

Tutorials - Electronics

TM1638

LED / Key controller.

The Chinese Titan produces numerous integrated circuits to control displays and keyboards, including the **TM1638**.

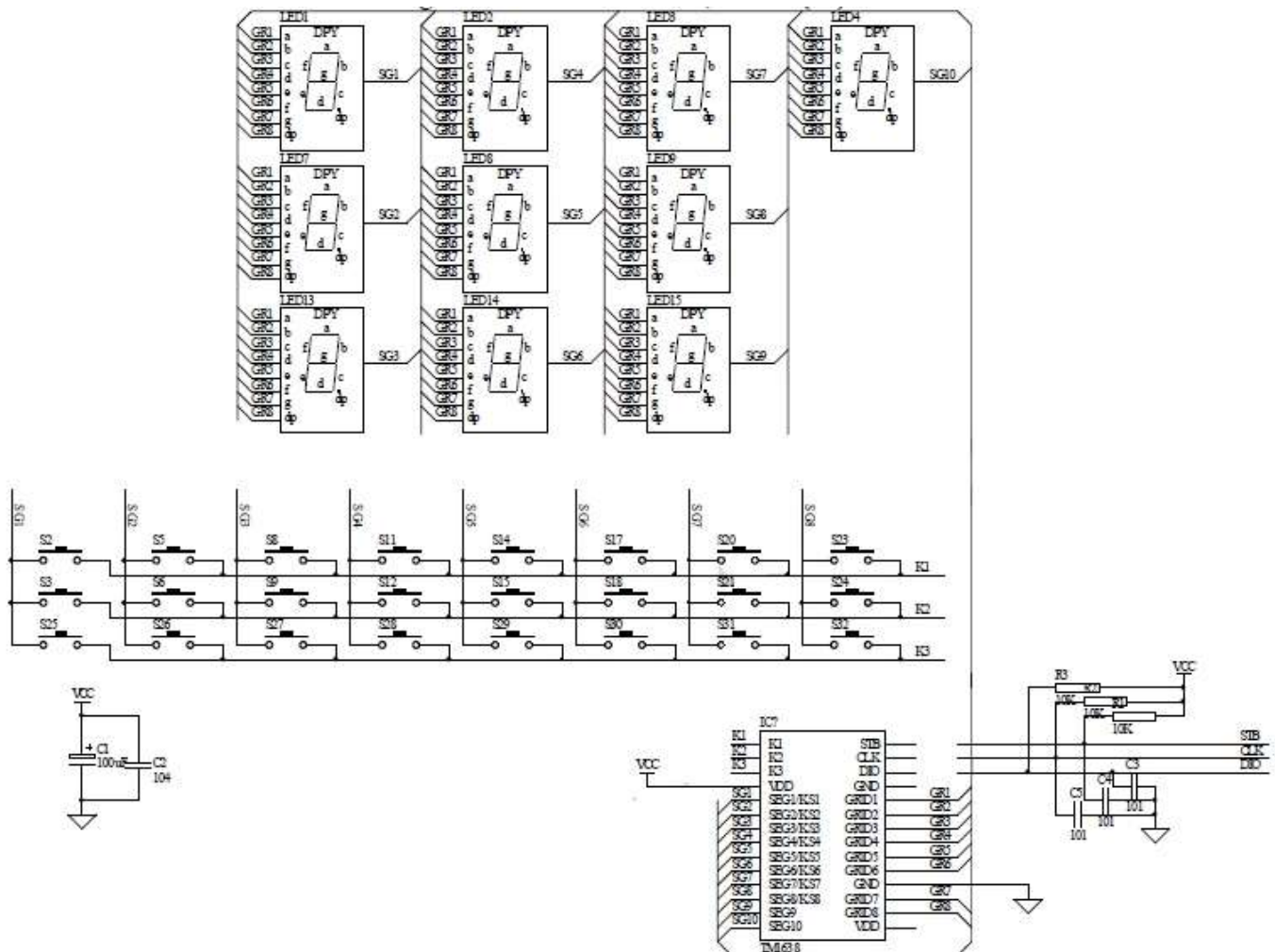
This controller is the basis of some boards suitable for experimentation with microcontrollers and easily available on the WEB with really interesting costs.

TM1638 has the following features:

- controls an 8 x 10 LED matrix
- pilot display with anode or common cathode
- adjustable brightness - 8 levels
- scan of 3 x 8 incoming contacts
- 3-wire synchronous interface, data / clock / strobe

It is analogous to TM1640, which allows you to control a larger number of displays and keys.

The typical application diagram for common anode displays is as follows:



The chip is available in 28-pin SOP package. The pinout is as follows:

			Label	First name	Pin	Description
			GOD	I / O date	26	Data input / output. In writing, the data is transferred on the rising edge of the CLK. Outgoing, on the falling front. In transmission, it is an open drain and requires a pull-up.
			CLK	Clock input	27	Communication clock
			STB	Strobe	28	Initialize the interface on the falling edge to receive instructions. The first byte after STB that goes low is considered an instruction. When an instruction is processed the other processes are blocked. With STB at a high level , the CLK is ignored.
			K1-K3	Keyboard scan input	1-2-3	Input of data pins from the keyboard.10k internal pull-down
			SG1-KS1 SG8-KS8	Outputs (segments)	5-12	Segment command output (P channel open drain) and key scan
			GRID1-GRID8	Outputs (digit)	24-19	Common anode outputs digit (N channel open drain)
			VDD	supply	15	power supply +
			GND	common	18	common mass

The datasheet states that the **TM1638** is powered up to 5V and can supply up to 50mA of sink current to the display segments.

