

Electronics Matrix LCD Driver (MAX7219)

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LED Matrix Displays

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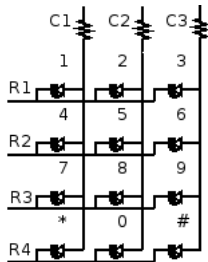
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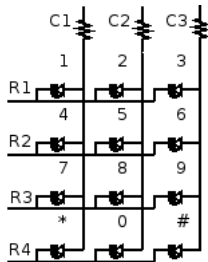
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- Often LEDs will be arranged in a matrix, such as a several digit 7-segment or dot-matrix display.
- Rather than having a pin for each element, having pins for each row and column reduces the total number needed.

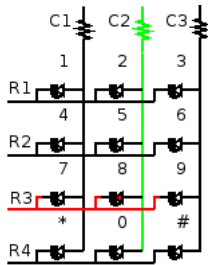
LED Matrix Displays

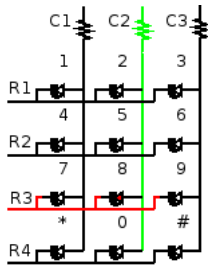
- Often LEDs will be arranged in a matrix, such as a several digit 7-segment or dot-matrix display.
- Rather than having a pin for each element, having pins for each row and column reduces the total number needed.
- This requires *strobing* in order to work.





LED matrix





LED 8 lighted

LED matrix operation

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- 1 Set the bit for the first column HIGH, and all others LOW.

LED matrix operation

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- 2 Set the bits for each of the rows LOW where you want an LED on, and set the others HIGH.

LED matrix operation

- 1 Set the bit for the first column HIGH, and all others LOW.
- 2 Set the bits for each of the rows LOW where you want an LED on, and set the others HIGH.
- 3 Repeat for each column.

Matrix Display Driver Chips

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Matrix Display Driver Chips

- This scenario use several digital signals, and requires constant refreshing.
- It can be simplified with a driver chip which uses a serial interface and refreshes automatically.
- The MAXIM MAX7219 is an example of this.

MAX7219 LED Display Driver Chip

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- The MAXIM MAX7219 can handle up to 64 individual LEDs, in various arrangements.

MAX7219 LED Display Driver Chip

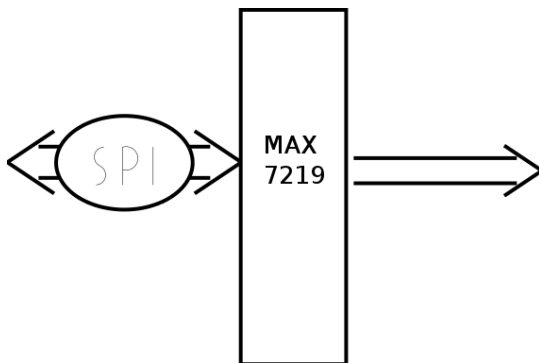
- The MAXIM MAX7219 can handle up to 64 individual LEDs, in various arrangements.
- It uses an SPI interface to communicate, so it only requires 3 signals.

MAX7219 LED Display Driver Chip

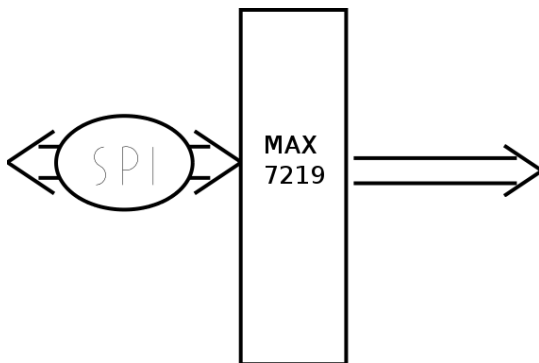
- The MAXIM MAX7219 can handle up to 64 individual LEDs, in various arrangements.
- It uses an SPI interface to communicate, so it only requires 3 signals.
- It is designed so that multiple MAX7219s can be *cascaded* to handle much bigger displays.

MAXX7219

MAXX7219



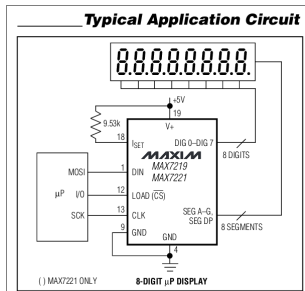
MAXX7219



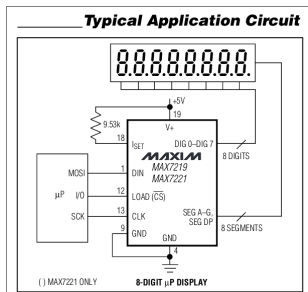
The MAX7219 uses an SPI interface, and has outputs for 8 'rows' and 8 'columns'.

