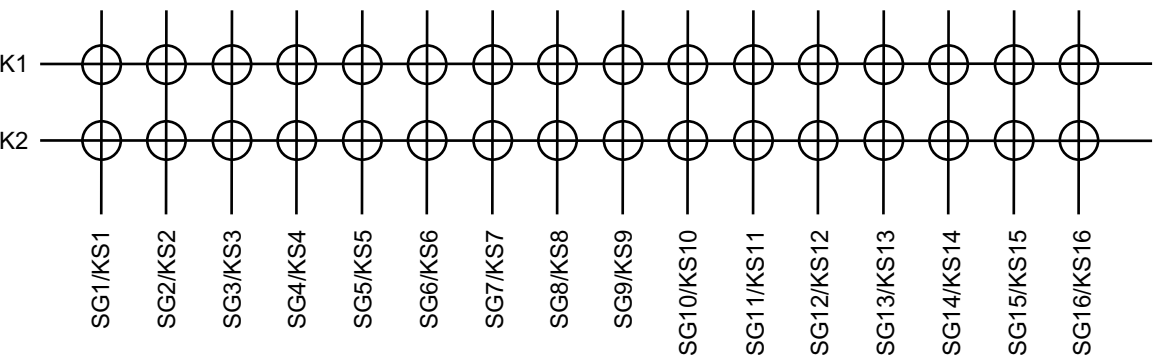
Each data inputted by each key are stored as follows. They are read by a READ Command, starting from the last significant bit. When the most significant bit of the data (SG16, b7) has been read, the least significant bit of the next data (SG1, b0) is read.

K1 .... K2	K1 .... K2	K1 .... K2	K1 .... K2	
SG1/KS1	SG2/KS2	SG3/KS3	SG4/KS4	
SG5/KS5	SG6/KS6	SG7/KS7	SG8/KS8	Reading Sequence
SG9/KS9	SG10/KS10	SG11/KS11	SG12/KS12	
SG13/KS13	SG14/KS14	SG15/KS15	SG16/KS16	
b0 .... b1	b2 .... b3	b4 .... b5	b6 .... b7	

LED Display

MC3401 provides 4 LED Display Terminals, namely LED1 to LED4. Data is written to the LED Port starting from the least significant bit (b0) of the port using a WRITE Command. Each bit starting from the least significant (b0) activates a specific LED Display Terminal – b0 corresponds LED1 Display, b1 activates LED2 and so forth. Since there are only 4 LED display terminals, bits 5 to 8 (b4 ~ b7) are not used and therefore ignored. This means that b4 to b7 does NOT in anyway activate any LED Display, they are totally ignored.

When a bit (b0 ~ b3) in the LED Port is "1", the corresponding LED is OFF. Conversely, when the bit is "0", the LED Display is turned ON. For example, Bit 1 (as designated by b0) has the value of "1", then this means that LED1 is OFF. **It must be noted that when power is turned ON, bit 1 to bit 4 (b0 to b3) are given the value of "0" (all LEDs are turned ON). Please** refer to the diagrams below.

```
   MSB                                 LSB
 ┌────┬────┬────┬────┬────┬────┬────┬────┐
 │  - │  - │  - │  - │ b3 │ b2 │ b1 │ b0 │
 └────┴────┴────┴────┴────┴────┴────┴────┘
      Don't Care                     └──────────► LED1
                                └──────────► LED2
                           └──────────► LED3
                      └──────────► LED4
```
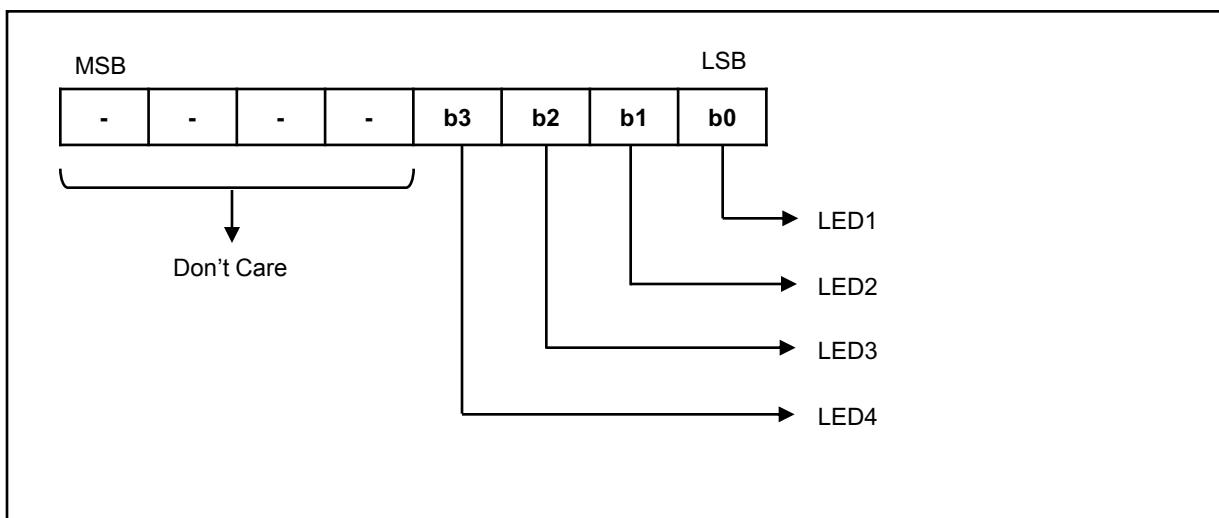
COMMAND 3 : ADDRESS SETTING COMMAND