The data sheet, at the end, also contains some tables of electrical parameters.

The communication interface.

Communication takes place over three wires:

- **CLK** : clock, provided by the master
- **STB** : strobe, provided by the master
- **GOD** : bi directional i / o date

It is a synchronous communication: the data coming from the microprocessor can be varied until the clock is low and are read on the rising edge.

The communication start condition is the application of a low level on the **STB** line .

When **STB** is at a high level. the TM1638 does not respond to any transmission of data or commands. This allows you to connect more TM1638s on the same clock and data lines, dedicating a separate strobe line to each one, similarly to the SS / CS signal of SPI communication.

The scheme proposed by the manufacturer (see above) includes **10k pull-ups on the communication lines and 100pF true ground capacitors** , inserted, these, to reduce disturbances in critical application environments.

In fact, the manufacturer indicates TM1638 as suitable for use in environments with EMC disturbances, such as household appliances and the like.

SPI?

The interface seems to adapt to the specifications of an SPI communication, manageable through the MSSP module present in many microcontrollers.

The STB pin has the same function as the SS / CS of SPI: when communicating with the TM1638, the STB must be low level. If the line is high, the chip does not accept any data.

To transmit or receive data, you set the CLK pin low, then set the DIO pin with the desired value and bring the CLK pin back to a high level. The transition allows the chip to acquire the data.

However, in practice there are some big differences:

- **A standard SPI interface has two lines for data, input and output (MOSI / MISO or SDO / SDI), while the TM1638 has only one bi-directional data line (DIO).**
This could be corrected by joining SDO / SDI with DIO, but by interposing a Schottky diode or a resistor between the DIO line and SDO, to isolate the high level condition.
- **At the output, the DIO pin of the TM1638 is an open drain** and therefore requires a pull-up
- **The least significant bits are sent first, while in the standard SPI interface it is just the opposite. You must have an SPI device that can reverse the issuing order .** For example, in C for Arduino and the like: `shiftOut (data, clock , LSBFIRST , address)` In the absence of this possibility, the bytes to be sent and those received must be 8 times.

The structure of the registers.

TM1638 can receive commands and data and the communication involves a simple command / data structure.

What is sent to the TM1638 follows the rule that the first byte after STB has been sent low is intended as a command. This can be single, or followed by one or more bytes of data depending on the selected function. A transmitted block is terminated by the STB line returning to high level.

The following functions are possible:

- **Activate / deactivate the display and adjust its brightness**
- **Select the data input mode, if single address or auto incrementing address**
- **Write a byte to a specific address**
- **Write more bytes starting from an address**
- **Read the keys**

The commands are processed directly, while the data is sent to the internal registers:

- There are 8 double registers (therefore a total of 16 addresses, from 00h 0Fh), which correspond to the signals of the **GRD8** pins : **1**
- Each controllable array is composed of 10 bits corresponding to the GRID-SEG combinations, at the intersections of which the controllable LEDs are connected.

It is possible to write a single register (with the single register mode) or even more registers subsequently (with the auto incremented mode). As bizarre as it is, the table proposed on the datasheet is replicated:

seg1	seg2	seg3	seg4	seg5	seg6	seg7	seg8	seg9	seg10	x	x	x	x	x	x
b0	b1	b2	b3	b4	b5	b6	b7	b0	b1	b2	b3	b4	b5	b6	b7

xxhL 4-bit low	xxhU 4 bit high	xxhL 4-bit low	xxhU 4 bit high	
00hL	00hU	01hL	01hU	GRID1
02hL	02hU	03hL	03hU	GRID2
04hL	04hU	05hL	05hU	GRID3
06hL	06hU	07hL	07hU	GRID4
08hL	08hU	09hL	09hU	GRID5
0AhL	0AhU	0BhL	0BhU	GRID6
0ChL	0ChU	0DhL	0DhU	GRID7
0EhL	0EhU	0FhL	0FhU	GRID8

The table should be understood in this sense:

- **80 LEDs or segments** are controllable
- these are organized in **8 arrays of 10, each dependent on a GRIDn line**
- **each array refers to two bytes**, each corresponding to an address inside the chip
- **the bytes at even addresses (0, 2, 4, etc.) each have 8 bits corresponding to the possibility of controlling an LED** (or segment)
- **the bytes at odd addresses (1,3,5, etc.) have only the first two bits (b1: 0)** which correspond to LEDs / segments; the other bits are not used.

The data contained in the registers are scanned by the internal clock and control connected LEDs and displays.

Even address registers correspond to SEG8 lines: 1.

The registers with odd addresses correspond to lines SEG10: 9 (the rest are not implemented and are at 0).

Where there are seven-segment digits, it makes sense to use **the 8 bits of the first byte for the 7 segments plus the decimal point and use the two bits of the second byte to control other LEDs**.

This is the common arrangement on Chinese modules, which generally contain 8 7-segment displays and 8 LEDs. Some of these readily available forms are presented below.

Obviously, TM1638 can be used to control any other configuration of LEDs or segments, for example dot matrix displays or custom displays. In such cases the correspondence between display elements and register bits will be determined.

The contents of the registers will be presented on the relative display with a multiplex that uses the internal clock (about 450kHz) and a variable and programmable duty cycle to adjust the brightness.

Note.