Basic wiring

Basic wiring

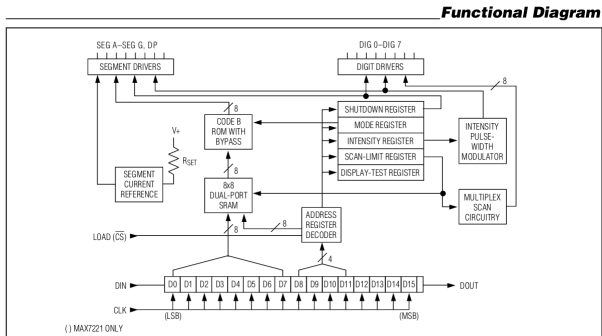


Basic wiring

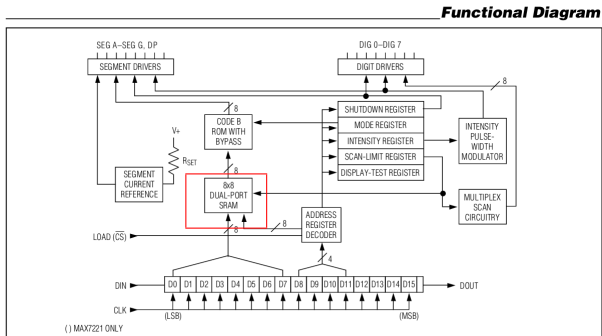


For a dot matrix display, *rows* correspond to *segments* and *columns* correspond to *digits*.

Internal block diagram

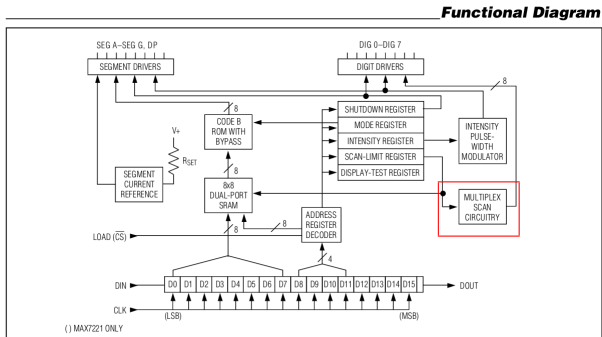


Internal block diagram



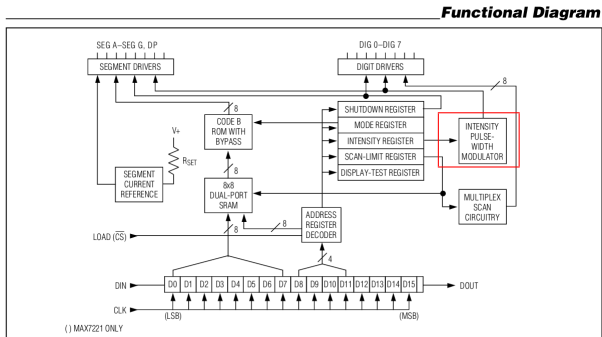
8x8 SRAM stores bit values for the automatic refresh.

Internal block diagram



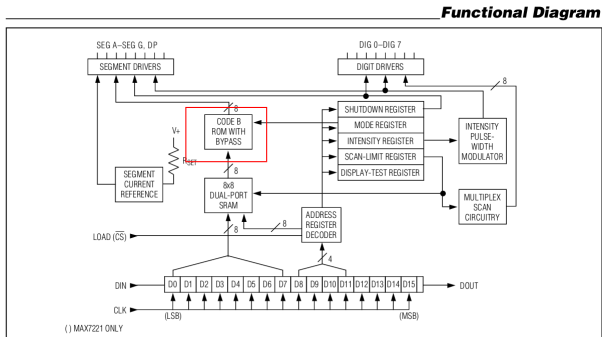
Multiplex scan circuitry handles the automatic refresh.

Internal block diagram



Intensity pulse width modulation controls brightness.

Internal block diagram



Code B ROM with bypass handles decode (or not) of individual digits (or columns).