The display memory is addressed by Address Setting Command. The valid address range is "00H" to 23H". If the address is set to 24H or higher, the data is ignored until a valid address is set. When power is turned ON, the address is set at "00H".

Please refer to the diagram below.

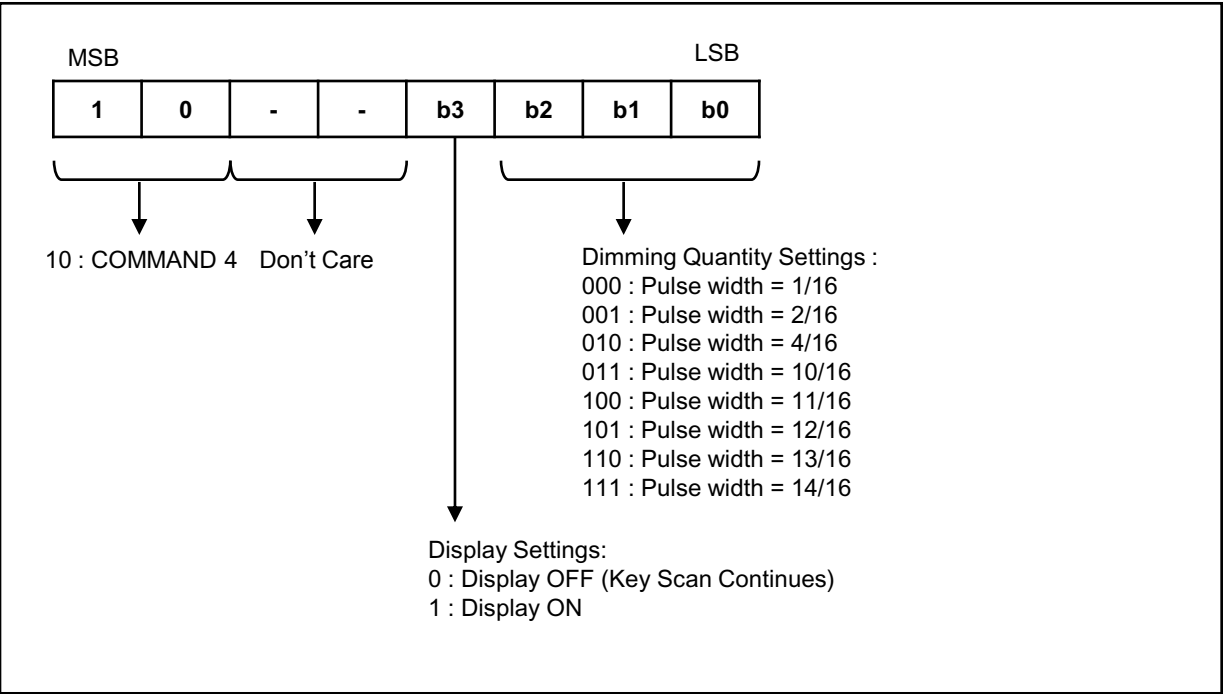| MSB							LSB
1	1	b5	b4	b3	b2	b1	b0

11 : COMMAND 3   Address : 00H to 23H
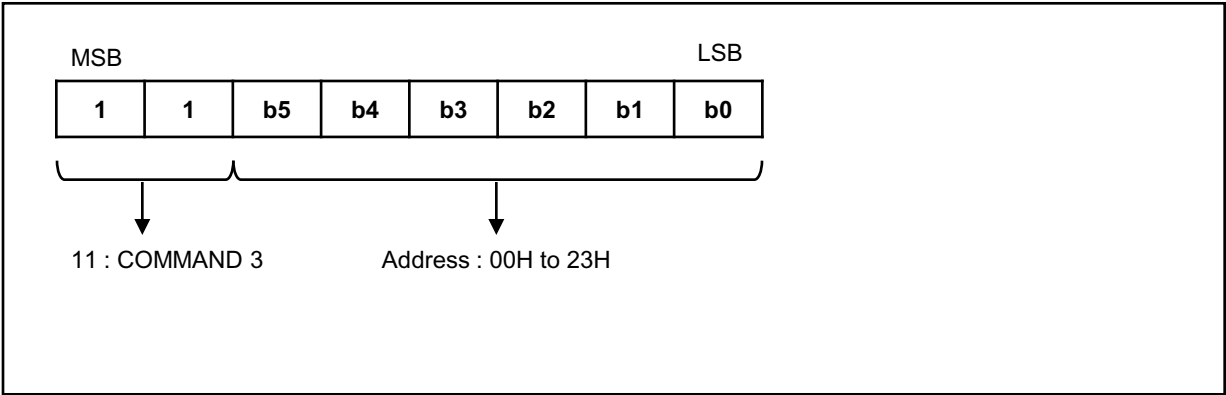
COMMAND 4 : DISPLAY CONTROL COMMANDS