1. **TM1638 does not have a decoding between data and segments**, so the bits sent at 1 correspond to segments on, those at 0 correspond to segments off. A simple external lookup table must be used to convert the symbols to be presented in the corresponding bit mask to be displayed.
2. When turned on, the display is off (low consumption condition), but the registers are not cleared and may contain random values.

The commands.

In the first byte sent after the falling edge of the clock with **STB = 0**, a command must be inserted. The commands are groups of 8 bits of which bits 6 and 7 indicate the type:

b7	b6	Command
0	1	Commands relating to data processing

1	0	Display control
1	1	Register address setting

In the event that STB goes high during the transmission of a command, this is invalidated (the commands and data sent before remain valid).

The commands relating to data processing are:

b7	b6	b5	b4	b3	b2	b1	b0	Function	Description
0	1	0 0				0	0	Read / write data	Writes data to the display
0	1					1	0		Read scan inputs
0	1				0			Addressing mode	Automatic increment
0	1				1				Fixed address
0	1			0				Test mode	Normal way
0	1			1					Test mode

Bits **b0** and **b1** must not contain **01** or **11**.

The **bits 7: 6** is the identifier of the command.

The **bit5: 4** may be 0. As for bits that are not shown, it should be understood that these should also be set to 0.

However, filling the empty spaces with 0, we have that the command " Normal mode " has the same value of command " Write data on display " and " Automatic increase ", so the table should be interpreted as follows:

- 01000000 **0x40** is the normal operating mode: it causes the byte sent below to be data to the display, with the automatic increase of the destination addresses
- 01000010 **0x42** starts reading the inputs
- 01000100 **0x44** sets a fixed address
- 01001000 **0x48** test mode (for internal use)

There is no description of the " Test Mode ", but, as it is cryptically referred to as " (for internal) " it must be assumed that it is an aid to testing the chip before release from the foundry.

Three operating modes are possible (command 0x40 and 0x44):

- **0x40 with self-increasing destination address** : if the command is followed by the address of a register, the subsequent data will be sent progressively to subsequent addresses starting from the one selected.
- **0x44 with fixed destination address** : if the command is followed by the address of a register, the subsequent data will be sent only to this address.
- **0x42** with the subsequent reading of 4 bytes that code the state of the buttons

The addresses of the registers, with **bits 7: 6 to 1**, correspond to the controllable LEDs.

In general, on cards like those presented below, the even addresses correspond to the 7-segment displays, while the addresses equal to the LEDs:

b7	b6	b5	b4	b3	b2	b1	b0	Address	Useful bits
1	1	0 0		0	0	0	0	C0h	8
1	1			0	0	0	1	C1h	2
1	1			0	0	1	0	C2h	8
1	1			0	0	1	1	C3h	2

1	1	0	1	0	0	C4h	8
1	1	0	1	0	1	C5h	2
1	1	0	1	1	0	C6h	8
1	1	0	1	1	1	C7h	2
1	1	1	0	0	0	C8h	8
1	1	1	0	0	1	C9h	2
1	1	1	0	1	0	CAh	8
1	1	1	0	1	1	CBh	2
1	1	1	1	0	0	CCh	8
1	1	1	1	0	1	CDh	2
1	1	1	1	1	0	CEh	8
1	1	1	1	1	1	CFh	2

Note that, in effect, **the Master will have to send the address plus bits 7: 6 to 1; consequently the value to be sent, for example, for address 0 will be C0h, that for the last address, 0Fh, will be CFh.**

In single increment mode, after the command the address to be written to and the relative data must be sent.

In auto-increment mode, the starting address and the data must be sent in succession; any amount of data can be written until the registers are filled.

By default at reset (power supply arrival) the selected address is **00h**, that is the first digit on the left. It is possible to write any number of registers.

If an address greater than **0Fh** is sent, it is ignored and there is no effect until a valid address is sent.

After the application of the supply voltage the contents of the registers are not reset, so there will be segments / LEDs lit in random combinations; its contents can be reset by writing 0 in all sixteen registers.

The commands relating to the control of the display concern the on / off status of the same and the brightness variation, obtained with a PWM.

b7	b6	b5	b4	b3	b2	b1	b0	Function	Description
1	0	0 0			0	0	0	Brightness	PWM 1/16
1	0				0	0	1		PWM 2/16
1	0				0	1	0		PWM 4/16
1	0				0	1	1		PWM 10/16
1	0				1	0	0		PWM 11/16
1	0				1	0	1		PWM 12/16
1	0				1	1	0		PWM 13/16
1	0				1	1	1		PWM 14/16
1	0			0				Display on / off	Display OFF
1	0			1					Display ON

The table is not very clear. In fact, it turns out that the **on / off bit3 must be added to the brightness value**. Thus we have that:

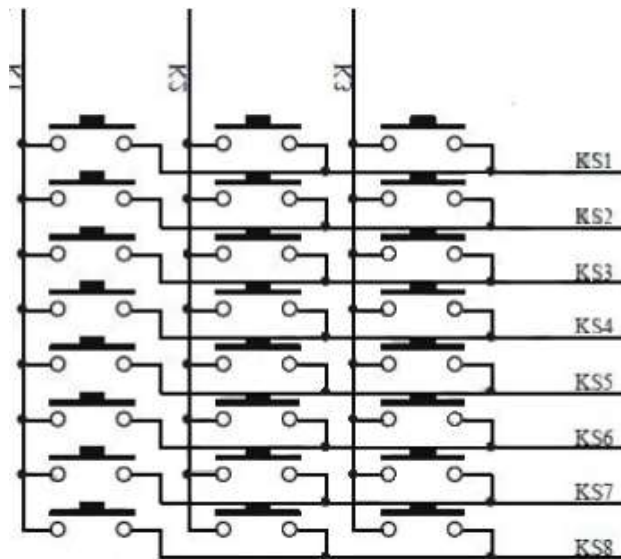
- 10000000 **0x80** turns off the display
- 10001000 **0x88** turns on the display with PWM 1/16
- 10001001-100001111 **0x89-0x8F** 7 additional brightness adjustment steps

After power is applied, the display is turned off, which is the lowest consumption condition. To illuminate the active segments, an on command must be sent with the desired brightness.