Data format

Data format

Table 1. Serial-Data Format (16 Bits)

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	X	X	X	ADDRESS				MSB	DATA						LSB

Data format

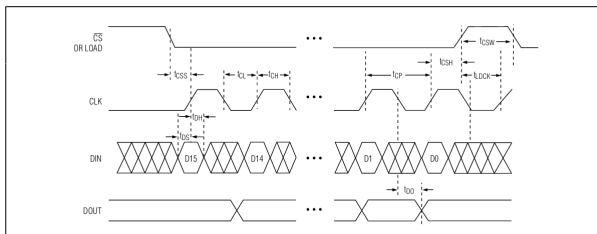
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X	X	X	X	ADDRESS				MSB	DATA						LSB

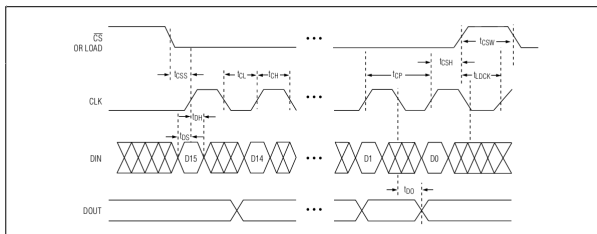
The address is 4 bits since there are 14 internal registers.

SPI details

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SPI details



Two byte SPI transfer keeps \overline{CS} low between bytes.

Internal registers

Internal registers

- The MAXIM MAX7219 has 14 internal registers.

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Internal registers

- The MAXIM MAX7219 has 14 internal registers.
There is one register for each digit.
There are additional registers for
shutdown,
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intensity,
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and **scan limit**
- There is also a **no-op** register.

Internal register configuration

Internal register configuration

Table 2. Register Address Map

REGISTER	ADDRESS					HEX CODE
	D15–D12	D11	D10	D9	D8	
No-Op	X	0	0	0	0	0xX0
Digit 0	X	0	0	0	1	0xX1
Digit 1	X	0	0	1	0	0xX2
Digit 2	X	0	0	1	1	0xX3
Digit 3	X	0	1	0	0	0xX4
Digit 4	X	0	1	0	1	0xX5
Digit 5	X	0	1	1	0	0xX6
Digit 6	X	0	1	1	1	0xX7
Digit 7	X	1	0	0	0	0xX8
Decode Mode	X	1	0	0	1	0xX9
Intensity	X	1	0	1	0	0xXA
Scan Limit	X	1	0	1	1	0xXB
Shutdown	X	1	1	0	0	0xXC
Display Test	X	1	1	1	1	0xFF

Internal register configuration

Table 2. Register Address Map

REGISTER	ADDRESS					HEX CODE
	D15–D12	D11	D10	D9	D8	
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Digit 1	X	0	0	1	0	0xX2
Digit 2	X	0	0	1	1	0xX3
Digit 3	X	0	1	0	0	0xX4
Digit 4	X	0	1	0	1	0xX5
Digit 5	X	0	1	1	0	0xX6
Digit 6	X	0	1	1	1	0xX7
Digit 7	X	1	0	0	0	0xX8
Decode Mode	X	1	0	0	1	0xX9
Intensity	X	1	0	1	0	0xXA
Scan Limit	X	1	0	1	1	0xXB
Shutdown	X	1	1	0	0	0xXC
Display Test	X	1	1	1	1	0xFF

Note digit register number has 1 added, since address zero is no-op.

Decode mode register

Decode mode register

Table 4. Decode-Mode Register Examples (Address (Hex) = 0xX9)

DECODE MODE	REGISTER DATA								HEX CODE
	D7	D6	D5	D4	D3	D2	D1	D0	
No decode for digits 7-0	0	0	0	0	0	0	0	0	0x00
Code B decode for digit 0 No decode for digits 7-1	0	0	0	0	0	0	0	1	0x01
Code B decode for digits 3-0 No decode for digits 7-4	0	0	0	0	1	1	1	1	0x0F
Code B decode for digits 7-0	1	1	1	1	1	1	1	1	0xFF

Decode mode register

Table 4. Decode-Mode Register Examples (Address (Hex) = 0xX9)

DECODE MODE	REGISTER DATA								HEX CODE
	D7	D6	D5	D4	D3	D2	D1	D0	
No decode for digits 7-0	0	0	0	0	0	0	0	0	0x00
Code B decode for digit 0 No decode for digits 7-1	0	0	0	0	0	0	0	1	0x01
Code B decode for digits 3-0 No decode for digits 7-4	0	0	0	0	1	1	1	1	0x0F
Code B decode for digits 7-0	1	1	1	1	1	1	1	1	0xFF

For dot matrix display you want *no decode*. For full digit display use decode for digits 0-7. (Set the bit for any digit(s) you want decoded.)