The Display Control Commands are used to turn ON or OFF a display. It is also used to set the pulse width. Please refer to the diagram below. When the power is turned ON, a 1/16 pulse width is selected and the display is turned OFF (the key scanning is stopped).

MSB							LSB
1	0	-	-	b3	b2	b1	b0

10 : COMMAND 4   Don't Care

Dimming Quantity Settings :
000 : Pulse width = 1/16
001 : Pulse width = 2/16
010 : Pulse width = 4/16
011 : Pulse width = 10/16
100 : Pulse width = 11/16
101 : Pulse width = 12/16
110 : Pulse width = 13/16
111 : Pulse width = 14/16

Display Settings:
0 : Display OFF (Key Scan Continues)
1 : Display ON

SCANNING AND DISPLAY TIMING

The Key Scanning and display timing diagram is given below. One cycle of key scanning consists of 2 frames. The data of the 16 x 2 matrix is stored in the RAM.

Internal Operating Frequency (fosc) = 224/T
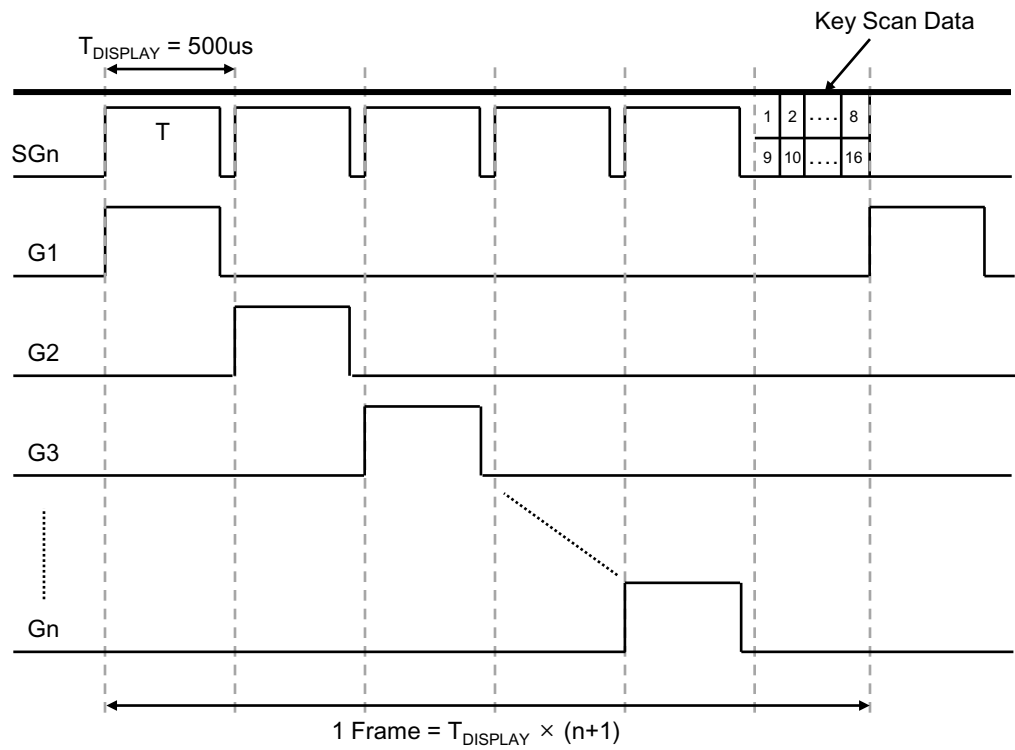
Note : T is the width of segment only

SERIAL COMMUMICATION FORMAT

The following diagram shows the MC3401 serial communication format. The DOUT Pin is an N-channel, open-drain output pin, therefore, it is highly recommended that an external pull-up resistor (1KΩ to10KΩ) must be connected to DOUT.