Once an addressing mode or brightness value has been programmed, these remain set until they are changed by a different command or the power supply fails.

Reading the keyboard.

TM1638 can support 3 blocks of 8 contacts each.



The keys are connected to three common (K3: 1) and to 8 lines (KS8: 1), common with the segment control (SEG8: 1).

The condition of the keys can be requested by sending a specific command (0x42), followed by an 8-bit reading loop. **The lowest bit (bit0) is transmitted first**.

In data output, the DIO pin of the TM1638 is configured as open drain and therefore requires an external pull-up.

The bytes read encode the button as follows:

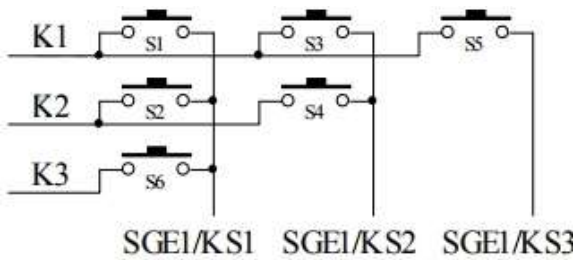
b0	b1	b2	b3	b4	b5	b6	b7	
K3	K2	K1	-	K3	K2	K1	-	
KS1				KS2				Byte 1
KS3				KS4				Byte 2
KS5				KS6				Byte 3
KS7				KS8				Byte 4

Basically, bits b2: 0 and b6: 4 of each byte are significant.

Keyboard scanning is performed automatically by the TM1638 without user control. The users just have to read the key codes according to the timeline. It takes one view cycle to scan the keyboard and one view cycle takes about 4.7ms. During this time, if two different keys are pressed, the key code read in both times is that of the key pressed first.

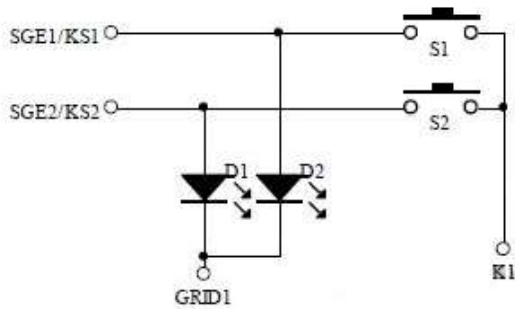
More than one key belonging to the same row (KSn) can be pressed: for example, for K1 and KS8, K2 and KS8, K3 and KS8 at the same time, bits 6: 4 of the fourth byte are set to 1. Push buttons with the same K, but on different KS.

There are several ways of connecting the buttons.



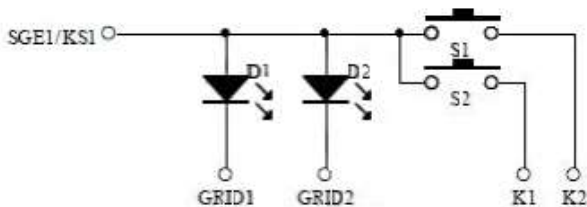
This is the simplest situation, to use where multiple keys are not required to be pressed simultaneously.

Pressing S1, bit b0 of the first byte read will be at 1.

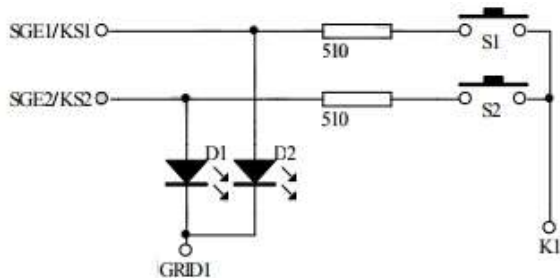


By pressing several buttons at the same time, the relative SEGn lines will be put in contact, with the result of having the relative segments on.

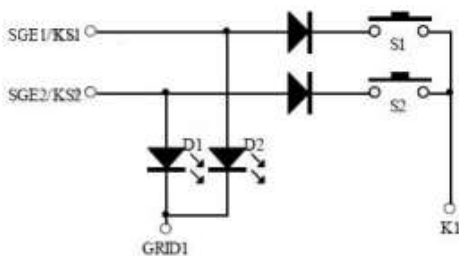
If, for example, we pressed S1 and S2, we will end up with D1 and d2 on



One solution is to insert the buttons that must be pressed simultaneously on two different Kn lines.