Code B format

Code B format

Table 5. Code B Font

7-SEGMENT CHARACTER	REGISTER DATA						ON SEGMENTS = 1							
	D7*	D6-D4	D3	D2	D1	D0	DP*	A	B	C	D	E	F	G
0		X	0	0	0	0		1	1	1	1	1	1	0
1		X	0	0	0	1		0	1	1	0	0	0	0
2		X	0	0	1	0		1	1	0	1	1	0	1
3		X	0	0	1	1		1	1	1	1	0	0	1
4		X	0	1	0	0		0	1	1	0	0	1	1
5		X	0	1	0	1		1	0	1	1	0	1	1
6		X	0	1	1	0		1	0	1	1	1	1	1
7		X	0	1	1	1		1	1	1	0	0	0	0
8		X	1	0	0	0		1	1	1	1	1	1	1
9		X	1	0	0	1		1	1	1	1	0	1	1
—		X	1	0	1	0		0	0	0	0	0	0	1
E		X	1	0	1	1		1	0	0	1	1	1	1
H		X	1	1	0	0		0	1	1	0	1	1	1
L		X	1	1	0	1		0	0	0	1	1	1	0
P		X	1	1	1	0		1	1	0	0	1	1	1
blank		X	1	1	1	1		0	0	0	0	0	0	0

*The decimal point is set by bit D7 = 1

Code B format

Table 5. Code B Font

7-SEGMENT CHARACTER	REGISTER DATA						ON SEGMENTS = 1							
	D7*	D6-D4	D3	D2	D1	D0	DP*	A	B	C	D	E	F	G
0		X	0	0	0	0		1	1	1	1	1	1	0
1		X	0	0	0	1		0	1	1	0	0	0	0
2		X	0	0	1	0		1	1	0	1	1	0	1
3		X	0	0	1	1		1	1	1	1	0	0	1
4		X	0	1	0	0		0	1	1	0	0	1	1
5		X	0	1	0	1		1	0	1	1	0	1	1
6		X	0	1	1	0		1	0	1	1	1	1	1
7		X	0	1	1	1		1	1	1	0	0	0	0
8		X	1	0	0	0		1	1	1	1	1	1	1
9		X	1	0	0	1		1	1	1	1	0	1	1
—		X	1	0	1	0		0	0	0	0	0	0	1
E		X	1	0	1	1		1	0	0	1	1	1	1
H		X	1	1	0	0		0	1	1	0	1	1	1
L		X	1	1	0	1		0	0	0	1	1	1	0
P		X	1	1	1	0		1	1	0	0	1	1	1
blank		X	1	1	1	1		0	0	0	0	0	0	0

*The decimal point is set by bit D7 = 1

As noted, D7 is for the decimal point. Decoding takes care of digits 0-9 plus a few letters.

Display test register

Display test register

**Table 10. Display-Test Register Format
(Address (Hex) = 0xXF)**

MODE	REGISTER DATA							
	D7	D6	D5	D4	D3	D2	D1	D0
Normal Operation	X	X	X	X	X	X	X	0
Display Test Mode	X	X	X	X	X	X	X	1

Note: The MAX7219/MAX7221 remain in display-test mode (all LEDs on) until the display-test register is reconfigured for normal operation.

Display test register

**Table 10. Display-Test Register Format
(Address (Hex) = 0xXF)**

MODE	REGISTER DATA							
	D7	D6	D5	D4	D3	D2	D1	D0
Normal Operation	X	X	X	X	X	X	X	0
Display Test Mode	X	X	X	X	X	X	X	1

Note: The MAX7219/MAX7221 remain in display-test mode (all LEDs on) until the display-test register is reconfigured for normal operation.

Display test mode turns on all segments. Normal operation uses 8x8 SRAM.