RECEPTION (Data/Command Write)

Transmission (Data Read)

where: t_{wait} (waiting time) ≥ 1µs

It must be noted that when the data is read, the waiting time (twait) between the rising of the eighth clock that has set the command and the falling of the first clock that has read the data is greater or equal to 1µs.
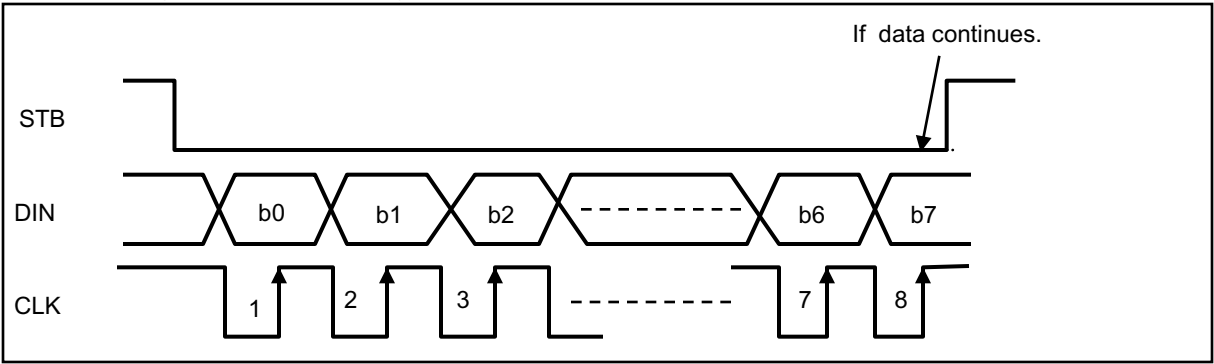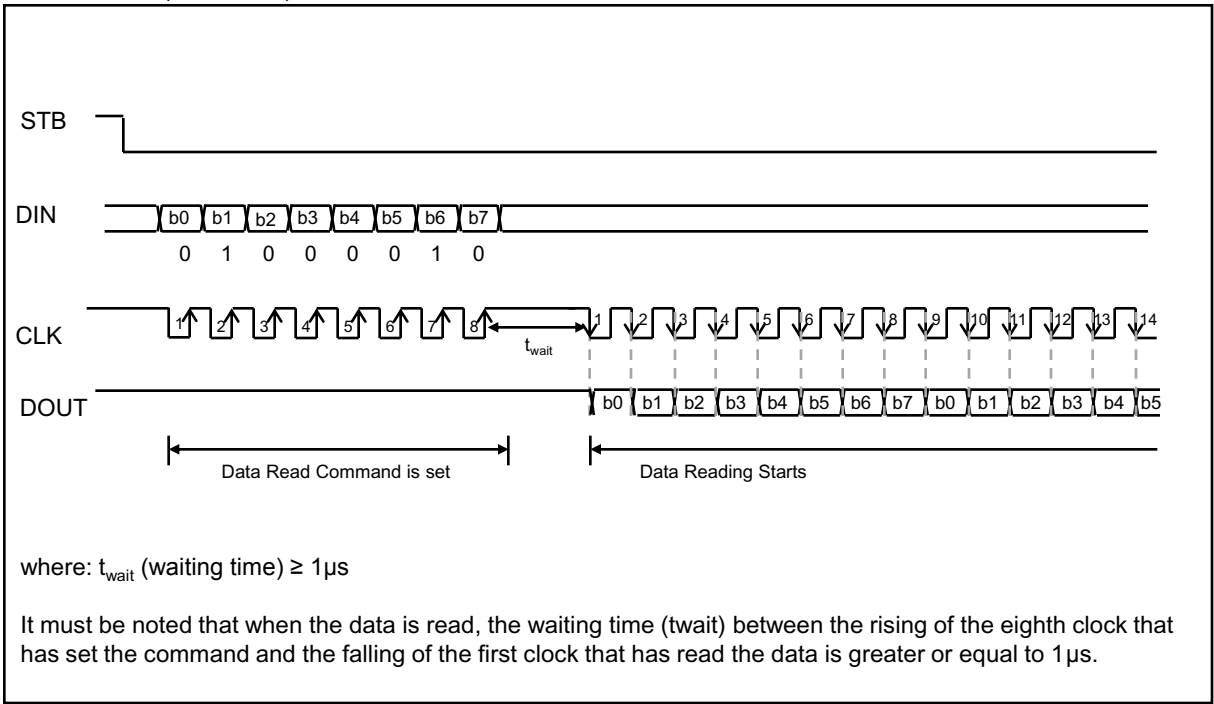
SERIAL COMMUNICATION EXAMPLES

Serial communication timing diagram for initialization setting.