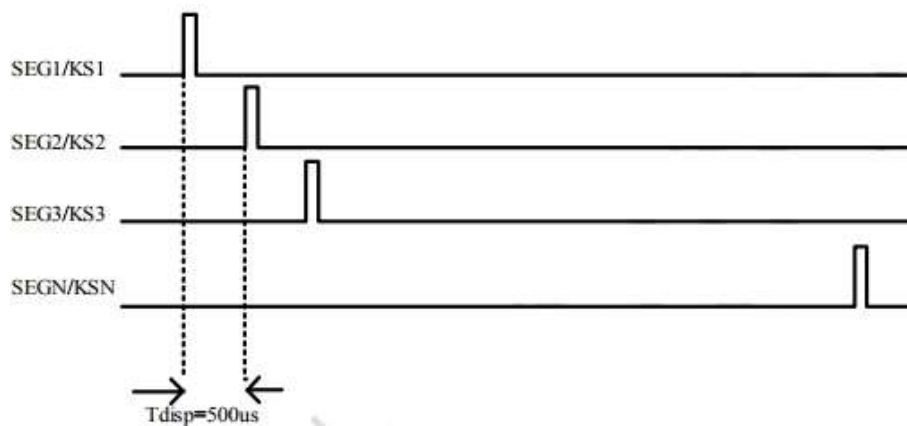


Another solution is to insert resistors in series with the keys.



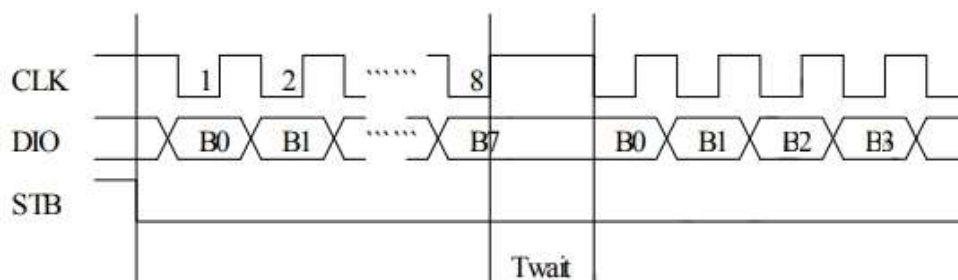
Or use diodes to separate the buttons, a solution which is the most common in commercial modules.

The data sheet shows a diagram of the key scan:



Scanning between the KSs takes about 500us, depending on the chip clock.

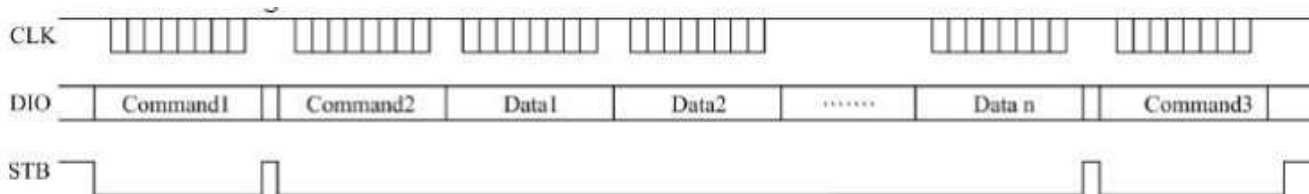
When reading the status of the buttons, a wait of at least 1us must be introduced between the 0x42 command (reading the buttons) and the subsequent bytes read.



The management of the registers.

Registers management involves a simple command / data structure.

Let's see in the following diagram an example of simple command transmission with self-increasing address:



The first transmission includes a single command for setting the addressing mode (in this case self-increasing). STB is brought low at the beginning of the transmission and raised high at the end of the transmission.

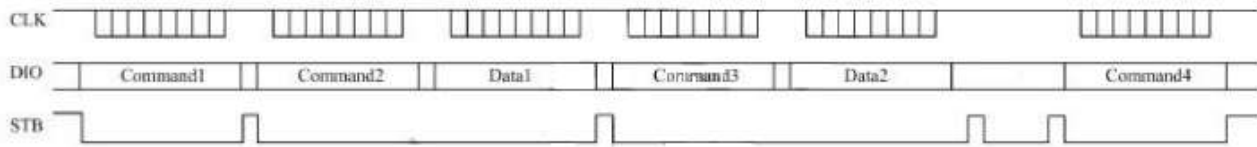
Command2 contains the starting address and is followed by the transmission of the desired number of data. High level STB closes the transmission.

Command3 is a simple command, such as brightness adjustment.

- **Command1 set display mode**
- **Command2 sending starting address en Data**
- **Command3 set brightness**

See also the operating examples below.

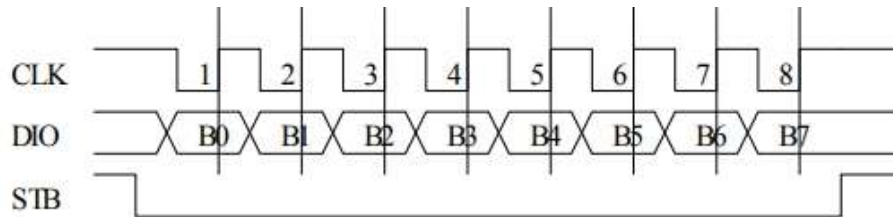
If we write to single addresses, each command / data group is separated from the next by the strobe.



- **Command1 set display mode**
- **Command2-Data1 send address and data**
- **Command3-Data2 sending address and data**
-
- **Command4 set luminosità**

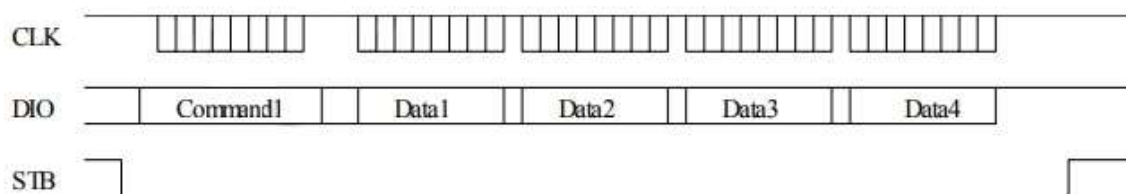
Vedere anche gli esempi operativi più avanti.

Nella scrittura di un byte vanno rispettate queste temporizzazioni:



I dati sono acquisiti sul fronte di salita del clock.

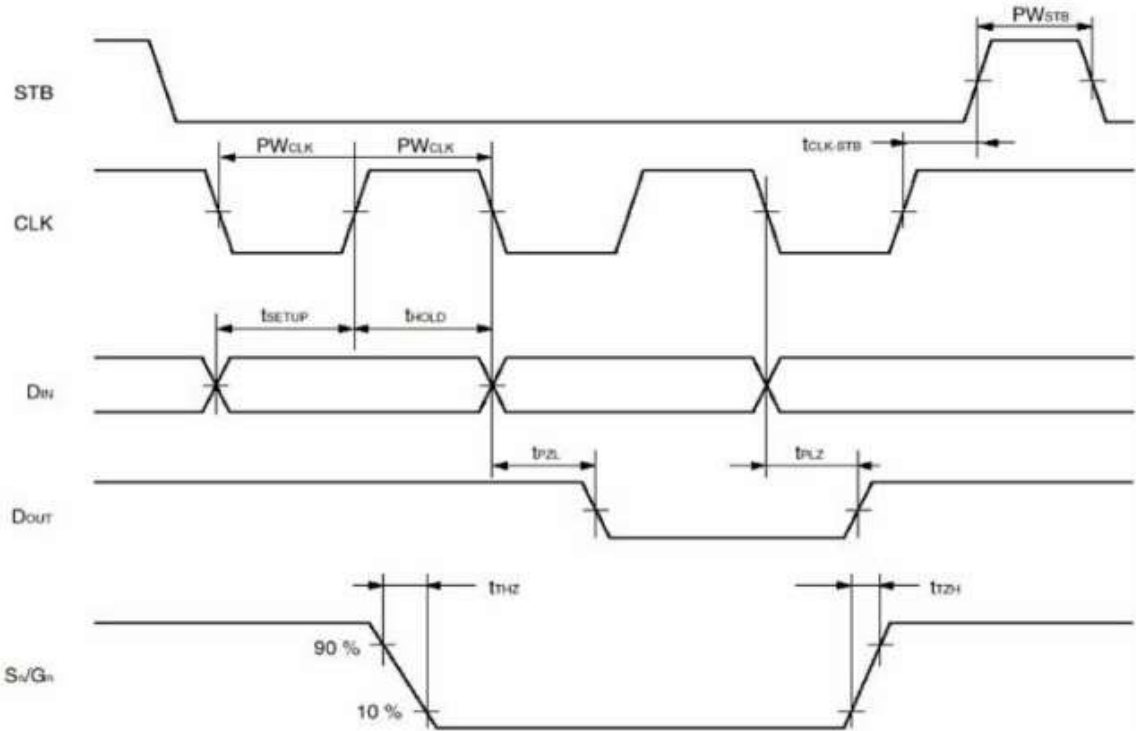
Per la lettura dello stato dei pulsanti:



- **Command1 set key read mode**
- **wait 1us min.**
- **Data1 lettura primo byte**
- **Data2 lettura secondo byte**
- **Data3 lettura terzo byte**
- **Data4 lettura quarto byte**

Da notare che non si deve alzare e ri-abbassare lo strobe dopo in comando di lettura tasti, ma occorre inserire un wait di almeno 1us prima della lettura dei 4 bytes.

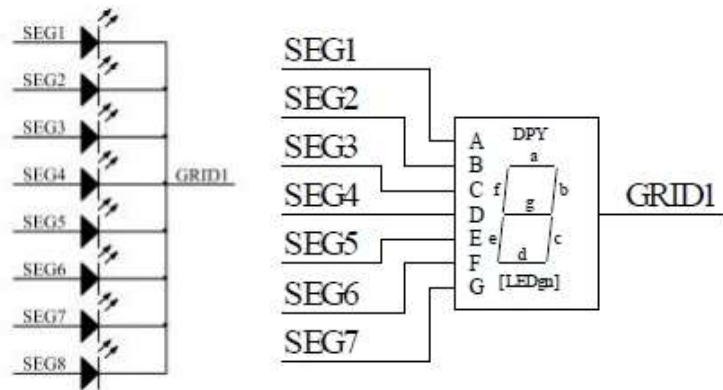
Timing.



Parametro	min.	max.	Descrizione
TPLZ		300ns	transmit delay time
TPZL		100ns	
PWCLK	400ns		clock pulse width
PWSTB	1us		gate pulse width
Tsetup	100ns		data building time
Thold	100ns		data hold time
TIHZ		120ns	STB falling time
TTZH		500ns	STB rising time
Fmax		1MHz	clock frequency

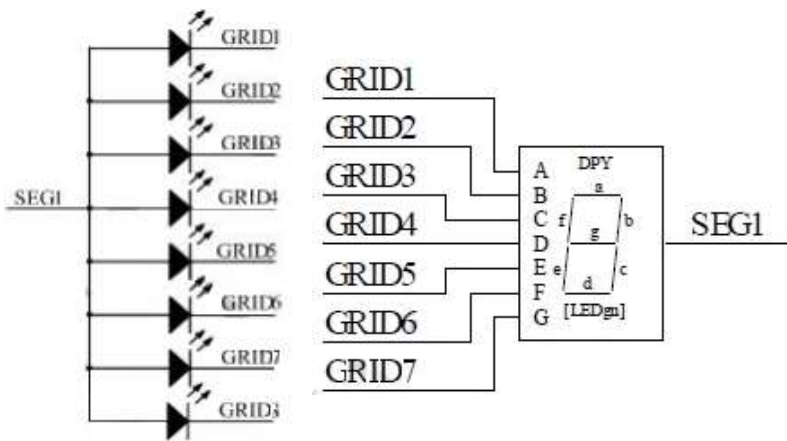
Display and LED.

Common cathode displays can be driven:



Thus, to light the digit 0 it will be necessary to write 00111111 (3Fh) in the desired register. The decimal point (dp) corresponds to bit7. By writing 0 all segments will be off.

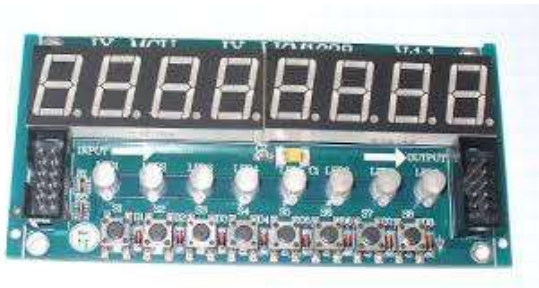
It is also possible to use common anode displays:



Typical hardware.

TM1638 can control up to 80 LEDs or segments, which can be configured in the most diverse ways. On the market there are some modules of Chinese production with a certain number of LEDs, displays and keys, attributable to the three examples shown below. As common for this class of products, they are not accompanied by any documentation and it is necessary to do research on the WEB to get some more information.

A typical card with TM1638, sold on many sites, has 8 seven-segment digits, 8 bi-color LEDs, and 8 buttons.



Note the 10-pin DIL connector which allows multiple modules to be connected in cascade: DIO and CLK are connected to all, while each module depends on its own STB line. The chain is made with flat ten-pole cables.


[Here](#) the wiring diagram.

Function	pin	pin	Function
Vcc	1	2	GND
CLK	3	4	GOD
STB0	5	6	STB1
STB2	7	8	STB3
STB4	9	10	nc

The signals needed by the local board are at pins 1/2/3/4/5. Pins 6/7/8/9 are the strobes for subsequent cards

Each of the 7-segment displays is accessible at an even address, where the 8 bits correspond to the segments + the dp.
Note that TM1638 has no decoder and the value of each bit transmitted as data is carried over to the corresponding segment.

b7	b6	b5	b4	b3	b2	b1	b0
dp	following	seg f	seg e	following	following	following	seg a

ap	following	seg r	seg and	following	following	following	seg a	
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Thus, for example, to have the digit 9 it will be necessary to turn on the segments a, b, c, d, f, g, that is to send the value 00011111. By sending 11111111 all the segments (digit 8) plus the decimal point will light up.

The two useful bits of the odd addresses are connected to the two-color LEDs .

The following table shows the assignments for this type of card.

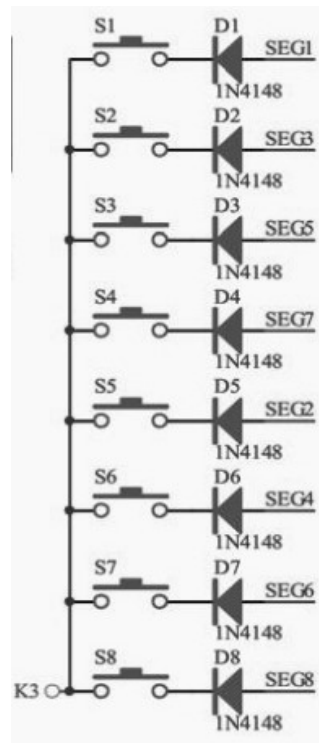
Register	Address command	Function	LED
00	0xC0	display 1	
01	0xC1	LED 1	0x01 red 0x02 green
02	0xC2	display 2	
03	0xC3	LED 2	0x01 red 0x02 green
04	0xC4	display 3	
05	0xC5	LED 3	0x01 red 0x02 green
06	0xC6	display 4	
07	0xC7	LED 4	0x01 red 0x02 green
08	0xC8	display 5	
09	0xC9	LED 5	0x01 red 0x02 green
0A	0xCA	display 6	
0B	0xCB	LED 6	0x01 red 0x02 green
0C	0xCC	display 7	
0D	0xCD	LED 7	0x01 red 0x02 green

0E	0xCE	display 8	
0F	0xCF	LED 8	0x01 red 0x02 green

The LEDs are connected to the SEG10: 9 lines and, accordingly, depend on the odd registers, with bits b1: 0.

In this case (bi-color LED), bit b0 controls the red color and bi b1 controls the green color.

The bit set at 0 turns off the LED, while at 1 it turns it on.



The buttons are connected between common K3 and SEG8: 1, as in the figure on the side.

The diodes in series prevent disturbing the display if several keys are pressed simultaneously.

From the links it follows that the coding is the one visible in the following table:

b7	b6	b5	b4	b3	b2	b1	b0	
			S5				S1	byte 1
			S6				S2	byte 2
			S7				S3	byte 3
			S8				S4	byte 4

So, if S1 is closed, the read will render 00000001 in the first byte and 0 in all others.

If S8 is closed, the read will return 00010000 in the fourth byte and so on.



There are also boards with mono color LEDs.

In this case, the LEDs are connected to the GR8: 1 and have the SEG9 in common.

So they are controlled by the bit b0 of the odd addresses (b0 = 1 LED on, b0 = 0 LED off).

Here, too, the buttons have K3 and the connections seen above in common.

[Here](#) the wiring diagram.



There are also modules with different quantities of displays and buttons, like this one, with 8 digits and 16 buttons, but without additional LEDs.

These cards allow you to add alerts and buttons to any project with negligible expense, since they have incredibly low costs, especially if sent directly from China.

Operational example.

As an initial operation after applying voltage, it may be necessary to clear all memory locations of the TM1638, which may initially contain random values.

This is easily obtained by setting the automatic address increase mode (0x40), selecting 0 as the starting address (0xC0) and sending the data 0 sixteen times.

1. Low STB
2. 0x40; command for writing to self-increasing address
3. High STB
4. Low STB
5. 0xC0; address of the first digit on the left
6. 0x00; all off
7. repeat the data for another 15 times
8. High STB

Observe that **STB** opens and closes communication, both for issuing the mode command and for the address-data sequence.

Now that the card is ready to work, you can send data to view.

For example, let's write 8 in the last digit on the right and 1 in the first left.

Since these are two non-consecutive addresses, we use the single address mode.

The sequence to be sent will be this:

1. Low STB
2. 0x44; single address write command
3. High STB
4. Low STB
5. 0xC0; address of the first digit on the left
6. 0x06; 00000110 which corresponds to segments b and c on
7. High STB
8. Low STB
9. 0xCE; address of the last digit on the right
10. 0x7F; 01111111 which corresponds to all lit segments
11. High STB

Observe that **STB** opens and closes the communication, both for the issue of the mode command and for the sequence of the address-data pairs.

Or, we write the numbers from 1 to 4 in the first displays, turning on the decimal points and the LEDs alternately of different colors:

1. Low STB
2. 0x40; command for writing with self-increasing address
3. High STB
4. Low STB
5. 0xC0; address of the first digit on the left
6. 0x06; 00000110 digit 1 segments b, c lit
7. 0x01; Red LED
8. 0xDB; 11011011 2- segment digit a, b, d, g, dp on
9. 0x02; Green LED
10. 0xCF; 01001111 digit 3 segments a, b, c, d, e, g lit
11. 0x01; Red LED
12. 0xB6; 1 0110110 digit 4 segments b, c, e, f, dp acces i
13. 0x02; Green LED
14. High STB

It should be noted that, since the TM1638 does not have an encoder, it is not necessary to send the digits to be displayed, but the corresponding 7-segment mask, obtainable from a retlw table.

If we want to turn on the third LED and the fourth decimal point:

1. Low STB
2. 0x40; command for writing with self-increasing address
3. High STB
4. Low STB
5. 0xC4; third address LED
6. 0x02; Green LED on
7. 0x80; dp of the next lit display
8. High STB

To read the situation of the buttons, it is necessary to send the appropriate command (0x42) and then read 4 bytes.

The first byte contains the status of buttons S1 (bit 1) and S5 (bit 4), the second byte contains the status of buttons S2 (bit 2) and S6 (bit 5) and so on. If a bit is set to 1 it means that the corresponding button is pressed.

A delay of at least 1us must be inserted between the reading of one byte and the next

1. Low STB
2. 0x42; reading buttons
3. DIO line on the Master side as input
4. wait 1us
5. read a byte and save
6. read a byte and save
7. read a byte and save
8. read a byte and save
9. High STB
10. DIO line on Master side reconfigured as output

While reading the state of the buttons, the DIO line becomes an output driven by the TM1638 and the corresponding pin of the Master must be an input. The clock is always provided by the Master.

DRIVER.

Various examples of C libraries are available on the WEB.

As regards the Assembly, a **driver** has been created . [Here is](#) a version for **Enhanced Midrange** .

Some notes on the hardware.

1. - RC at the entrance

The 10k pull-ups and the 100pF capacitors on the input lines are installed on all the Chinese 4-digit cards and TM1638.

It should be noted that DIO, in output, does not drive the line at a high level, but is configured as an open drain and requires the pull-up.

The value of the capacitance is not negligible and influences the rise and fall times of the signals.

2. - Chinese module hardware

Modules with displays, LEDs, buttons and TM1638 are available on the market at very low prices.

The costs are very low, but, as for most of the Chinese products of this class, the technical documentation

of these modules does not exist: there is not even a miserable piece of paper to accompany the object, nor are there any information to that effect on most of the sellers' sites, even if some, rare, show diagrams or even extensive documentation (but only in Chinese ...)

Even for displays it may be difficult to find a data sheet, even if only indicative.

Therefore, except for searches on the WEB, there is no information on how the components are connected and therefore on the corresponding registers.

In the case of common modules, such as those outlined above, it is possible to trace the connections by analyzing the existing drivers.

In the modules there may be no indication that the LEDs are mono color; a generic differentiation can be done by looking at the photos of the modules: red LEDs are only this color, LEDs with a white body are two-colored.

3. - Nutrition

A final note concerns the supply voltage: if TM1638 can be powered from 3 to 5V, it is the minimum conduction voltage of the LEDs that determines the minimum supply value. Thus, blue LEDs cannot be powered at less than 5V.

Documentation.

- [TM1638](#)
- [Shenzen Titan Microelectronics](#)