Intensity register

Intensity register

Table 7. Intensity Register Format (Address (Hex) = 0xXA)

DUTY CYCLE		D7	D6	D5	D4	D3	D2	D1	D0	HEX CODE
MAX7219	MAX7221									
1/32 (min on)	1/16 (min on)	X	X	X	X	0	0	0	0	0xX0
3/32	2/16	X	X	X	X	0	0	0	1	0xX1
5/32	3/16	X	X	X	X	0	0	1	0	0xX2
7/32	4/16	X	X	X	X	0	0	1	1	0xX3
9/32	5/16	X	X	X	X	0	1	0	0	0xX4
11/32	6/16	X	X	X	X	0	1	0	1	0xX5
13/32	7/16	X	X	X	X	0	1	1	0	0xX6
15/32	8/16	X	X	X	X	0	1	1	1	0xX7
17/32	9/16	X	X	X	X	1	0	0	0	0xX8
19/32	10/16	X	X	X	X	1	0	0	1	0xX9
21/32	11/16	X	X	X	X	1	0	1	0	0xXA
23/32	12/16	X	X	X	X	1	0	1	1	0xXB
25/32	13/16	X	X	X	X	1	1	0	0	0xXC
27/32	14/16	X	X	X	X	1	1	0	1	0xDD
29/32	15/16	X	X	X	X	1	1	1	0	0xDE
31/32	15/16 (max on)	X	X	X	X	1	1	1	1	0xDF

Intensity register

Table 7. Intensity Register Format (Address (Hex) = 0xXA)

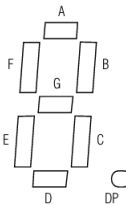
DUTY CYCLE		D7	D6	D5	D4	D3	D2	D1	D0	HEX CODE
MAX7219	MAX7221									
1/32 (min on)	1/16 (min on)	X	X	X	X	0	0	0	0	0xX0
3/32	2/16	X	X	X	X	0	0	0	1	0xX1
5/32	3/16	X	X	X	X	0	0	1	0	0xX2
7/32	4/16	X	X	X	X	0	0	1	1	0xX3
9/32	5/16	X	X	X	X	0	1	0	0	0xX4
11/32	6/16	X	X	X	X	0	1	0	1	0xX5
13/32	7/16	X	X	X	X	0	1	1	0	0xX6
15/32	8/16	X	X	X	X	0	1	1	1	0xX7
17/32	9/16	X	X	X	X	1	0	0	0	0xX8
19/32	10/16	X	X	X	X	1	0	0	1	0xX9
21/32	11/16	X	X	X	X	1	0	1	0	0xXA
23/32	12/16	X	X	X	X	1	0	1	1	0xXB
25/32	13/16	X	X	X	X	1	1	0	0	0xXC
27/32	14/16	X	X	X	X	1	1	0	1	0xXD
29/32	15/16	X	X	X	X	1	1	1	0	0xXE
31/32	15/16 (max on)	X	X	X	X	1	1	1	1	0xFF

Note 0 still gives 1/32 duty cycle.

Relationship between data bit and segment

Relationship between data bit and segment

Table 6. No-Decode Mode Data Bits and Corresponding Segment Lines

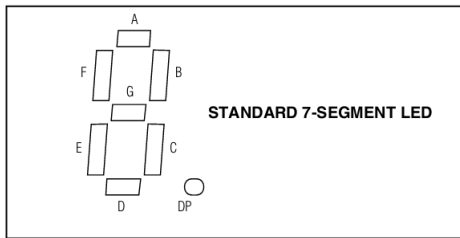


STANDARD 7-SEGMENT LED

	REGISTER DATA							
	D7	D6	D5	D4	D3	D2	D1	D0
Corresponding Segment Line	DP	A	B	C	D	E	F	G

Relationship between data bit and segment

Table 6. No-Decode Mode Data Bits and Corresponding Segment Lines



	REGISTER DATA							
	D7	D6	D5	D4	D3	D2	D1	D0
Corresponding Segment Line	DP	A	B	C	D	E	F	G

With a dot matrix display, rows correspond to segments. (Columns correspond to digits.)

Scan limit register

Scan limit register

Table 8. Scan-Limit Register Format (Address (Hex) = 0xB)

SCAN LIMIT	REGISTER DATA								HEX CODE
	D7	D6	D5	D4	D3	D2	D1	D0	
Display digit 0 only*	X	X	X	X	X	0	0	0	0x0
Display digits 0 & 1*	X	X	X	X	X	0	0	1	0x1
Display digits 0 1 2*	X	X	X	X	X	0	1	0	0x2
Display digits 0 1 2 3	X	X	X	X	X	0	1	1	0x3
Display digits 0 1 2 3 4	X	X	X	X	X	1	0	0	0x4
Display digits 0 1 2 3 4 5	X	X	X	X	X	1	0	1	0x5
Display digits 0 1 2 3 4 5 6	X	X	X	X	X	1	1	0	0x6
Display digits 0 1 2 3 4 5 6 7	X	X	X	X	X	1	1	1	0x7

*See *Scan-Limit Register* section for application.