STB							
CLK					--------------------		
DIN	Command2	Command3	Data 1	Data 2	--------------------	Command1	Command4
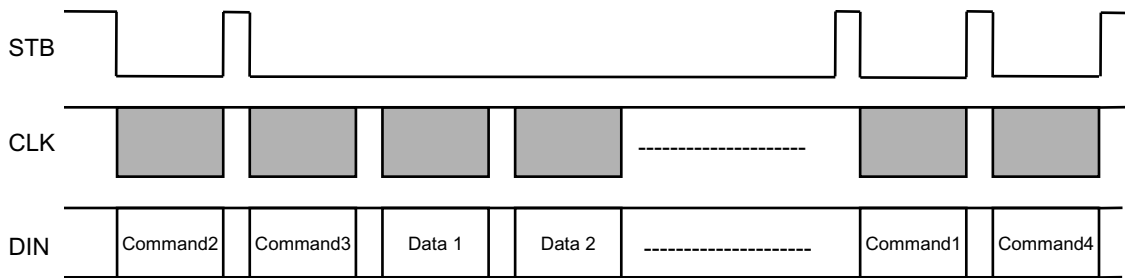
Where : Command 1 : Display Mode Setting
           Command 2 : Data Setting Command
           Command 3 : Address Setting Command
           Data 1 to n   : Transfer Display Data (36 Bytes max.)
           Command 4 : Display Control Command

Transmission diagram for new Data on specific addresses.

STB					
CLK					
DIN	command2	command3	Data	command3	Data
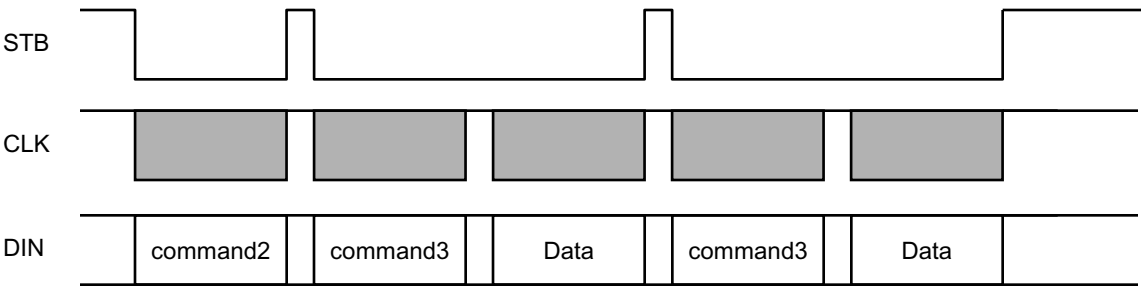
Where : Command 2 -- Data Setting Command
           Command 3 -- Address Setting Command
           Data -- Display Data

Transmission diagram for LED Data setting diagram.

STB		
CLK		
DIN	command2	LED Data
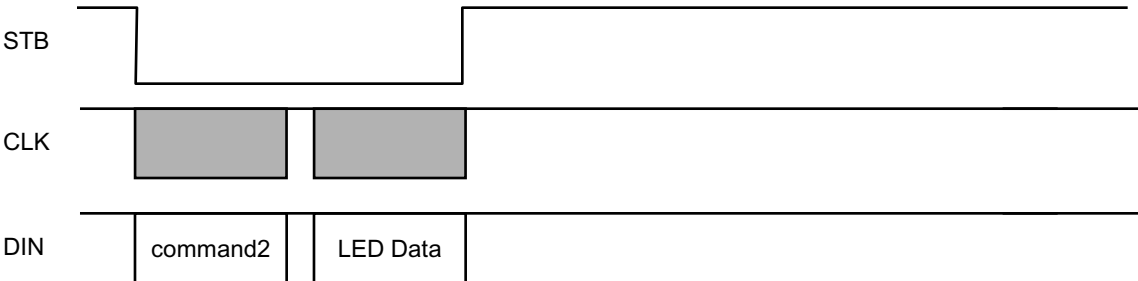
Where : Command 2 -- Data Setting Command
           LED Data – 4 LED(LED1 to LED4) Display Data
           (bit value 0: LED is turned ON, bit value 1: LED is turned OFF)

RECOMMENDED SOFTWARE PROGRAMMING FLOW CHART

```
                    ┌──────────────┐
                    │    START     │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │  Delay 200ms │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 2   │
                    │ (Write Data) │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 3   │          INITIAL
                    │Clear Display │          SETTING
                    │    RAM       │
                    │ (see Note 5) │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 1   │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 4   │
                    │(88H~8FH :    │
                    │ Display ON)  │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │    MAIN      │
                    │  PROGRAM     │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 2   │
                    │ (Read key &  │          MAIN
                    │ Write Data   │          LOOP
                    │  Included)   │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 3   │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 1   │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │     SET      │
                    │  COMMAND 4   │
                    └──────┬───────┘
                           ▼
                    ┌──────────────┐
                    │    END       │
                    └──────────────┘
```

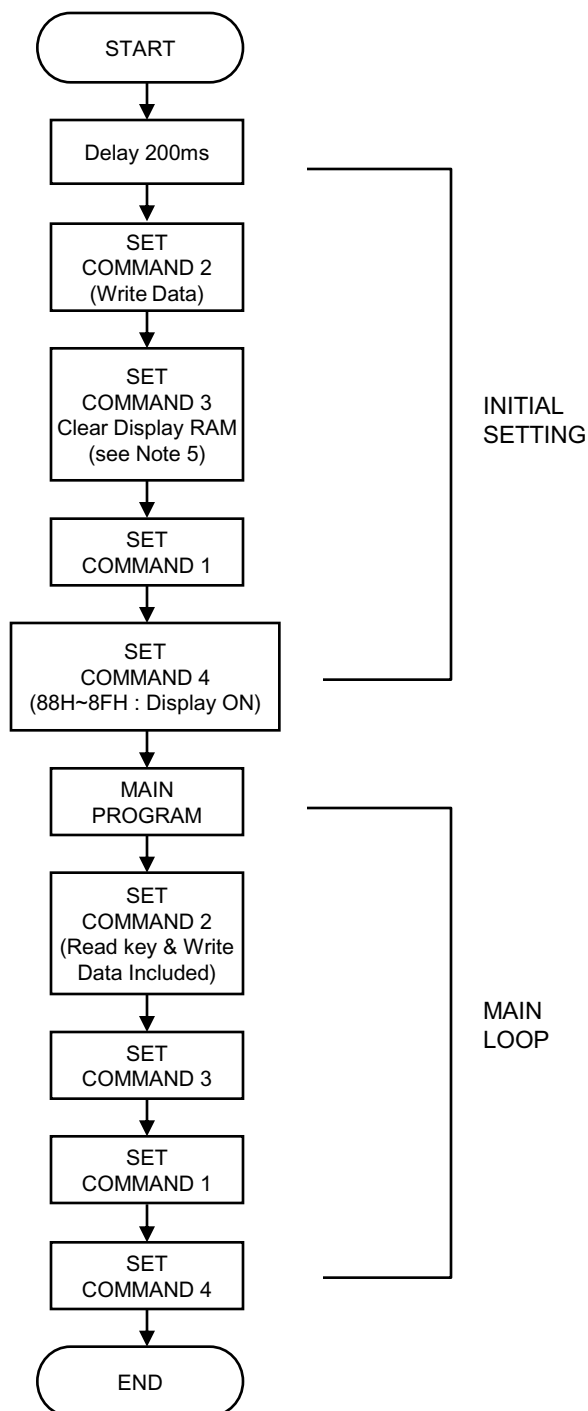- • Note : 1. Command 1 : Display Mode Setting
  2. Command 2 : Data Setting Commands
  3. Command 3 : Address Setting Commands
  4. Command 4 : Display Control Commands
  5. When IC power is applied for the first time, the contents of the Display RAM are not defined : thus, it is strongly suggested that the contents of the Display RAM must be cleared during the initial setting.