Scan limit register

Table 8. Scan-Limit Register Format (Address (Hex) = 0xXB)

SCAN LIMIT	REGISTER DATA								HEX CODE
	D7	D6	D5	D4	D3	D2	D1	D0	
Display digit 0 only*	X	X	X	X	X	0	0	0	0xX0
Display digits 0 & 1*	X	X	X	X	X	0	0	1	0xX1
Display digits 0 1 2*	X	X	X	X	X	0	1	0	0xX2
Display digits 0 1 2 3	X	X	X	X	X	0	1	1	0xX3
Display digits 0 1 2 3 4	X	X	X	X	X	1	0	0	0xX4
Display digits 0 1 2 3 4 5	X	X	X	X	X	1	0	1	0xX5
Display digits 0 1 2 3 4 5 6	X	X	X	X	X	1	1	0	0xX6
Display digits 0 1 2 3 4 5 6 7	X	X	X	X	X	1	1	1	0xX7

*See *Scan-Limit Register* section for application.

Set the scan limit to the number of digits (or columns).

Shutdown register

Shutdown register

Table 3. Shutdown Register Format (Address (Hex) = 0xXC)

MODE	ADDRESS CODE (HEX)	REGISTER DATA							
		D7	D6	D5	D4	D3	D2	D1	D0
Shutdown Mode	0xXC	X	X	X	X	X	X	X	0
Normal Operation	0xXC	X	X	X	X	X	X	X	1

Shutdown register

Table 3. Shutdown Register Format (Address (Hex) = 0xXC)

MODE	ADDRESS CODE (HEX)	REGISTER DATA							
		D7	D6	D5	D4	D3	D2	D1	D0
Shutdown Mode	0xXC	X	X	X	X	X	X	X	0
Normal Operation	0xXC	X	X	X	X	X	X	X	1

Shutdown mode turns off display. Use normal mode otherwise.

Operation

Operation

To operate, place appropriate values in each of the registers.

Operation

To operate, place appropriate values in each of the registers. When all have been loaded, the display should be static until values are changed.

Current limiting

Current limiting

- Current is limited by the R_{set} resistor.

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- The value should be adjusted based on:

Current limiting

- Current is limited by the R_{set} resistor.
- The value should be adjusted based on:
the total number of digits

Current limiting

- Current is limited by the R_{set} resistor.
- The value should be adjusted based on:
 - the total number of digits
 - the forward voltage of the LEDs

Current limiting resistor

Current limiting resistor

Table 11. R_{SET} vs. Segment Current and LED Forward Voltage

I _{SEG} (mA)	V _{LED} (V)				
	1.5	2.0	2.5	3.0	3.5
40	12.2	11.8	11.0	10.6	9.69
30	17.8	17.1	15.8	15.0	14.0
20	29.8	28.0	25.9	24.5	22.6
10	66.7	63.7	59.3	55.4	51.2

Current limiting resistor

Table 11. R_{SET} vs. Segment Current and LED Forward Voltage

I_{SEG} (mA)	V_{LED} (V)				
	1.5	2.0	2.5	3.0	3.5
40	12.2	11.8	11.0	10.6	9.69
30	17.8	17.1	15.8	15.0	14.0
20	29.8	28.0	25.9	24.5	22.6
10	66.7	63.7	59.3	55.4	51.2

Note: R_{set} is in $k\Omega$. Minimum value is $9.53k\Omega$ for 40mA current.

Current and number of segments

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Table 9. Maximum Segment Current for 1-, 2-, or 3-Digit Displays

NUMBER OF DIGITS DISPLAYED	MAXIMUM SEGMENT CURRENT (mA)
1	10
2	20
3	30

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NUMBER OF DIGITS DISPLAYED	MAXIMUM SEGMENT CURRENT (mA)
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Since corresponding segments for all digits are on simultaneously, current scales.

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What would you have to do if you wanted to use common *anode* displays?
- Since this is a 5V device, is there a problem connecting the signals directly to Raspberry Pi GPIO pins?
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- What can you do if a display has *more* than 8 segments?

Cascading devices

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(i.e each write pushes the word to the next device in the chain.)