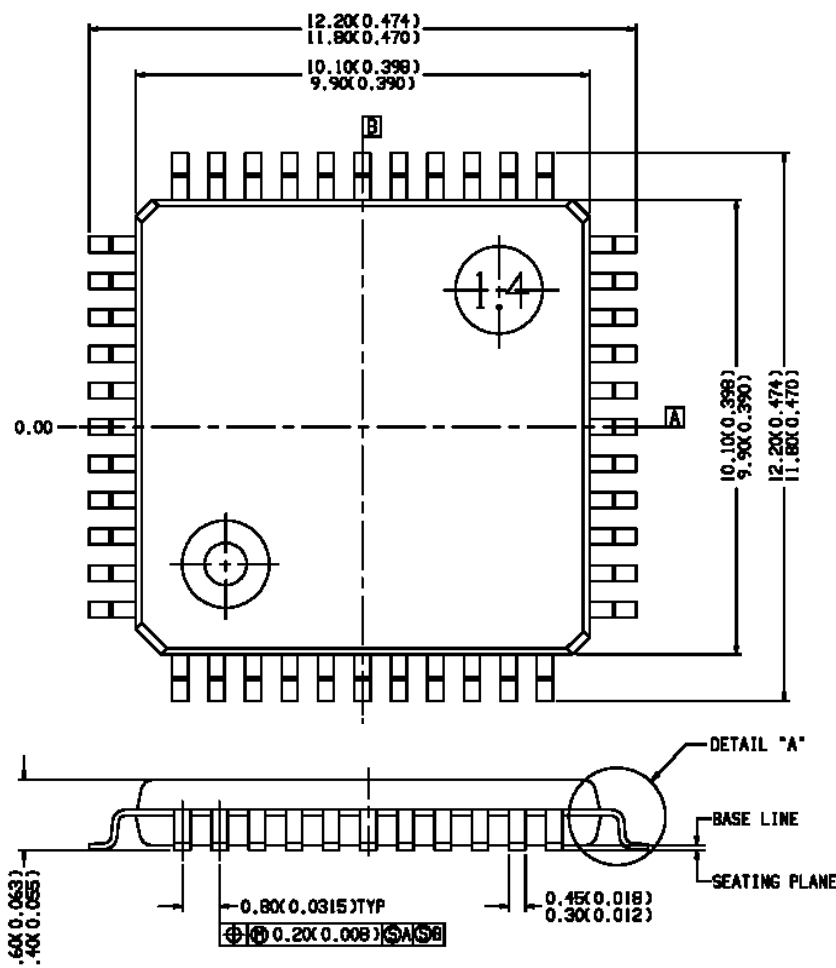
APPLICATION CIRCUIT
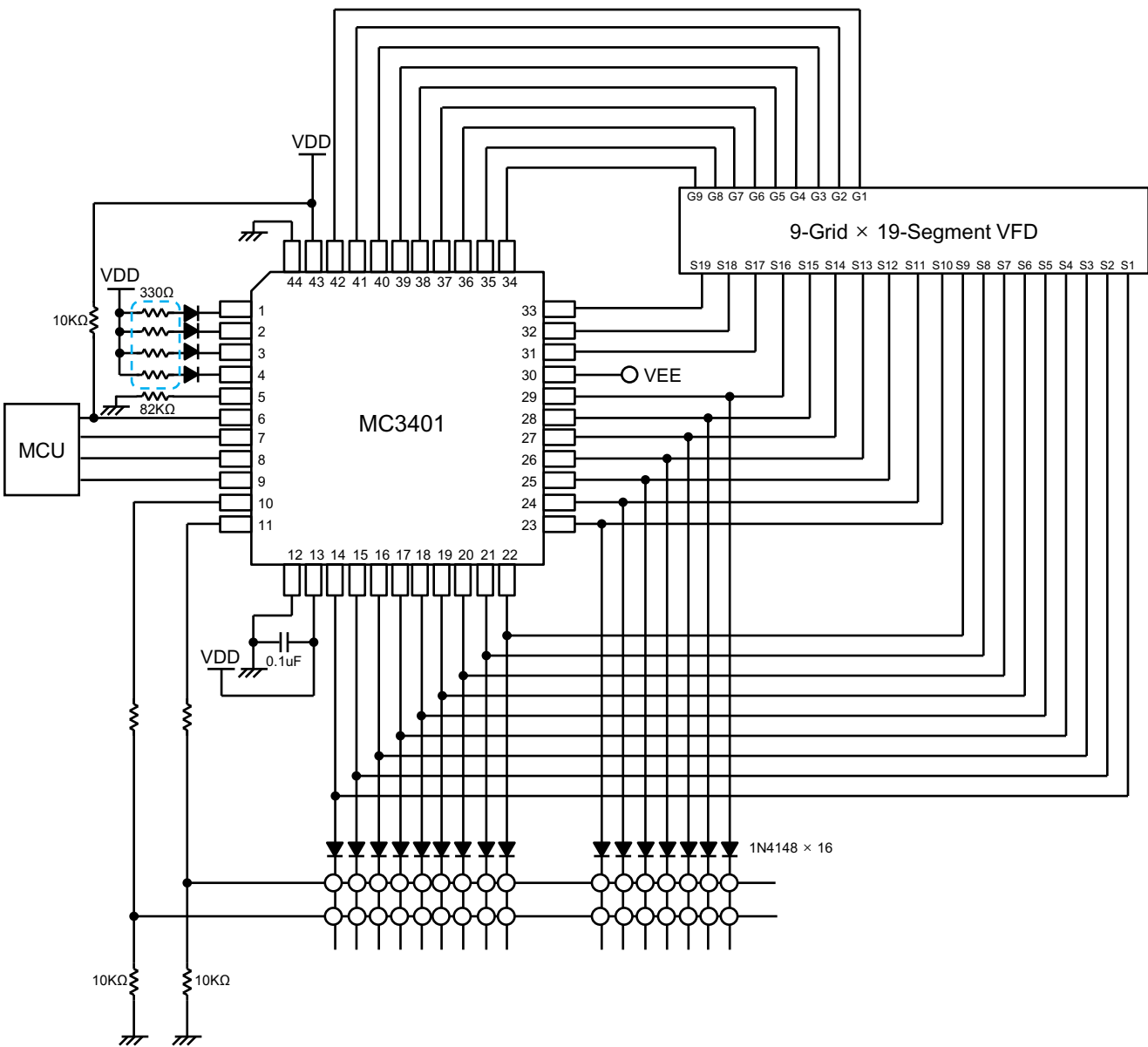
Note : The capacitor (0.1μF) connected between the GND and the VDD pins must be located as close as possible to the MC3401 chip.
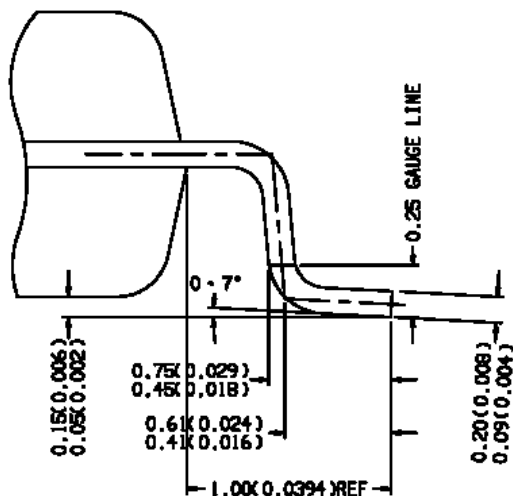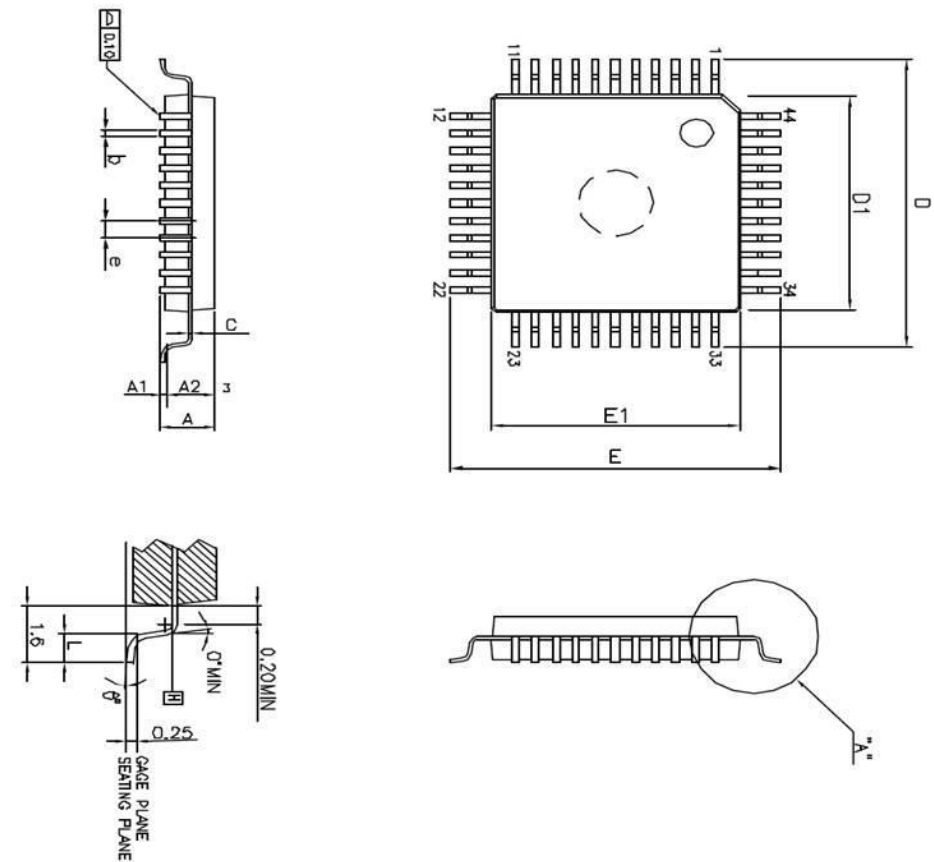
PACKAGE INFORMATION

44-PIN LQFP

NOTE
1) LEAD FRAME : C7025
2) LEAD FINISH : SOLDER PLATED.
3) BACK EJECTOR PIN MARKED "KOREA".
4) BOTH PACKAGE LENGTH AND WIDTH DO NOT INCLUDE FLASH.
5) FORMED LEAD SHALL BE PLANAR WITH RESPECT TO ONE ANOTHER
   WITHIN 0.10(0.004) MM.
6) CONTROLLING DIMENSION : MM(INCHES)

DETAIL "A"(40/1)

PACKAGE INFORMATION

44-PIN MQFP

SYMBOLS	MIN.	NOM.	MAX.
A	–	–	2.7
A1	0.25	–	0.50
A2	1.9	2.0	2.2
b	0.3 (TYP.)		
D	13.00	13.20	13.40
D1	9.9	10.00	10.10
E	13.00	13.20	13.40
E1	9.9	10.00	10.10
L	0.73	0.88	0.93
e	0.80 (TYP.)		
θ°	0		7
C	0.1	0.15	0.2

UNIT : mm

NOTES:

1. JEDEC OUTLINE=MO-108 AA-1

2. DATUM PLANE Ⓗ IS LOCATED AT THE BOTTOM OF THE MOLD PARTING LINE COINCIDENT WITH WHERE THE LEAD EXITS THE BODY.

3. DIMENSIONS D1 AND E1 DO NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 mm PER SIDE. DIMENSIONS D1 AND E1 DO INCLUDE MOLD MISMATCH AND ARE DETERMINED AT DATUM PLANE Ⓗ

4. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION.