

Readerboard
User's Guide
WORKING
DRAFT

The information in this document, and the hardware and software it describes, are hobbyist works created as an educational exercise and as a matter of personal interest for recreational purposes.

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As an educational exercise, it is assumed that the user has the necessary skill to appropriately set up, build, and use this project. Do not proceed to use, whether exactly as provided in the repository or with modifications of your own, unless you know exactly what you're doing and have verified that your actions and the product materials are suitable for your purpose and function as expected.

For readerboard hardware (PCB) version 3.3.0, schematic version 3.3.0, and firmware version 0.0.0.

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HARDWARE

People who are really serious
about software should make
their own hardware.

—Alan Kay

AS A HOBBY PROJECT, the design of the hardware and software for the read-board project “grew in the telling” as new ideas sprang to mind. As of this writing, there are three different models of hardware prototypes which were designed and created.

Version 1

The initial prototype (PCB 1.0.1) was a fairly large board, approximately $20\frac{5}{8} \times 6\frac{3}{8}$ ” with an LED pitch of $\frac{1}{8}$ ”.

It requires an Arduino Mega 2560 or Arduino Due to drive it. A custom-made shield board attaches to the Arduino, which provides connectors for power and ribbon cables to drive the display (one to control the matrix, the other for the 8 status LEDs which appear in a horizontal row along the bottom right of the matrix).

Version 2

This version was based on the 1.0 design, but shrunk to a board size of about $18\frac{3}{16} \times 5\frac{3}{16}$ ” with an LED pitch of $\frac{1}{4}$ ”. It also replaced the obsolete TPIC6B595 with the newer STPIC6D595 chip. Further, it relocated the ribbon cable which

connects the Arduino controller to the LED matrix, moved the eight status LEDs to a vertical column to the right of the matrix, and switched to resistor arrays for the matrix current limiting resistors, instead of the individual discrete resistors used on the 1.0.1 board.

Version 2

Version 2.1 was a significant change to the 2.0 board in terms of how it interfaces with the Arduino, although it had the same size and physical layout as the 2.0 board.

This one eliminates the need for the ribbon cables and shield board. Instead, the Arduino controller mounts directly to the back of the display board. This means that the lower portion of the left edge of the enclosure has all of the external connections in one place, including power, RS-485 in and out, and the USB connector(s) on the Arduino itself.

Version 3

Revision 3.2 of the hardware expands on the version 2.1 design by replacing the single-color LEDs with RGB LEDs arranged into 24 logical rows—each of the eight physical rows is logically a row of red, green, and blue LED elements.

Note that the discrete status LEDs are mislabeled on the revision 3.2.2 PCB. L_0 should be the LED on the bottom (canonically green) and L_7 is on top (white).

Version 3.3 (current model)

The current version of the hardware (3.3.0) corrects some minor issues with the 3.2.2 revision by adding a cutout to avoid colliding with the connectors on the Arduino board and adjusting the mounting holes slightly. It also corrects the mislabeled L_0 – L_7 LEDs

It also adds a R51 for Arduino Due reset circuits, J3 to manually reset the Arduino, and J4, R52, R53, and U16 to support the addition of a external EEPROM chip for microcontrollers (such as the Due) which don't have one onboard.

Firmware Implications

The boards before PCB revision 3.3.0 are not supported by the firmware as currently stored in the project repository. They were prototype ideas which were never built, so this shouldn't be a problem.

There are compile-time switches documented starting on p. 65 which adjust the firmware image for different microcontrollers, default settings—

or the only settings if your hardware does not include an EEPROM memory—and possibly, in the future, different board revisions.

Construction

Once you have created a printed circuit board (PCB) from the fabrication files included with the readerboard Git repository and obtained the parts as listed in Figure 1.1, carefully solder the components in place.

Warning! Danger! Only perform the assembly operation if you are qualified to do so. Soldering electronic components may be hazardous due to the high temperatures, sharp objects, electrical voltages, potentially toxic materials, and other dangers. This requires skill and expertise as well as personal protection equipment to perform safely. Please also observe all precautions to avoid damaging the electronic components themselves from harm due to heat or static electricity discharge.

Suggested Order

For best results, solder components in a way that allows best access to the solder points without some parts getting in the way of connecting subsequent ones. For example:

1. Solder all the surface mount chips first: U0–U15 (and optionally, U16).
 - U0, U12, U13: CD74HCT238PWR
 - U1, U2, U14, U15: ULN2803CDWR (ULN2803A SOP-18 packages may be used if aligned to the top 18 pads, leaving the bottom two empty, if they have otherwise identical pinouts and characteristics)
 - U3–U10: STPIC6D595MTR
 - U11: THVD1439DR (Note that this chip is oriented 180° from the other chips on the board, with pin 1 to the lower right.)
 - If needed for your microcontroller (Arduino Due, usually), solder U16: AT24C256 EEPROM chip.
2. Solder the discrete resistors: R0–R7, R24–R50 (and optionally, R52 and R53). See below first to ensure the correct values are used for R24–R31 based on your choice of corresponding LEDs.
 - R0–R7, R35–50: 1K
 - R24, R29–R31: 300Ω
 - R25–R28: 360Ω
 - R32–R34: 10K

Part No.	Qty	Mouser	Description
	1		Printed circuit board rev 3.2.2
	1		Arduino Due or Mega 2560
C0–9,11,12	12	810-FA18X7R1H10400	0.1 μ F capacitor
C10	1	667-ECA-1HM100I	10 μ F electrolytic capacitor
D0–511	512		LED, 5mm, RGB, common cathode
D512	1		LED, 5mm, green
D513–14	2		LED, 5mm, yellow
D515–16	2		LED, 5mm, red
D517–18	2		LED, 5mm, blue
D519	1		LED, 5mm, white
J0	1		Arduino stacking pin set
J1	1		8-position Euro-style terminal block
J2,3	2		2-position jumper header
J4	1		3-position jumper header
P0–3	3		2-position jumper shunt
Q0–23	24	942-IRF9530NPBF	IRF9530 p-channel MOSFET
R0–7,35–51	24	604-MFR-24FRF521K	1K resistor
R8–23	16		4 \times 360 Ω resistor array, isolated
R24,29–31	4	603-MFR-25FTE52-300R	300 Ω resistor
R25–28	4		360 Ω resistor
R32–34,52–53	5	603-MFR-25FRF5210K	10K resistor
R _{TERM}	1		120 Ω resistor
U0,12,13	3	595-CD74HCT238PWR	CD74HCT238PWR non-inverting 3-to-8 decoder
U1,2,14,15	4		ULN2803CDWR octal NPN Darlington array
U3–10	8		STPIC6D595MTR power 8-bit shift register
U11	1		THVD1439 half-duplex RS-485 driver/receiver
U16	1		AT24C256 EEPROM
	24		TO-220 heat sinks for Q0–23 (optional)
	1		9V 2A DC power supply

Figure 1.1: Bill of Materials

- If U16 is installed, solder in R52–R53: 10K
3. Solder the 0.1 μ F capacitors: C0–C9, C11–C12.
 4. Solder the resistor arrays: R8–R23.
 5. Solder the RGB LEDs D0–D511. Ensure that the common cathode goes to pin 2 so that pins 1, 3, and 4 are respectively the red, green, and blue anodes.
 6. Solder the single-color LEDs D512–D519 in the colors of your choice, being mindful of the polarity. The anode has a square pin on the PCB. Our recommendation:
 - D512 (bottom): green (with R24=300 Ω)¹
 - D513: yellow (with R25=360 Ω)
 - D514: yellow (with R26=360 Ω)
 - D515: red (with R27=360 Ω)
 - D516: red (with R28=360 Ω)
 - D517: blue (with R29=300 Ω)
 - D518: blue (with R30=300 Ω)
 - D519 (top): white (with R31=300 Ω)
 7. **If you are using an Arduino Due:** solder R51 (1K).
 8. **If you are using an Arduino Mega 2560:** Solder the 10 μ F capacitor C10, being mindful of the correct polarity. **Do not solder both R51 and C10. Only one or the other will be appropriate for a given microcontroller.**
 9. Solder the Arduino bus stacking pins (six sets—1 \times 10-pin, 5 \times 8-pin—all labeled collectively at J0). Ensure the pins extend down and out the back of the board.
 10. Solder the 2-pin headers J2 and J3, and the 3-pin header J4.
 11. Solder the terminal block J1.

Option: Using Single-Color LEDs

If you don't need RGB LEDs for your application, the same PCB may be used with single-color 5mm LEDs instead. Simply solder them onto the board so that their cathode is on pin 2 and the anode is on pin 4 of the LED footprint. This means the LEDs will electrically all be connected to the blue circuit.

¹Resistor values based on typical LED voltage and current ratings. Check to see what is appropriate for your components.

Since they won't be used, omit parts U0, U2, U12, U14, C0, C11, Q0–Q15, R0–R7, and R35–R42.

Set the firmware value `HW_MODEL` to `MODEL_3xx_MONOCHROME` and recompile the firmware. This changes the behavior of the controller so that it understands it can only drive one color which is attached to the blue color plane. Now, all colors (other than “off”) will turn the LEDs on.

CHAPTER 2

PROTOCOL DESCRIPTION

I don't stand on protocol. Just call me
your Excellency.

—Henry Kissinger

THE CONTROL PROTOCOL used to display information on the readerboard sign is very simple. Commands are expressed largely in plain ASCII characters and are executed immediately as they are received.¹

In addition to plain, printable 7-bit ASCII characters, a few control codes are recognized as described below. String data may include any 8-bit value except as otherwise indicated.

Web Service API

The organization of the rest of this chapter is oriented toward a description of the protocol used to control the hardware directly over a USB or RS-485 connection. However, you can set up a central server which is connected to all the readerboard signs and busylight indicators in a small area (via USB or RS-485). This allows clients to send commands to the server over the network for control of the readerboards.

The protocol between clients and servers uses messages which are simple HTTP requests posted to the server's listening port URL. If the server were configured to run on `example.org` on port 43210, then all client requests to that server would begin with

`http://example.org:43210/readerboard/v1/<message>?a=<targets>`

¹Technically, they may even be executed *while* they are being received.

Message Data Fields

As a general rule, if a message expects a field that is not provided, a suitable “zero” value will be assumed for that field. Any extra fields sent that were not expected are silently ignored.

Boolean fields may have values `true` or `false`; if they are presented without a value, they are considered to be `true`, and if completely missing they are assumed to be `false`. Thus,

`.../readerboard/v1/<message>?a=<targets>&status=true`

is equivalent to

`.../readerboard/v1/<message>?a=<targets>&status`

and

`.../readerboard/v1/<message>?a=<targets>&status=false`

is equivalent to

`.../readerboard/v1/<message>?a=<targets>`

Message Target Addresses

Every message also has a field called “a” which is a comma-separated list of target readerboards to which the message applies.

So, for example, the message containing `a=2` would cause the server to transmit the corresponding command to the readerboard with address 2 directly connected to it via USB, or would transmit to the RS-485 network the command starting with the hex byte 92_{16} . (Why that byte value is sent will make sense after you read the protocol description that follows.)

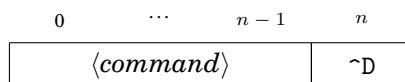
If multiple devices are targeted, e.g., with a message containing the field `a=2,5,37` with address 15 (i.e., $0F_{16}$) configured as the global address ad_G , it will transmit to the RS-485 network a command starting with the hex byte sequence $BF_{16} 03_{16} 02_{16} 05_{16} 25_{16}$.

USB vs. RS-485

The protocol used to send commands to the readerboard is different depending on whether the host is sending directly to a single readerboard over a USB cable, or to (possibly) multiple readerboards over an RS-485 bus network.

USB

A readerboard connected via USB accepts the commands just as documented below, with the addition that each such command is terminated by a `~D` byte (hex value 04_{16}).



If there is an error parsing or executing a command, the readerboard will ignore all subsequent input until a $\sim D$ is received, whereupon it will expect to see the start of another command. Thus, $\sim D$ may not appear in any transmitted data except to terminate commands.

Commands which contain arbitrary-size data fields, such as text strings or lists of LEDs to light in sequence, end such fields with a terminator byte. In most cases this may be either a dollar-sign (“\$”) character or the escape control character (hex byte $1B_{16}$), indicated in the protocol diagrams below simply as “\$”. In cases where a dollar-sign could be part of the data, then only an escape character may be used to terminate the field, in which case the protocol description will show the terminator as “ESC”.

RS-485

Commands sent over RS-485 are intended to target one or more of a set of connected readerboards over a network which may also contain other Lumos-protocol-compatible devices, so they adhere to a protocol that is also compatible with those devices.

Each command begins with one of the following binary headers, depending on the set of target readerboard signs which should obey the command.

Single Target or All Readerboards

To send a command to a single sign, begin with a single byte encoded as:

7	6	5	4	3	2	1	0
1	0	0	1	$\langle ad \rangle$			

where $\langle ad \rangle$ is the sign’s address on the bus, which must be a value in the range 0–15. This byte is followed by any command as described below. If the global address ad_G is given as the $\langle ad \rangle$ value, then all readerboards which have that set as their global address will obey the command.

Multiple Targets

Alternatively, a command may be targeted to multiple signs by starting the command with a multi-byte code:

7	6	5	4	3	2	1	0				
1	0	1	1	$\langle ad_G \rangle$							
0	0	$\langle n \rangle$									
0	0										
\vdots											
0	0	$\langle ad_{n-1} \rangle$									

where $\langle ad_G \rangle$ is the “global” device address which signals readerboards generally (see the = command below). This will send to the $\langle n \rangle$ devices addressed as $\langle ad_0 \rangle$ through $\langle ad_{n-1} \rangle$.

Note that device addresses are constrained to the range 0–15 if they are to be addressed in the command start byte. However, using the multiple target header, device addresses in the range 0–63 may be used.

Response Headers

For commands which send a response back to the computer, the RS-485 data stream begins with the header

7	6	5	4	3	2	1	0
1	1	0	1	$\langle ad \rangle$			

where $\langle ad \rangle$ is the device address of the responding unit if $\langle ad \rangle < 16$. For devices with higher-numbered addresses, the following extended format is used instead:

7	6	5	4	3	2	1	0
1	1	1	1	$\langle ad \rangle_G$			
0	1						
0	0	$\langle ad \rangle$					

All Off

As a special case, the single byte

7	6	5	4	3	2	1	0
1	0	0	0	$\langle ad \rangle$			

will cause the readerboard addressed as $\langle ad \rangle$ to turn off all LEDs. If $\langle ad \rangle$ is the ad_G address, then all readerboards will turn off all LEDs.

No other command bytes need to follow; this byte is sufficient to turn off the sign(s).

The corresponding HTTP message is `/readerboard/v1/alloff?a= $\langle ad \rangle$`

Subsequent Command Bytes

All subsequent bytes which follow the above binary headers *must* have their MSB cleared to 0.

To cover cases where a value sent as part of a command must have the MSB set, we use the following escape codes:

- A hex byte $7E_{16}$ causes the next byte received to have its MSB set upon receipt.
- A hex byte $7F_{16}$ causes the next byte to be accepted without any further interpretation.

Input Sequence	Resulting Byte
00	00
7D	7D
7F 7E	7E
7F 7F	7F
7E 00	80
7E 01	81
7E 7D	FD
7E 7E	FE
7E 7F	FF

Table 2.1: Examples of RS-485 Escape Bytes.

Thus, the byte $C4_{16}$ is sent as the two-byte sequence 7E 44, while a literal 7E is sent as 7F 7E and a literal 7F as 7F 7F.

If there is an error parsing or executing a command, the readerboard will ignore all subsequent input until a byte arrives with its MSB set to 1, whereupon it will expect to see the start of another command.

A few illustrative examples are shown in Table 2.1.

Command Summary

The eight discrete LEDs are intended for a simple display of status information in a manner analogous to the Busylight project by the same author.² To support this usage, the F, S, X, *, and ? commands are recognized in a manner compatible with how Busylight uses those same commands. These are categorized as “Busylight compatibility commands.” Unlike all other commands listed here, these are recognized regardless of case. Since the readerboard has a power supply capable of illuminating all of the status LEDs at once,³ a new command L is added which allows any arbitrary pattern of steady LEDs to be turned on.

The remaining commands are used for management of the matrix display. All commands are summarized in Table 2.2.

Although starting with the revision 2 hardware, the readerboard supports the ability to enable the RS-485 transmitter and send data back onto the network, this is not currently implemented by the firmware, and the intent is to have all devices listen passively to RS-485 traffic at all times. **This is expected to change with the next revision of the firmware which allows responding over the RS-485 network.**

²See github.com/MadScienceZone/busylight.

³The Busylight cannot, since it is powered from the host computer’s USB port.

Message	Cmd	Description	Notes
strobe	*	Strobe LEDs in Sequence	[1]
	?	Query discrete LED status	[1] [2] [4]
flash	F	Flash LEDs in Sequence	[1]
light	L	Light one or more LEDs steady	[3]
light	S	Light one LED steady	[1]
off	X	All LEDs off	[1]
	~D	Abort/terminate command	
test	%	Full lamp test	
scroll	<	Scroll text across display	
	=	Set operational parameters	[4]
move	@	Move current column cursor	
font	A	Select character font	
clear	C	Clear matrix display	
graph	H	Add histogram/bargraph data point	
bitmap	I	Draw bitmap graphic image	
color	K	Set current color	
	Q	Query matrix display status	[2] [4]
text	T	Display text on display	

[1] Busylight compatible command

[2] Sends response (USB only)

[3] Busylight extension (not in original Busylight)

[4] USB only

Table 2.2: Summary of All Commands

%—Run Full Lamp Test Pattern

$$\begin{array}{c} 0 \\ \boxed{\%} \end{array}$$

`/readerboard/v1/test?a=<ad>`

Displays various test patterns on the display to show that each element of each LED is working correctly individually and in concert with others.

While running the test pattern set, the device is not responsive to other inputs or background operations.

*—Strobe Lights in Sequence

$$\begin{array}{ccccccc} 0 & 1 & 2 & 3 & \cdots & n & n+1 \\ \boxed{*} & \boxed{\langle led_0 \rangle} & \boxed{\langle led_1 \rangle} & \boxed{\langle led_2 \rangle} & \cdots & \boxed{\langle led_{n-1} \rangle} & \boxed{\$} \end{array}$$

`/readerboard/v1/strobe?a=<ad>&l=<led0><led1>...<ledn-1>`

Code	Hex	Description
<code>^@</code>	00	Never allowed in strings (null byte)
<code>^C<pos></code>	03<pos>	Move current column cursor to <pos>
<code>^D</code>	04	Never allowed in strings (command terminator)
<code>^F<digit></code>	06<digit>	Switch current font
<code>^H<pos></code>	08<pos>	Move cursor left <pos> columns
<code>^K<rgb></code>	0B<rgb>	Change color to <rgb>
<code>^L<pos></code>	0C<pos>	Move cursor right <pos> columns
<code>^[</code>	1B	Never allowed in strings (string terminator)

Table 2.3: Control Codes in String Values

Each <led> value is an ASCII character corresponding to a discrete LED as shown in Table 2.9. An <led> value of “_” means there is no LED illuminated at that point in the sequence.

This command functions identically to the F command (see below), except that the lights are “strobed” (flashed very briefly with a pause between each light in the sequence).

<—Scroll Text Across Display

0	1	2	...	n+1	n+2
<	<loop>	<string>			ESC

/readerboard/v1/scroll?a=<ad>&loop=<bool>&t=<string>

Displays the text <string> by scrolling it across the display from right to left. If <loop> is “.”, the text is only scrolled once; if it is “L” then it repeatedly scrolls across the screen in an endless loop.

The text is rendered in the current font and may contain any 8-bit bytes except as otherwise noted (but avoiding ASCII control codes is wise to be safe from conflict with future control codes which may be added to the protocol). The string is terminated by an escape character (hex byte 1B₁₆), indicated in the protocol description as ESC.

The string may include control codes as listed in Table 2.3.

=—Set Operational Parameters

0	1	2	3	4
=	<ad>	<uspd>	<rspd>	<ad _G >

This command sets a few operational parameters for the sign. Once set, these will be persistent across power cycles and reboots.

Code	Speed
0	300
1	600
2	1,200
3	2,400
4	4,800
5	9,600 (default)
6	14,400
7	19,200
8	28,800
9	31,250
A	38,400
B	57,600
C	115,200

Table 2.4: Baud Rate Codes

If the $\langle ad \rangle$ parameter is “.” then the RS-485 interface is disabled entirely. Otherwise it is a value from 0–63 encoded as described in Table 2.5. This enables the RS-485 interface and assigns this sign’s address to $\langle ad \rangle$.

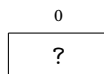
The baud rate for the USB and RS-485 interfaces is set by the $\langle uspd \rangle$ and $\langle rspd \rangle$ values respectively. Each is encoded as per Table 2.4.

The $\langle ad_G \rangle$ value is an address in the range 0–15 which is not assigned to any other device on the RS-485 network. This is used to signal that all readerboards should pay attention to the start of the command because it might target them either as part of a list of specific readerboards or because the command is intended for all readerboards at once. This is encoded in the same way as $\langle ad \rangle$. If you only have one readerboard or do not wish to assign a global address, just set $\langle ad_G \rangle$ to the same value as $\langle ad \rangle$.

This command may only be sent over the USB port.

By default, an unconfigured readerboard is set to 9,600 baud with the RS-485 port disabled, but these defaults may be changed when compiling the firmware for specific devices.

?—Query Discrete LED Status



This command causes the sign to send a status report back to the host to indicate what the discrete LEDs are currently showing. This response has the form:

0	1	2	3	4	5	6	7	8
L	$\langle led_0 \rangle$	$\langle led_1 \rangle$	$\langle led_2 \rangle$	$\langle led_3 \rangle$	$\langle led_4 \rangle$	$\langle led_5 \rangle$	...	$\langle led_{n-1} \rangle$
\$	F	flasher status (see below)						\$
S	strober status (see below)						\$	\n

Each $\langle led_x \rangle$ value is a single character which is “_” if the corresponding LED is off, or the LED’s color code or position number if it is on. One such value is sent for each LED installed in the sign (typically eight for reader-boards), followed by a “\$” to mark the end of the list.

The flasher and strober status values are variable-width fields which indicate the state of the flasher (see F command) and strober (see * command) functions. In each case, if there is no defined sequence, the status field will be:

0	1
$\langle run \rangle$	-

Otherwise, the state of the flasher or strober unit is indicated by:

0	1	2	3	4	...	$n+3$
$\langle run \rangle$	$\langle pos \rangle$	@	$\langle led_0 \rangle$	$\langle led_1 \rangle$	...	$\langle led_{n-1} \rangle$

In either case, $\langle run \rangle$ is the ASCII character “S” if the unit is stopped or “R” if it is currently running. If there is a defined sequence, $\langle pos \rangle$ indicates the 0-origin position within the sequence of the light currently being flashed or strobed, encoded as described in Table 2.5. The $\langle led_x \rangle$ values are as allowed for the F or * command that set the sequence. (Regardless of the actual F or * command parameters, the report will show symbolic color codes where possible, or numeric position codes otherwise.)

The status message sent to the host is terminated by a newline character (hex byte 0A), indicated in the protocol description above as “\n”.

This command may only be sent on the USB port.

@—Set Column Cursor Position

0	1
@	$\langle pos \rangle$

/readerboard/v1/move?a= $\langle ad \rangle$ &pos= $\langle pos \rangle$

Sets the column cursor position to the value indicated by $\langle pos \rangle$. See Table 2.5.

7	6	5	4	3	2	1	0
0	0	1	1	$\langle n \rangle \quad (n < 16)$			
0	1	$\langle n \rangle - 16 \quad (n \geq 16)$					

Value	Code	Value	Code
0–9	0–9	17–42	A–Z
10	:	43	[
11	;	44	\
12	<	45]
13	=	46	^
14	>	47	_
15	?	48	`
16	@	49–63	a–o

(Each code is the numeric value plus 48.)

Table 2.5: ASCII Encoded Integer Values (0–63)

Code	Font Description
0	Fixed-width 5×7 matrix plus descenders in 8th row
1	Variable-width version of font 0
2	Bold alphanumerics and special symbols

Table 2.6: Font Codes

A—Select Font

0	1
A	$\langle digit \rangle$

`/readerboard/v1/font?a= $\langle ad \rangle$ &idx= $\langle digit \rangle$`

Sets the font to use for rendering text with the < and T commands. The font codes for $\langle digit \rangle$ are listed in Table 2.6. The full text fonts support the printable ASCII characters plus a majority of the Unicode glyphs with codepoints less than 256. See Tables 2.7–2.8 for a complete font glyph listing with codepoint assignments.

C—Clear Matrix Display

0
C

`/readerboard/v1/clear?a= $\langle ad \rangle$`

Clears the matrix display so that no LEDs are illuminated. Does not affect the discrete LEDs.

	0	1	2	3	4	5	6	7	
00x				move	end		font		0x
01x	back			color	forw				
02x									
03x				esc					1x
04x		!	"	#	\$	%	&	'	
05x	(	)	*	+	,	-	.	/	2x
06x	0	1	2	3	4	5	6	7	
07x	8	9	:	;	<	=	>	?	3x
10x	@	A	B	C	D	E	F	G	
11x	H	I	J	K	L	M	N	O	4x
12x	P	Q	R	S	T	U	V	W	
13x	X	Y	Z	[	\	\]	^	_	5x
14x	'	a	b	c	d	e	f	g	
15x	h	i	j	k	l	m	n	o	6x
16x	p	q	r	s	t	u	v	w	
17x	x	y	z	{	|	}	~	///	7x
20x	“	”	‘	’	†	‡	...	'	
21x	”	!!	—	←	→	↑	↓	≠	8x
22x	≤	≥	≈	Γ	Δ	Ξ	Π	Σ	
23x	Ω	π	ρ	σ	—	‰			9x
24x		¡	¢	£	¤	¥	¦	§	
25x		©	ª	«	¬	-	®		Ax
26x	°	±	²	³		μ	¶	•	
27x		¹	º	»	¼	½	¾	¿	Bx
30x	À	Á	Â	Ã	Ä	Å	Æ	Ç	
31x	È	É	Ê	Ë	Ì	Í	Î	Ï	Cx
32x	Ð	Ñ	Ò	Ó	Ô	Õ	Ö	×	
33x	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß	Dx
34x	à	á	â	ã	ä	å	æ	ç	
35x	è	é	ê	ë	ì	í	î	ï	Ex
36x	ð	ñ	ò	ó	ô	õ	ö	÷	
37x	ø	ù	ú	û	ü	ý	þ	ÿ	Fx
	8	9	A	B	C	D	E	F	

Table 2.7: Font Table for Fonts #0 and #1

	0	1	2	3	4	5	6	7	
00x				move	end		font		0x
01x	back			color	forw				
02x									
03x				esc					1x
04x		!	□	■					
05x					,		.	thin .	2x
06x	0	1	2	3	4	5	6	7	
07x	8	9							3x
10x	©	A	B	C	D	E	F	G	
11x	H	I	J	K	L	M	N	O	4x
12x	P	Q	R	S	T	U	V	W	
13x	X	Y	Z						5x
14x	®	←	→	↑	↓	↖	↗	↘	
15x	✓	←	→	↑	↓	■	■		6x
16x	✓	✓	∞	Œ	œ	€	∴	∴	
17x	✕	◀	▶	▲	▼	↕	◆	◇	7x
20x	λ	Θ	Φ	Ψ	♂	♀	zero	zero	
21x	±	∓	⊕	⊙	≡	clover	notes		8x
22x	AM	PM	°F	°C					
23x	NM	WC	1Q	WG	FM	WG	3Q	WC	9x
24x		TS1	TS2	TS3	TS4	TS5	TS6	TS7	
25x	TS8								Ax
	8	9	A	B	C	D	E	F	

TS(*n*) = Thin space of *n* pixels

Table 2.8: Font Table for Font #2

F—Flash Lights in Sequence

0	1	2	3	...	<i>n</i>	<i>n</i> + 1
F	<i>led</i> ₀	<i>led</i> ₁	<i>led</i> ₂	...	<i>led</i> _{<i>n</i>-1}	\$

/readerboard/v1/flash?a=<ad>&l=<led₀><led₁><led₂>...<led_{*n*-1}>

Each *led* value is an ASCII character corresponding to a discrete LED as shown in Table 2.9. Note that the assignment of colors to these LEDs is dependent on your particular hardware being assembled that way. As an open source project, of course, you (or whomever assembled the unit) may choose any color scheme you like when building the board.

An *led* value of “_” means there is to be no LED illuminated at the corresponding position in the sequence.

Up to 64 *led* codes may be listed. The sign will cycle through the sequence, lighting each specified LED briefly before moving on to the next

Code*	Light	Color
W	L ₇	white
B	L ₆	blue
b	L ₅	blue
R	L ₄	red
r	L ₃	red
Y	L ₂	yellow
y	L ₁	yellow
G	L ₀	green
—	—	(no LED/off)
0–9	L ₀ –L ₉	LED installed at physical position 0–9

*If a sign is built with different colors in these positions, the letter codes for those LEDs will match the custom color arrangement for that sign.

(Custom firmware modification required.)

Table 2.9: Discrete LED Codes and Colors

one. The sequence is repeated forever in a loop until an L, S or X command is received.

If only one $\langle led \rangle$ is specified, that light will be flashed on and off. Setting an empty sequence (no codes at all) stops the flasher’s operation.

The sequence is terminated by either a dollar-sign (“\$”) character or the escape control character (hex byte 1B₁₆), indicated in the protocol diagram above simply as “\$”.

This command may be given in upper- or lower-case (“f” or “F”).

H—Draw Bar Graph Data Point

0

1

H

$\langle n \rangle$

0

1

2

3

4

5

6

7

H

K

$\langle rgb_0 \rangle$

$\langle rgb_1 \rangle$

$\langle rgb_2 \rangle$

$\langle rgb_3 \rangle$

$\langle rgb_4 \rangle$

$\langle rgb_5 \rangle$

$\langle rgb_6 \rangle$

$\langle rgb_7 \rangle$

0

1

2

3

4

5

6

7

H

K

$\langle rgb_0 \rangle$

$\langle rgb_1 \rangle$

$\langle rgb_2 \rangle$

$\langle rgb_3 \rangle$

$\langle rgb_4 \rangle$

$\langle rgb_5 \rangle$

$\langle rgb_6 \rangle$

$\langle rgb_7 \rangle$

This command is used to draw a bar-graph element. Repeating this command causes a scrolling data display which shows a set of data samples over some period of time.

In the simplest form, it takes a single byte parameter. The value $\langle n \rangle$ is an ASCII digit character in the range “0”–“8”, and is drawn in the far-right column of the matrix display, as a column of $\langle n \rangle$ lights stacked up from the

bottom row (a value of 0 results in no lights, up to 8 which is a full column of eight lights; a value of 9 is treated as if it were 8). All existing matrix data are scrolled left one column.

In the second form, it takes eight $\langle rgb \rangle$ values (see Table 2.11) which give the color to light up each row in the bar-graph column. For consistency with other drawing commands, $\langle rgb_0 \rangle$ refers to the topmost LED in the column.

In HTTP, the value of $\langle n \rangle$ is sent as an integer value.

I—Draw Bitmap Image

0	1	2	3	4	5	6	7	
I	$\langle merge \rangle$	$\langle pos \rangle$	$\langle trans \rangle$	$\langle R coldata_0 \rangle$	$\langle R coldata_1 \rangle$			...
$\langle R coldata_{n-1} \rangle$	\$	$\langle G coldata \rangle \dots$	\$	$\langle B coldata \rangle \dots$	\$	$\langle flashdata \rangle \dots$	\$	
$\langle flashdata \rangle \dots$	\$							

```

/readerboard/v1/bitmap?a= $\langle ad \rangle$ &merge= $\langle bool \rangle$ &pos= $\langle pos \rangle$ 
&trans= $\langle trans \rangle$ &image= $\langle R coldata \rangle \dots \$ \langle G coldata \rangle \dots \$ \langle B$ 
                         $coldata \rangle \dots \$ \langle flashdata \rangle$ 

```

Draws an arbitrary bitmap image onto the matrix display starting at column $\langle pos \rangle$, encoded as per Table 2.5. A $\langle pos \rangle$ value of “~” represents the current column cursor position.

Each column data, from left to right, are given by $\langle coldata \rangle$ values, each of which is a two-digit ASCII hexadecimal value with the least-significant bit representing the top row of the matrix.

The column data values are terminated by either a dollar-sign (“\$”) character or the escape control character (hex byte 1B₁₆), indicated in the protocol diagram above simply as “\$”.

They may be short (or entirely empty if the corresponding color plane has no pixels set).

The first set of column data provide the bits for the red color plane. After the terminating byte (\$ or ESC), two more sets of column data are sent, each with identical format to the first, to provide the bits for the green and blue color planes, respectively. The final plane, $\langle flashdata \rangle$, causes the corresponding pixel to flash for any bits set to 1. Monochrome boards accept only two color bitplanes: the bitmap of pixels to light and then the flash plane.

The column cursor is moved to be after the end of the image.

If $\langle merge \rangle$ is the character “.” then each column’s contents is cleared before setting the pixels as per the $\langle coldata \rangle$ value. If $\langle merge \rangle$ is “M” the bits set in $\langle coldata \rangle$ are added to the lit pixels already in the column.

The $\langle trans \rangle$ value indicates the transition effect to use when adding the image to the display. See Table 2.10.

Code	Transition
.	No transition
>	Scroll in from left
<	Scroll in from right
^	Scroll up from bottom
v	Scroll down from top
L	wipe left
R	wipe right
U	wipe up
D	wipe down
|	wipe left and right from middle column
-	wipe up and down from middle row
?	choose a random transition

Table 2.10: Transition Effect Codes

7	6	5	4	3	2	1	0
0	0	1	1	<i>flash</i>	<i>blue</i>	<i>green</i>	<i>red</i>

Code	Color	Code	Color
0	off	8	off
1	red	9	flashing red
2	green	:	flashing green
3	yellow	;	flashing yellow
4	blue	<	flashing blue
5	magenta	=	flashing magenta
6	cyan	>	flashing cyan
7	white	?	flashing white

Table 2.11: Color codes for *rgb* parameters

K—Set Current Color

0	1
K	<i>rgb</i>

/readerboard/v1/color?a=*ad*&color=*rgb*

This command sets the color which all future commands will use by default (although some of them allow for the specification of colors directly on an *ad hoc* basis, which does not affect the current default color).

The *rgb* value is a value encoded as defined in Table 2.11. Note that anything drawn in black simply turns off the corresponding pixels.

L—Light Multiple LEDs

0	1	2	3	...	n	$n + 1$
L	$\langle led_0 \rangle$	$\langle led_1 \rangle$	$\langle led_2 \rangle$	...	$\langle led_{n-1} \rangle$	\$

`/readerboard/v1/light?a= $\langle ad \rangle$ &l= $\langle led_0 \rangle \langle led_1 \rangle \langle led_2 \rangle \dots \langle led_{n-1} \rangle$`

This command is identical to the S command (see below), except that multiple discrete LEDs can be specified, all of which are illuminated simultaneously. See Table 2.9. Note that if a strobe sequence is running (via a previous * command), it remains running.

The list of $\langle led \rangle$ values is terminated by either a dollar sign (\$) character or an escape byte (hex value 1B), represented in the protocol diagram as “\$”.

Q—Query Readerboard Status

0
Q

This command causes the sign to send a status report back to the host to indicate the general status of the device except for the discrete LED display which may be queried using the ? command. The response has the form:

0	1	2	3	4	5	6	7	8
Q	$\langle model \rangle$	=	$\langle ad \rangle$	$\langle uspd \rangle$	$\langle rspd \rangle$	$\langle ad_G \rangle$	$\langle EE \rangle$	\$
V	$\langle hwversion \rangle$		\$	R	$\langle romversion \rangle$		\$	S
$\langle serial \rangle$	\$	M	$\langle R coldata_0 \rangle$	...	$\langle R coldata_{63} \rangle$			\$
$\langle G coldata_0 \rangle$	...		$\langle G coldata_{63} \rangle$		\$	$\langle B coldata_0 \rangle$...	
$\langle B coldata_{63} \rangle$		\$	$\langle flashdata_0 \rangle$	...	$\langle flashdata_{63} \rangle$			\$
\n								

The $\langle model \rangle$ field may be “L” for the legacy hardware the author still has lying around (but this shouldn’t be something anyone else would need to see), “M” for 64×8 matrix display hardware with monochrome LEDs, or “C” for 64×8 RGB color display boards.

$\langle hwversion \rangle$ and $\langle romversion \rangle$ indicate the versions, respectively, of the hardware the firmware was compiled to drive, and of the firmware itself. Each of these fields are variable-width and conform to the semantic version standard 2.0.0.⁴ Each is terminated by a dollar-sign (\$) character (and thus those strings may not contain dollar signs).

⁴See semver.org.

The $\langle serial \rangle$ field is a variable-width alphanumeric string which was set when the firmware was compiled. It should be a unique serial number for the device (although that depends on some effort on the part of the person compiling the firmware to insert that serial number each time). Serial numbers RB000–RB299 are reserved for the original author’s use. This string is also terminated with a dollar sign.

The $\langle EE \rangle$ field is “x” if the device is fitted with an external EEPROM chip or module, “I” if using the EEPROM memory on the Arduino controller board, or “_” if there is no EEPROM memory at all (and thus, configuration settings made with the = commaand are not persistent).

The $\langle coldata \rangle$ bytes are sent just as with the I command, as hexadecimal values indicating the LEDs lit on the matrix display, with $\langle coldata_0 \rangle$ being the leftmost column of the display and $\langle coldata_{63} \rangle$ being the rightmost. In each column, the least significant bit indicates the LED on the top row.

Note that monochrome boards only send a single color plane of data plus the flash plane.

The $\langle ad \rangle$, $\langle ad_G \rangle$, $\langle uspd \rangle$, and $\langle rspd \rangle$ values are as last set by the = command (or the factory defaults if they were never changed).

The status message sent to the host is terminated by a newline character (hex byte 0A₁₆), indicated in the protocol description above as “\n”.

Busylight Device Query Response

If a dedicated (non-readerboard) busylight device is sent the Q command, it responds with the following information.

0	1	2	3	4	5	6	7	8
Q	B	=	$\langle ad \rangle$	$\langle uspd \rangle$	$\langle rspd \rangle$	$\langle ad_G \rangle$	I	\$
V	$\langle hwversion \rangle$		\$	R	$\langle romversion \rangle$		\$	S
$\langle serial \rangle$	\$	\n						

For Busylight devices, serial numbers B000–B299 are reserved for use by the original author.

S—Light Single LED

0	1
S	$\langle led \rangle$

/readerboard/v1/light?a= $\langle ad \rangle$ &l= $\langle led \rangle$

Stops the flasher (cancelling any previous F command) and turns off all discrete LEDs. The single LED indicated by $\langle led \rangle$ is turned on. See Table 2.9. Note that if a strobe sequence is running (via a previous * command), it remains running.

This command may be given in upper- or lower-case (“s” or “S”).

T—Display Text

0	1	2	3	4	...	n+4
T	<i>merge</i>	<i>align</i>	<i>trans</i>	<i>string</i>		ESC
<i>/readerboard/v1/text?a=ad&merge=bool &align=align&trans=trans&t=string</i>						

Displays the text *string* at the current cursor position. The cursor position is then moved past the text to be ready for the next string to be printed.

The *align* code indicates how the text is aligned on the display (TBD).
Not currently implemented.

The *trans* code specifies the transition effect to be used to add this string to the display as shown in Table 2.10.

The text is rendered in the current font and may contain any 8-bit bytes except as otherwise noted (but avoiding ASCII control codes is wise to be safe from conflict with future control codes which may be added to the protocol). The string is terminated by an escape character (hex byte 1B), indicated in the protocol description as ESC. (Since a dollar sign may appear in *string*, the terminator must be an escape character for this command.)

The string may include control codes as listed in Table 2.3.

X—Turn off Discrete LEDs

0
X

/readerboard/v1/off?a=ad

Turns off the flasher, strober, and all discrete LEDs.
This command may be given in upper- or lower-case (“x” or “X”).

SERVER-ONLY COMMANDS

The enjoyment of one's tools is
an essential ingredient of
successful work.

—Donald E. Knuth

FOR THE MOST PART the server exists as a way to host readerboards and busylights from a central machine while allowing users on other networked machines to post messages to them. It also provides a solution to the lack of an ability for signs to coordinate content with each other. If you use the server's API to tell a set of target signs to change their display contents, that will change whatever the sign was doing to what you are now telling it to do, even if other users had put their own messages on it.

This chapter describes server-side coordination between users in a network environment by providing a set of commands which clients can post to the server to request information to be displayed for them alongside other content other users have posted. It also provides some services to keep boards updated with information known to the server which the devices don't themselves track, such as time of day.

post—Post a Message to the Displays

```
/readerboard/v1/post?a=<ad>&t=<text>&id=<id>&trans=<trans>
&until=<datetime>&hold=<duration>&color=<rgb>&repeat=<schedule>
```

Adds a text message to the display list. The message may include the special tokens listed in Table 3.1. The server will maintain the list of posted

Code	Description
{big}	Display letters and numbers in large font
{date}	Date as “ <i><dd>-<mmm>-<yyyy></i> ”
{normal}	Stop displaying numbers in large font
{mdy}	Date as “ <i><mm>/<dd>/<yyyy></i> ”
{pom}	Phase of the moon (as a symbol)
{time12}	Time as “ <i><hh>:<mm></i> AM/PM” on 12-hour clock
{time24}	Time as “ <i><hh>:<mm></i> ” on 24-hour clock
{ymd}	Date as “ <i><yyyy>-<mm>-<dd></i> ”
{ <i><name></i> }	User variable <i><name></i>
{	Literal “{”
}	Literal “}”

Table 3.1: Special Codes in Post Messages

images and will update the devices as needed to display dynamic content.

If any lower-level display matrix commands are received that directly manipulate the matrix, the display of posted messages is suspended in favor of the directly set content. When a `clear` command is received, then display of the posted message list will resume.

The *<id>* value must be unique but the server doesn’t assign these in order to keep the API simple. Thus, it is recommended that you assign these as UUIDs or other scheme to keep them from colliding.

If `trans` is given, this message will be introduced using the specified transition effect.

If `until` is given, the message will automatically unpost when the specified date and time is reached.

If `hold` is given, the message will remain on-screen for the specified time duration before moving on to the next posted message.

If `color` is given, the current color will be changed to the specified value before writing the message; otherwise (or additionally) color codes may be added in-line in the message text.

If `repeat` is given, *<schedule>* specifies (in a way yet to be determined) a repeating display schedule for this message (e.g., display this every hour on the hour).

unpost—Remove a Posted Message

```
/readerboard/v1/unpost?a=<ad>&id=<id>
```

Remove the message with the given *<id>* from the display list.

update—Update Dynamic Content

`/readerboard/v1/update?<name0>=<value0>&<name1>=<value1>...`

For each *<name>* and *<value>* pair, define or update the corresponding user variable (usable in posted messages as `{${<name>}}`). The updated value will be displayed from this point until it is updated again.

PINOUTS

No cord or cable can draw so
forcibly, or bind so fast, as love
can do with a single thread.

—Robert Burton

THIS CHAPTER DESCRIBES each connector used by the readerboard devices and what signals are present on which pins. Note that this begins with the current hardware revision, which is most likely the only part you need to know about. Following that are the connector descriptions for older, legacy versions of the hardware. Be careful to know which version you need to refer to.

Connectors for Version 3.3 Boards

Arduino Bus Connectors [J0]

Two parallel rows of stacking pins, for a total of 50 pins, extend out of the back of the readerboard PCB. An Arduino Mega 2560 or Due microcontroller board is connected to these pins.

The USB connector on the Arduino board may be used to directly connect the readerboard to a PC for initial configuration and/or to use it as a directly-connected singleton device. (If there are multiple devices in use, it may be preferable to switch to the RS-485 network after initial configuration of the device.)

Power / RS-485 (8-pin terminal) [J1]

The single external connector on version 3.3.0 boards is an 8-pin screw terminal block. This accepts a +9 V DC power input and ground on pins 8 and 7 respectively, which powers the entire board and the attached Arduino controller. If RS-485 communications will be used, the incoming signal is received on pins 1, 2, and 6 while the outgoing signal is on pins 3, 4, and 5. (In actuality, the “input” and “output” sense is arbitrary and either set of A and B signals may be used as input or output.)

If this device is the last in the RS-485 network chain, insert a 120 Ω resistor between the A and B terminals that would have been used as the output if there had been another device connected there. This properly terminates the RS-485 network at that point.

1	A (Data in +)	5	GND
2	B (Data in –)	6	GND
3	A (Data out +)	7	GND
4	B (Data out –)	8	+9 V DC in

The pinout of J1 for revision 3.2.2 boards is different:

1	A (Data in +)	5	GND
2	B (Data in –)	6	GND
3	+9 V DC in	7	A (Data out +)
4	GND	8	B (Data out –)

Connectors for Legacy Boards**Connectors for Version 2.1 Boards****Power / RS-485 (8-pin terminal) [J0]**

This is wired the same as J1 on the revision 3.2 boards.

Earlier Boards**Matrix Control (24-pin ribbon cable) [J1]**

For readerboards before version 2.1.0, this 24-position ribbon cable carries signals to directly drive the 64 \times 8 LED matrix. The other end of this cable mates with J0 on the shield board. The pinout of its IDC header is:

1	D6	7	RCLK	13	+5 V DC	19	Gnd
2	D5	8	D2	14	+5 V DC	20	Gnd
3	D7	9	\overline{G}	15	+5 V DC	21	R2
4	D4	10	D1	16	+5 V DC	22	REN
5	SRCLK	11	\overline{SRCLR}	17	Gnd	23	R1
6	D3	12	D0	18	Gnd	24	R0

Discrete LEDs (10-pin ribbon cable) [J2]

2 ... 10



1 ... 9

For readerboards before version 2.1.0, this 10-position ribbon cable carries signals to directly drive the 64×8 LED matrix. The other end of the cable mates with J1 on the shield board. The pinout of its IDC header is:

1	GND	6	L6
2	GND	7	L2
3	L0	8	L5
4	L7	9	L3
5	L1	10	L4

Board Power (3-pin screw terminal) [J0]

This 3-position screw terminal block provides power to the readerboard. Note that the +5 V supply is also connected to pins 13–16, and Ground to pins 17–20 of J1, the only power required here is the +9 V input that drives the LEDs themselves.

1	+5 V DC in
2	GND
3	+9 V DC in

Shield Power (5-pin screw terminal) [Shield J2]

This 5-position screw terminal block accepts incoming +9 V DC power and ground on pins 4 and 3 respectively. It then provides +5 V DC, +9 V DC, and ground outputs on pins 1, 2, and 5 respectively to supply power to the main display board.

1	+5 V DC out
2	GND
3	GND
4	+9 V DC in
5	+9 V DC out

Shield RS-485 (6-pin screw terminal) [Shield J4]

This 6-position screw terminal block accepts incoming RS-485 signals A, B, and ground on pins 2, 1, and 3 respectively, and outputs the network signals A, B, and ground on pins 6, 5, and 4 respectively, to go on to the next device in the chain. If this is the last device, then nothing should be connected to pins 5 and 6. Instead, install jumper J5 which connects a 120Ω resistor across those terminals to terminate the network at that point.

- | | |
|---|----------------|
| 1 | B (Data In −) |
| 2 | A (Data In +) |
| 3 | GND |
| 4 | GND |
| 5 | B (Data Out −) |
| 6 | A (Data Out +) |

CHAPTER



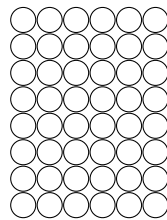
INSTALLING THE READERBOARD UNIT

CHAPTER
6

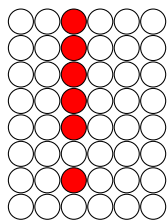
USING THE READERBOARD

FONT GLYPHS

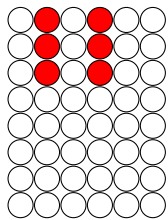
Font #0 standard.font



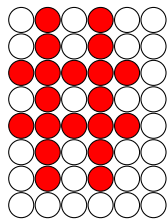
32 space



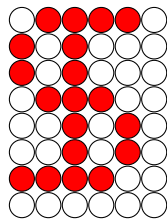
33 exclamation



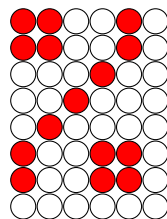
34 quotation mark



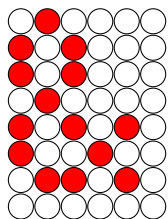
35 pound sign



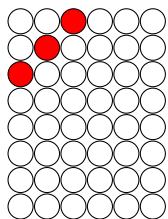
36 dollar sign



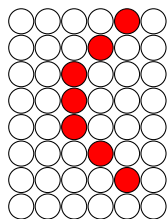
37 percent



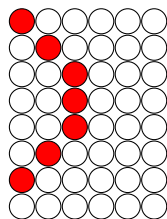
38 ampersand



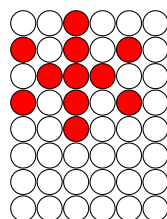
39 apostrophe



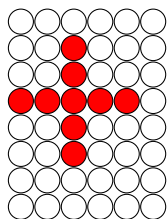
40 left paren



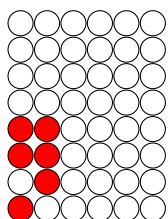
41 right paren



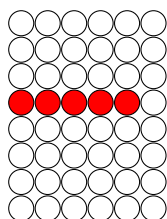
42 asterisk



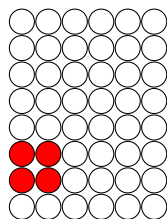
43 plus



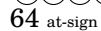
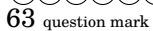
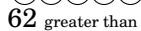
44 comma

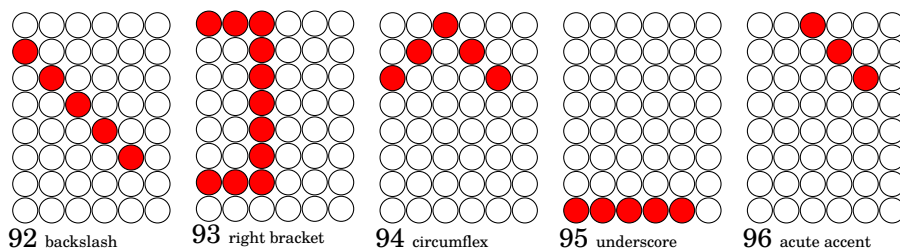
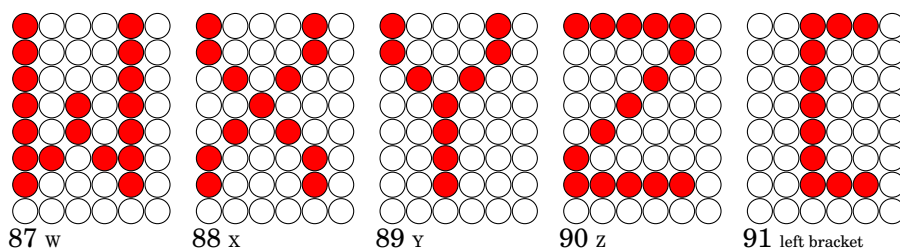
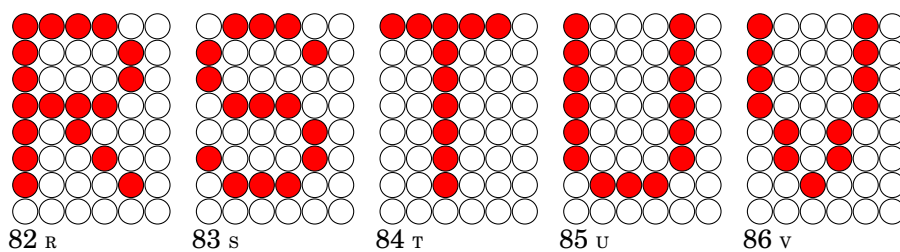
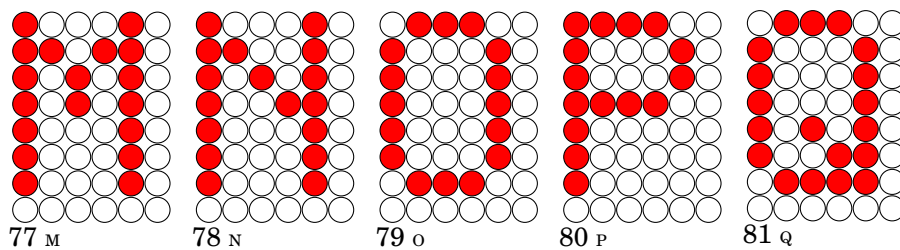
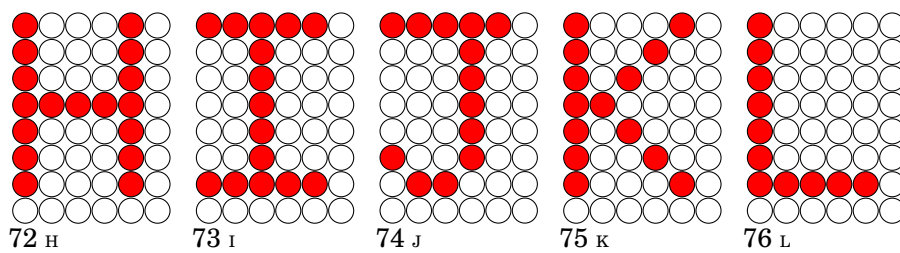


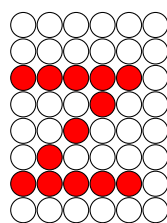
45 minus



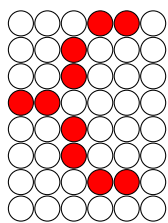
46 period



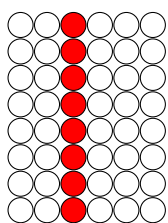




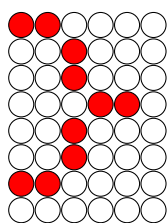
122 z



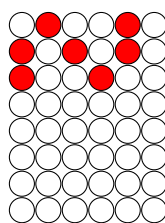
123 open brace



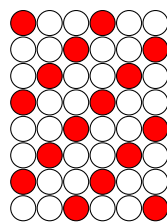
124 vertical bar



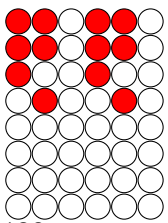
125 close brace



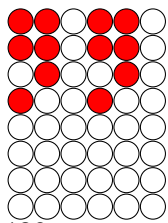
126 tilde



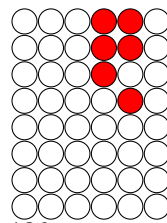
127 delete



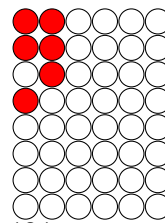
128 open dbl quote



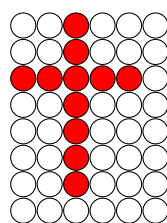
129 close dbl quote



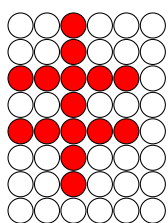
130 open sgl quote



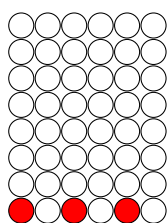
131 close sgl quote



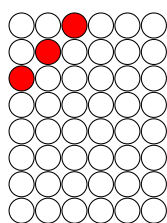
132 dagger



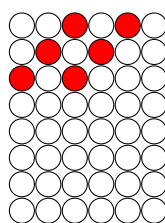
133 double dagger



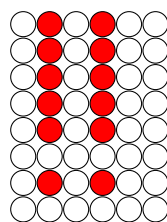
134 ellipsis



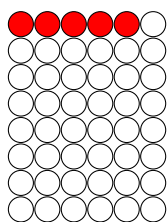
135 prime



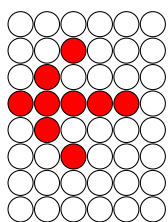
136 double prime



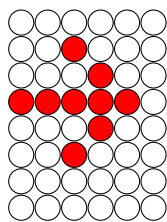
137 double !



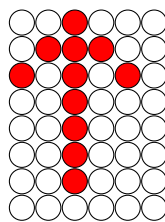
138 overline



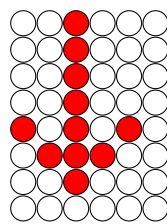
139 left arrow



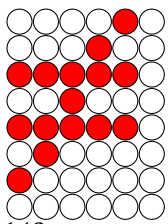
140 right arrow



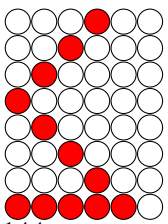
141 up arrow



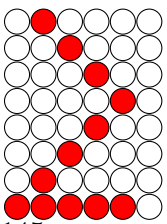
142 down arrow



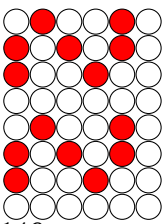
143 not equals



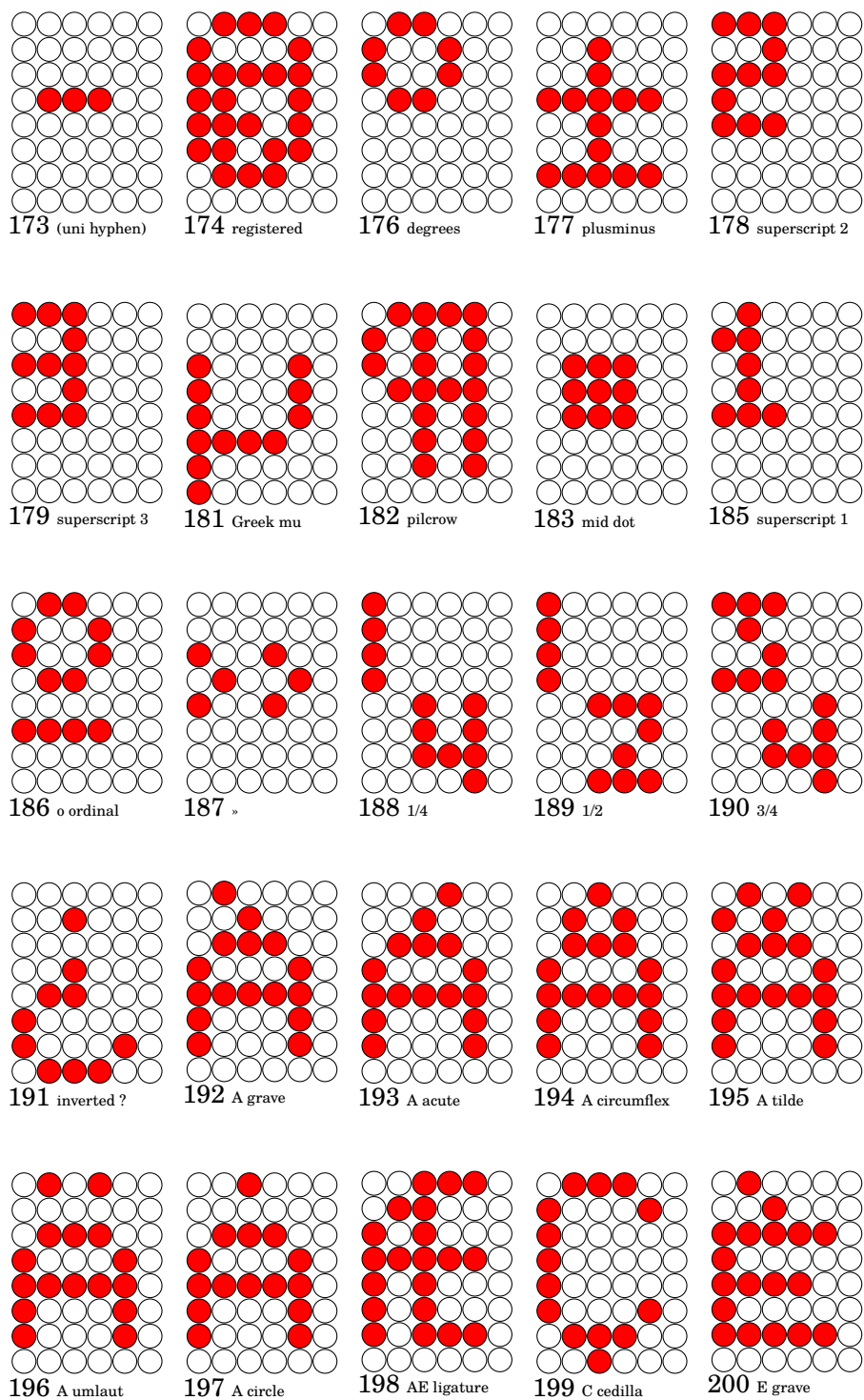
144 less or equal

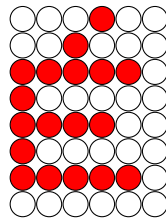


145 greater/equal

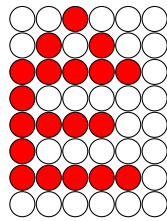


146 approximation

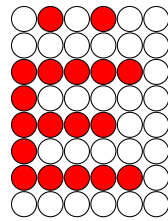




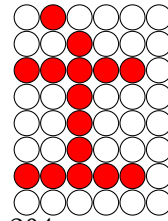
201 E acute



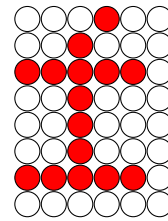
202 E circumflex



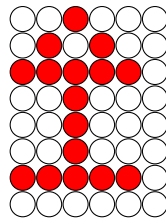
203 E umlaut



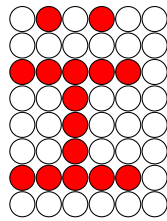
204 I grave



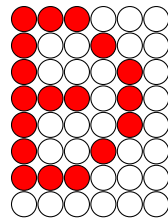
205 I acute



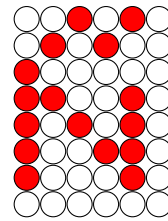
206 I circumflex



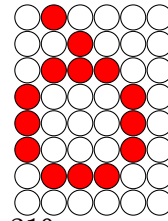
207 I umlaut



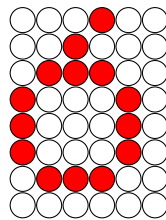
208 eth



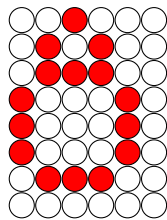
209 N tilde



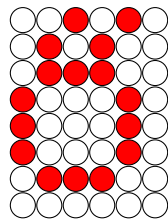
210 O grave



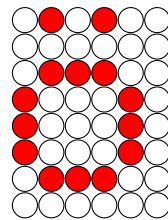
211 O acute



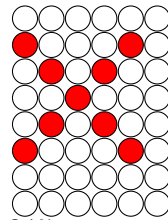
212 O circumflex



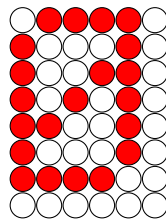
213 O tilde



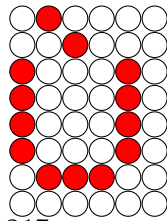
214 O umlaut



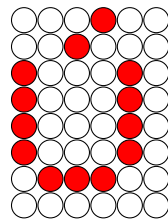
215 multiplication



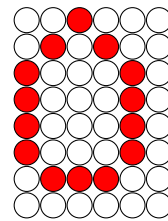
216 slashed O



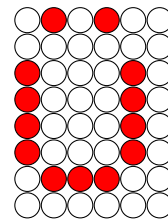
217 U grave



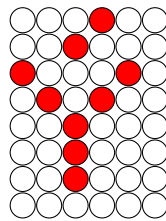
218 U acute



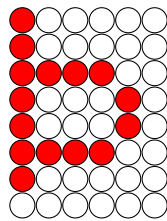
219 U circumflex



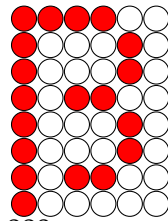
220 U umlaut



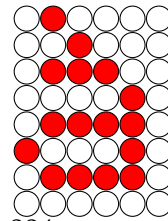
221 Y acute



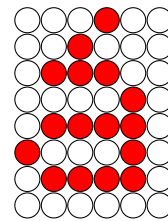
222 thorn



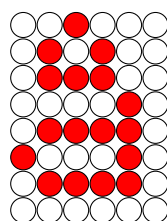
223 sharp S



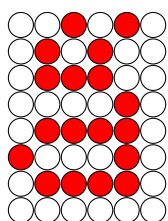
224 a grave



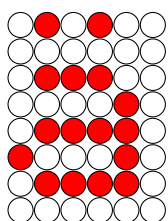
225 a acute



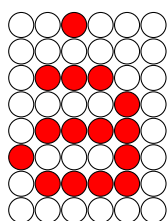
226 a circumflex



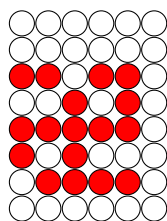
227 a tilde



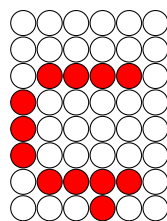
228 a umlaut



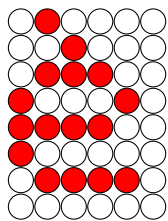
229 a circle



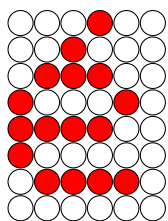
230 ae ligature



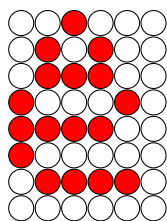
231 c cedilla



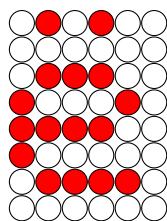
232 e grave



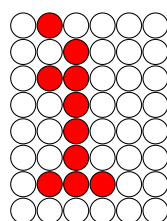
233 e acute



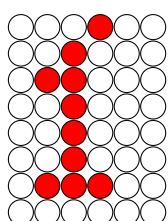
234 e circumflex



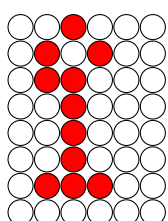
235 e umlaut



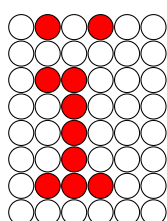
236 i grave



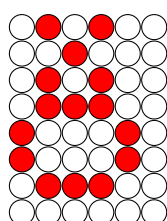
237 i acute



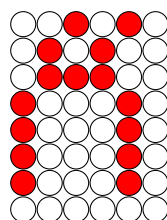
238 i circumflex



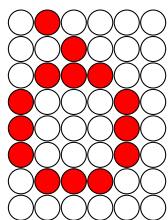
239 i umlaut



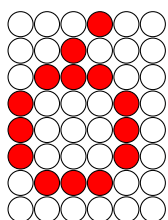
240 eth



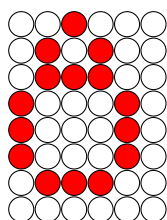
241 n tilde



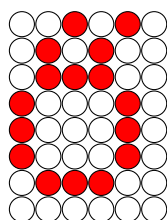
242 o grave



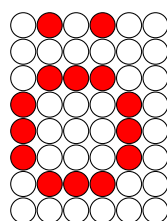
243 o acute



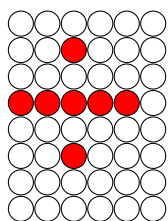
244 o circumflex



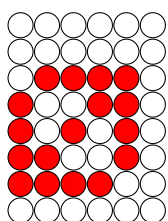
245 o tilde



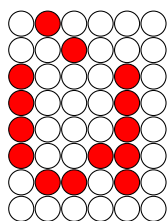
246 o umlaut



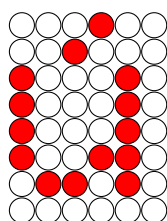
247 division sign



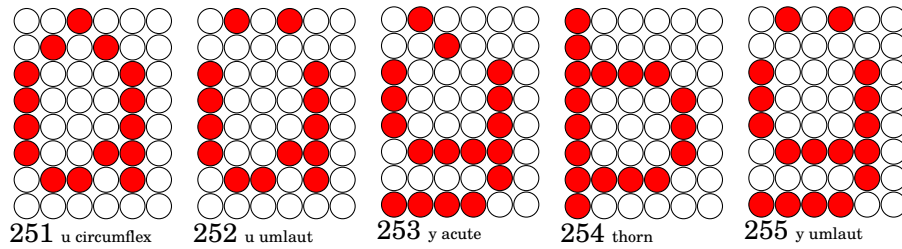
248 slashed o



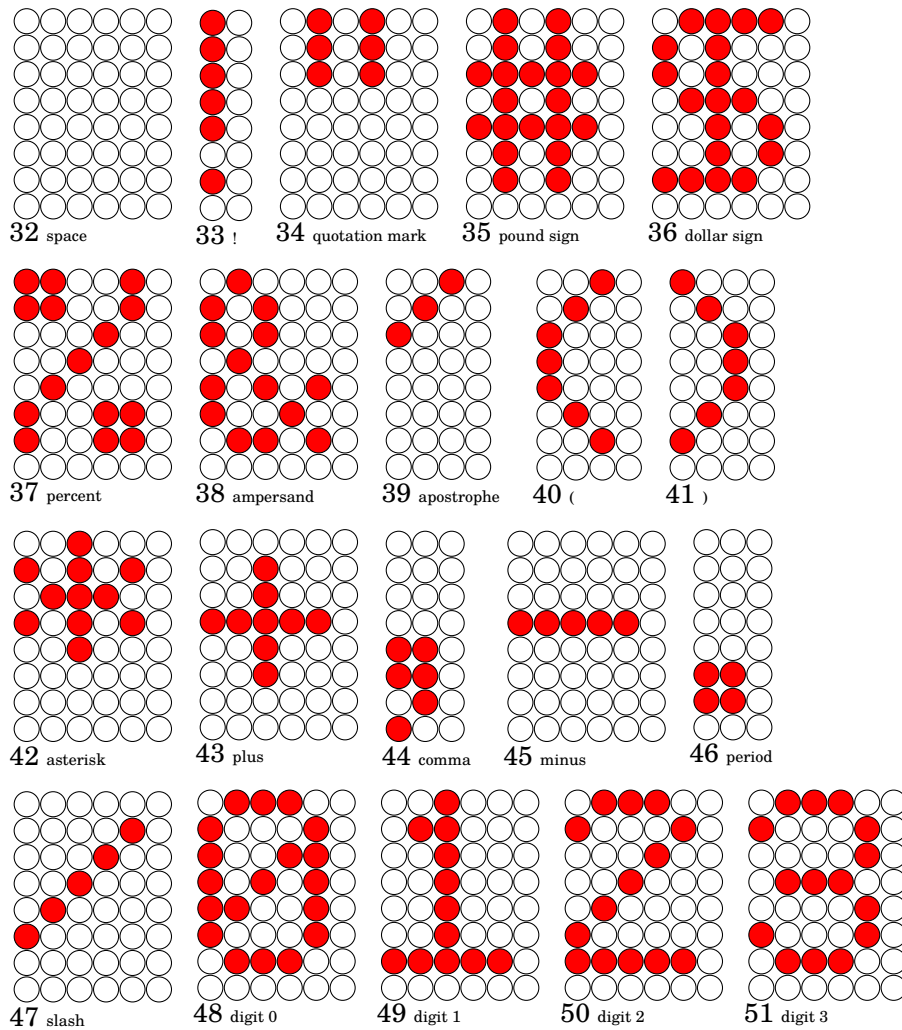
249 u grave

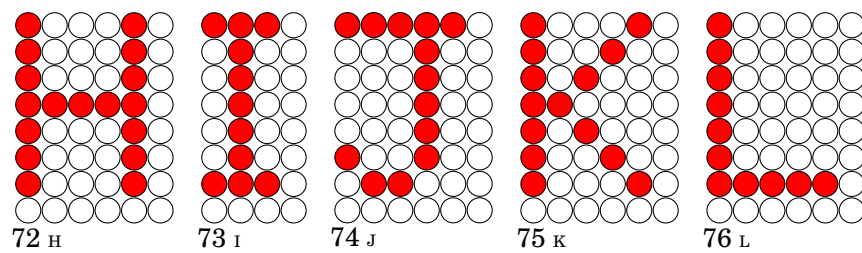
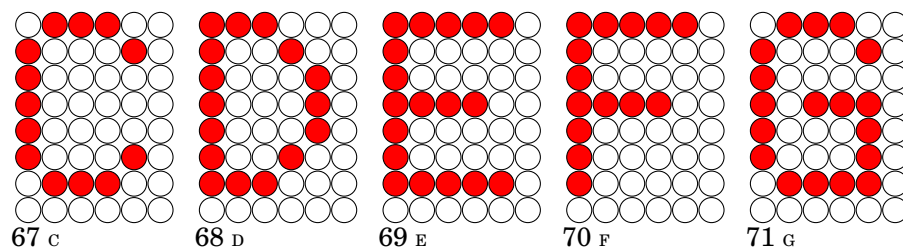
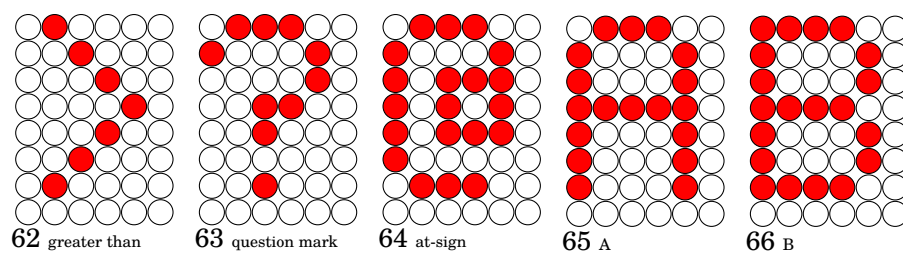
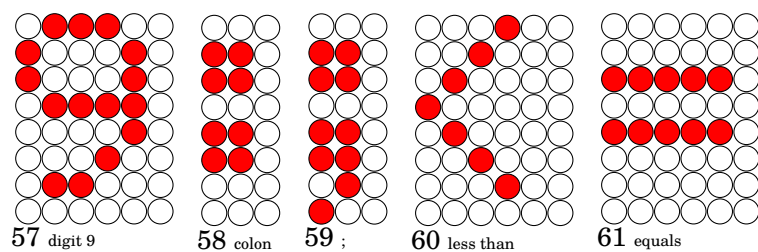
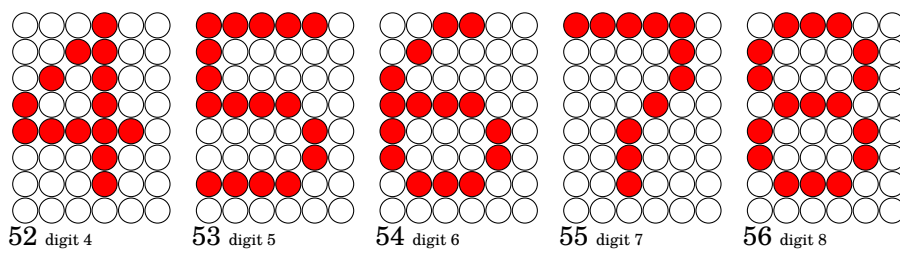


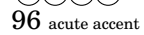
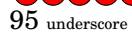
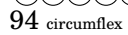
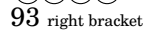
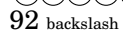
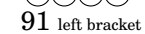
250 u acute

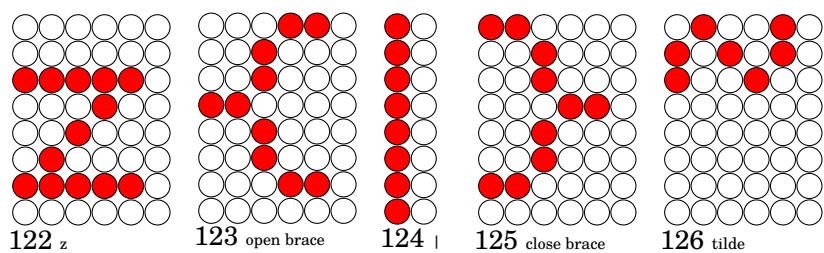
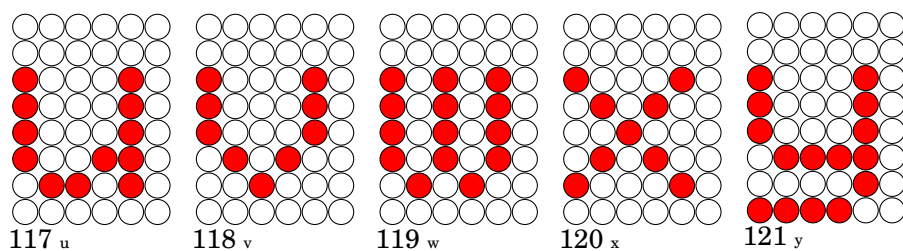
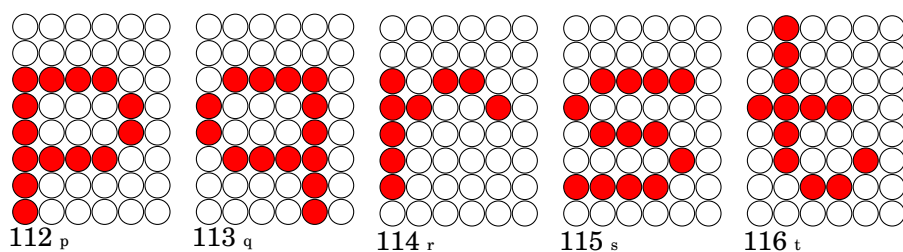
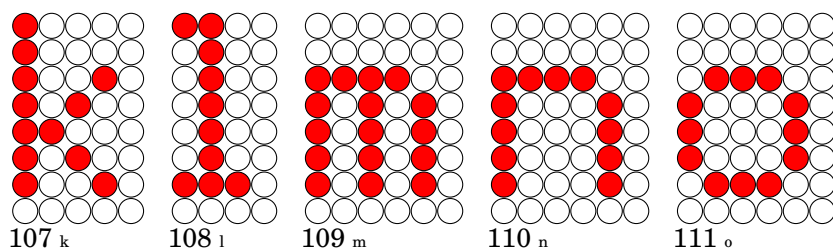
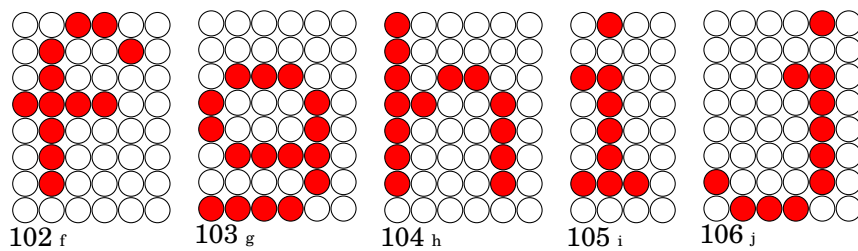


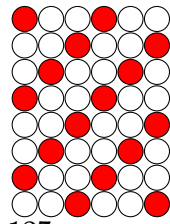
Font #1 standard_variable.font



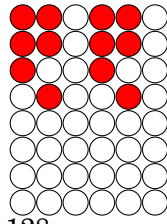




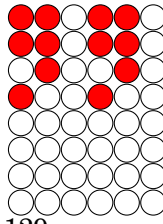




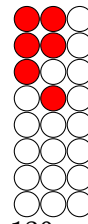
127 delete



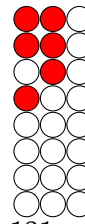
128 open dbl quote



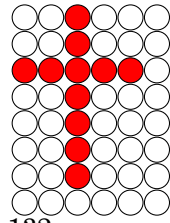
129 close dbl quote



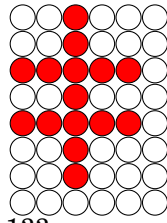
130 ' ,



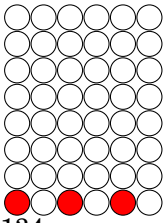
131 ' ,



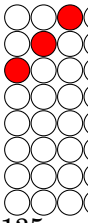
132 dagger



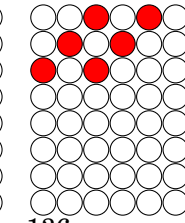
133 double dagger



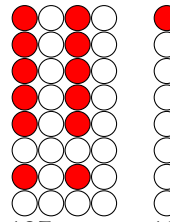
134 ellipsis



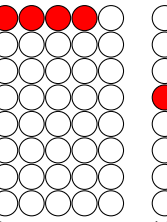
135 prime



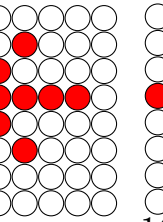
136 double prime



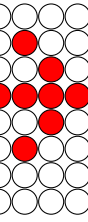
137 double !



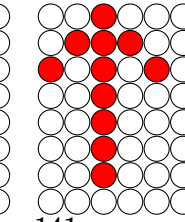
138 overline



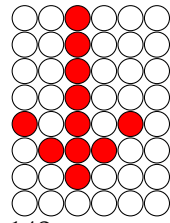
139 left arrow



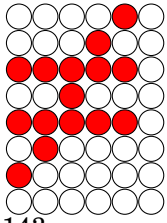
140 right arrow



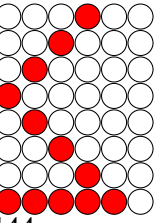
141 up arrow



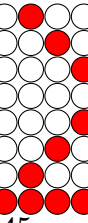
142 down arrow



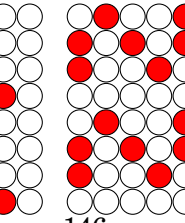
143 not equals



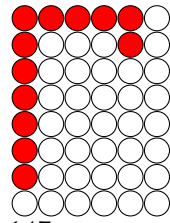
144 less or equal



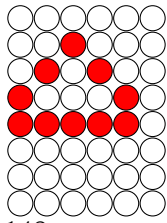
145 greater/equal



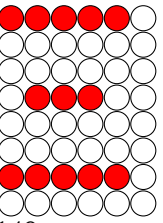
146 approximation



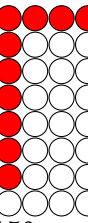
147 Gamma



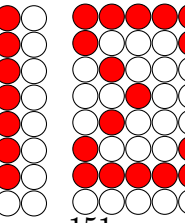
148 Delta



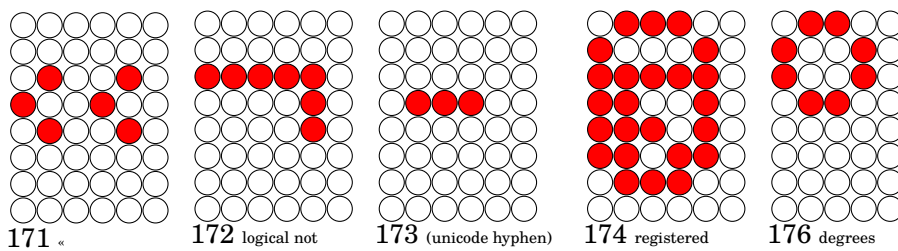
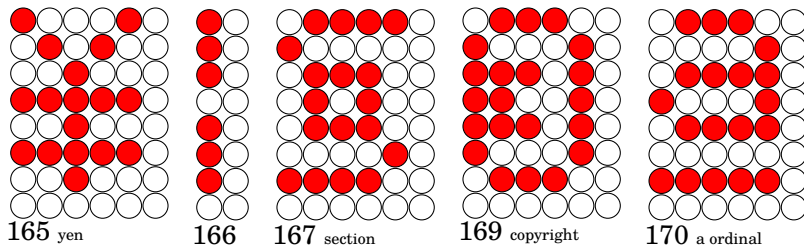
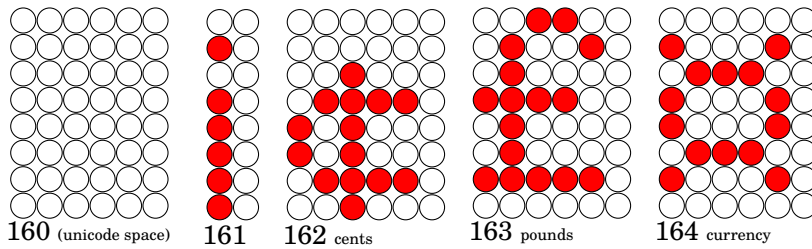
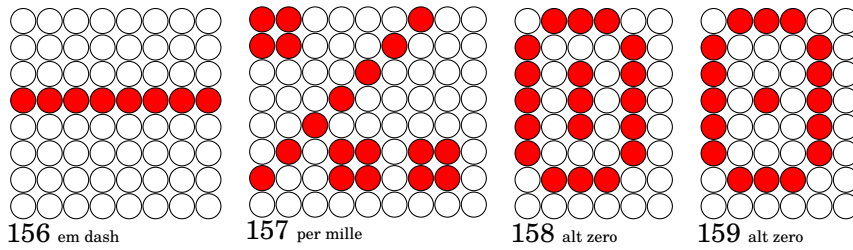
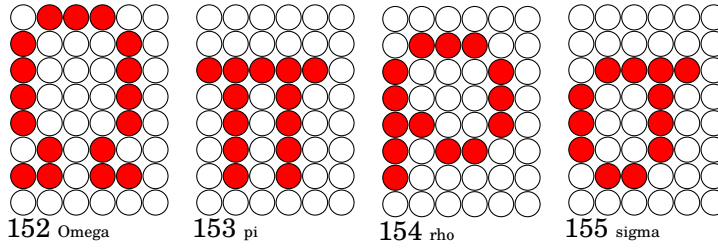
149 Xi

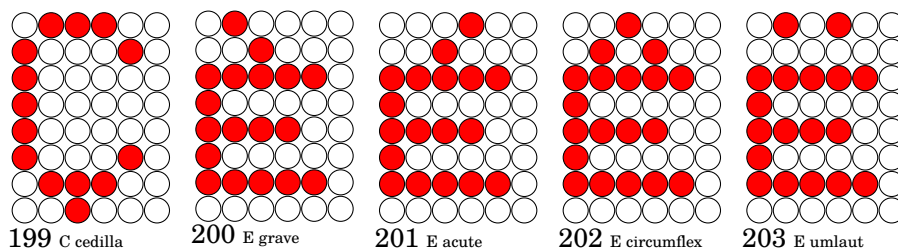
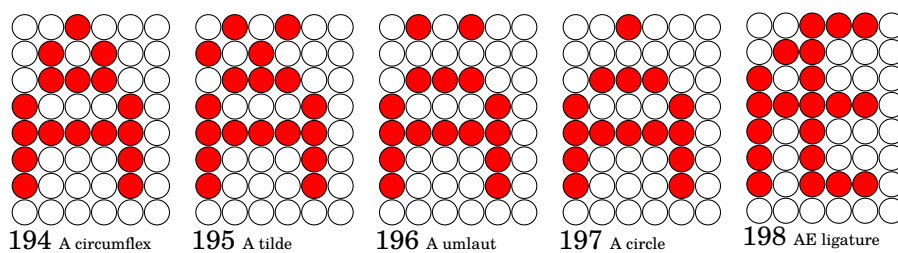
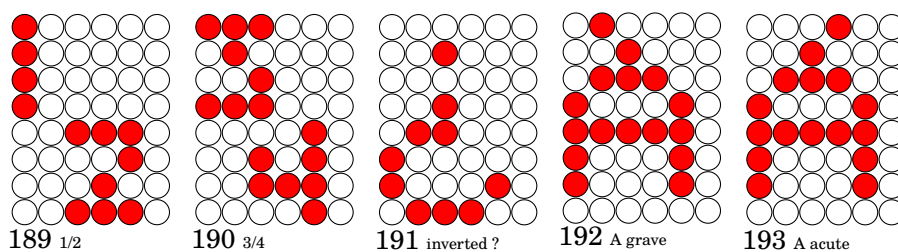
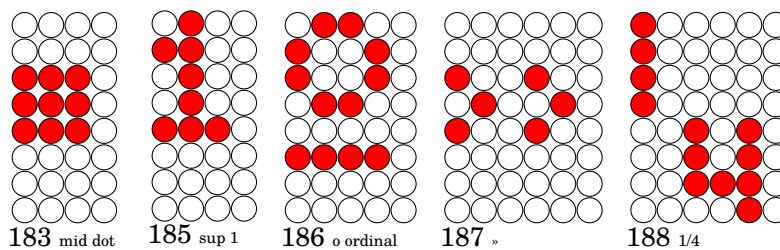
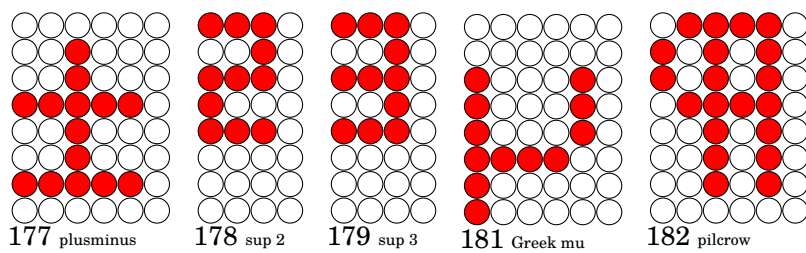


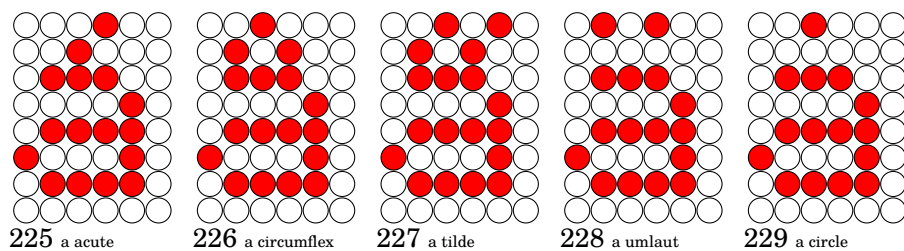
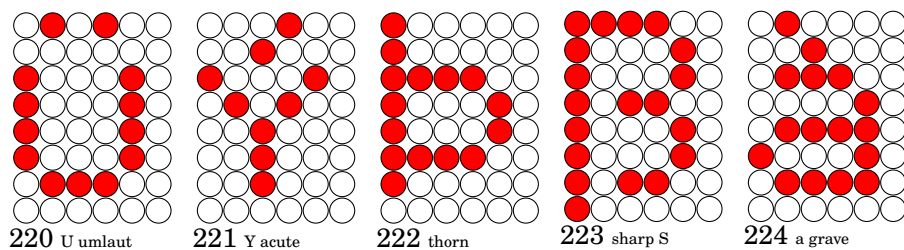
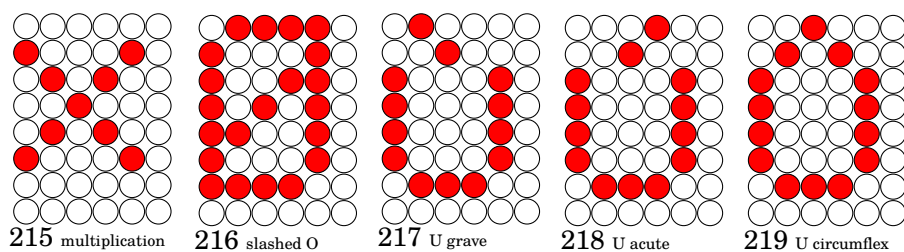
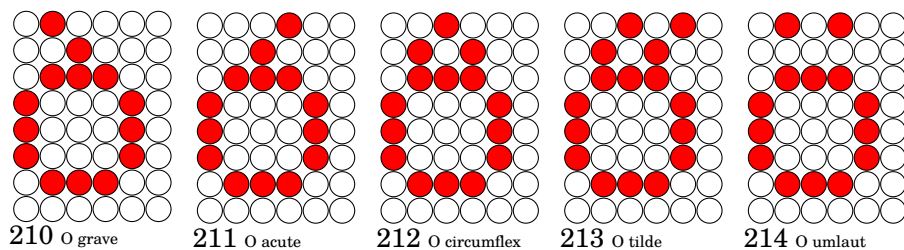
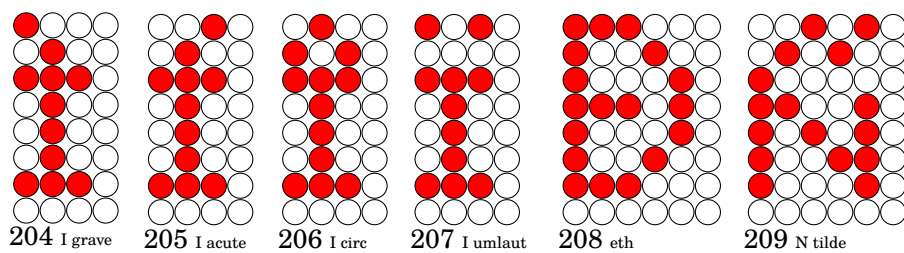
150 Pi

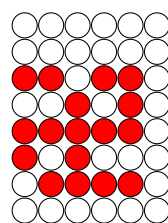


151 Sigma

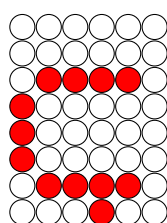




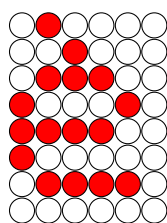




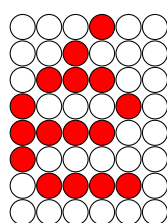
230 ae ligature



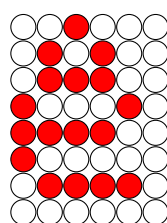
231 c cedilla



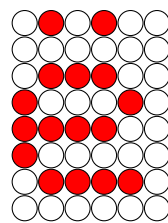
232 e grave



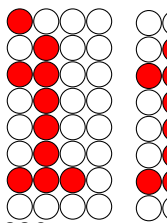
233 e acute



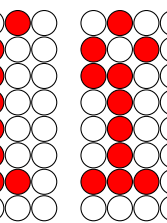
234 e circumflex



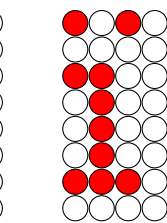
235 e umlaut



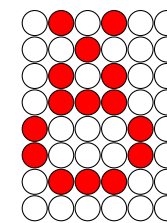
236 i grave



237 i acute



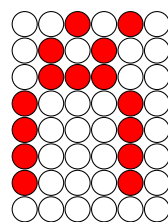
238 i circumflex



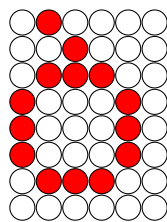
239 i umlaut



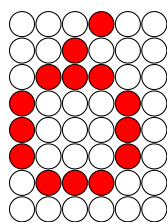
240 eth



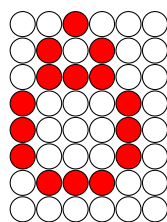
241 n tilde



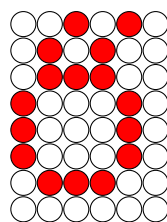
242 o grave



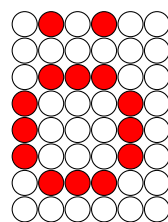
243 o acute



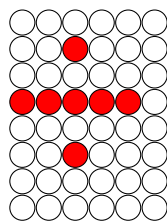
244 o circumflex



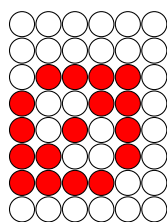
245 o tilde



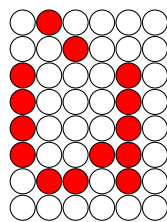
246 o umlaut



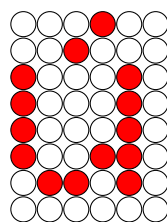
247 division sign



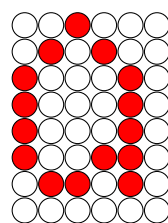
248 slashed o



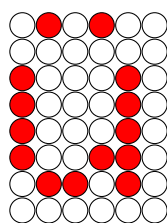
249 u grave



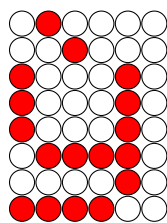
250 u acute



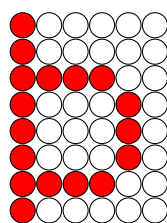
251 u circumflex



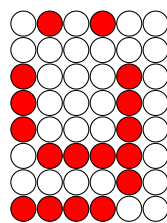
252 u umlaut



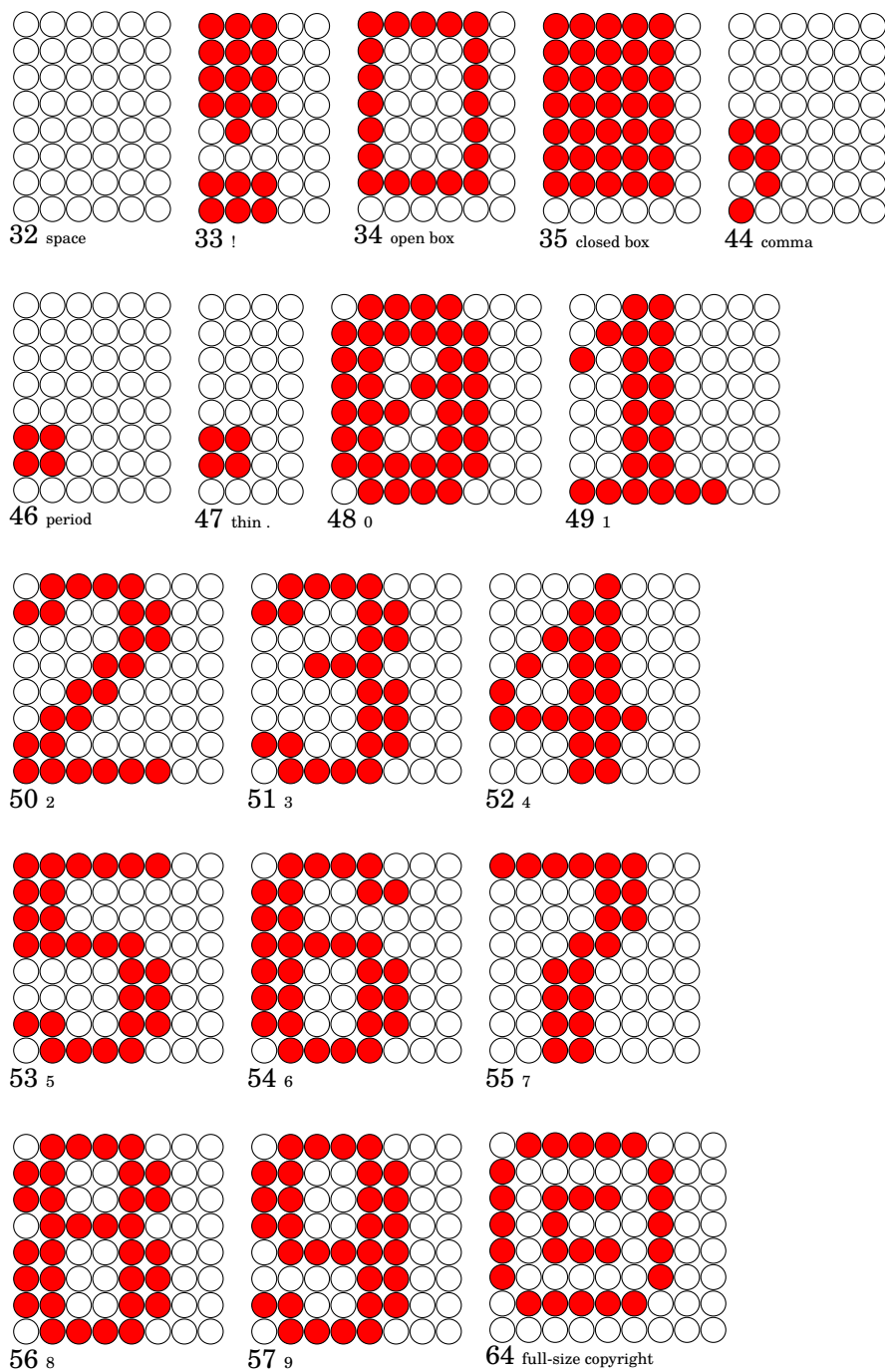
253 y acute

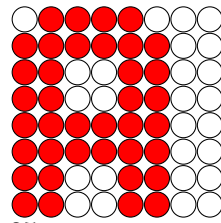
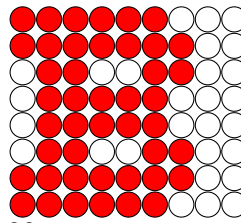
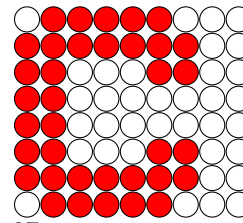
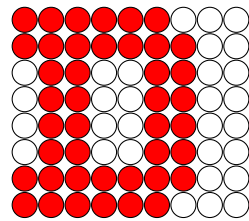
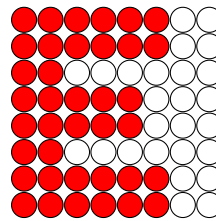
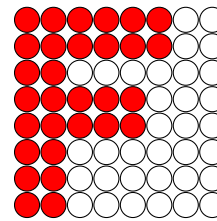
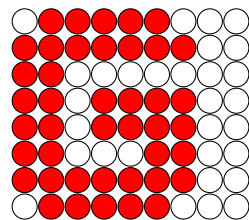
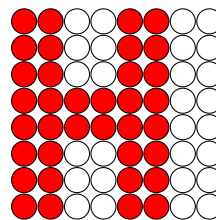
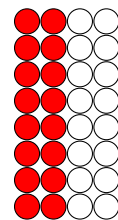
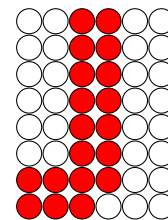
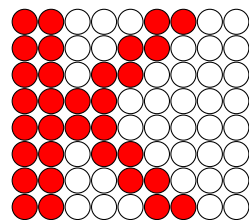
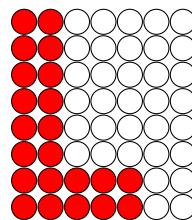
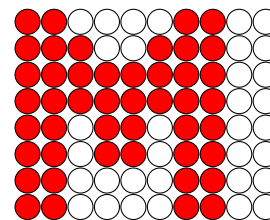
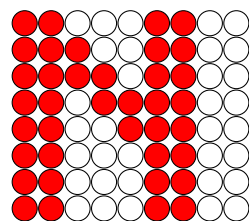
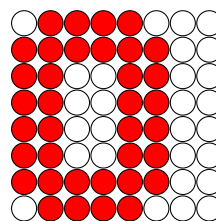
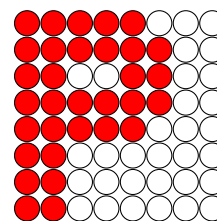


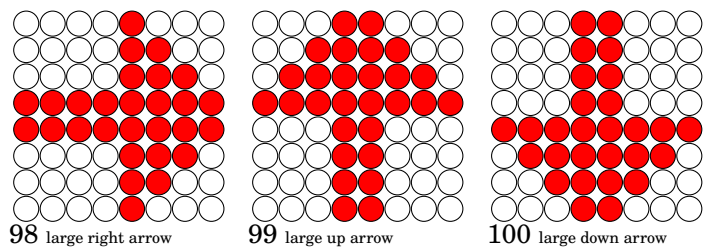
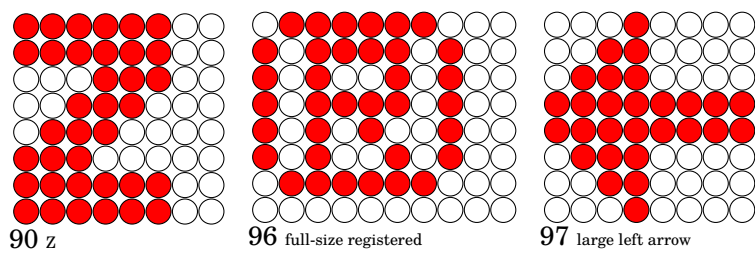
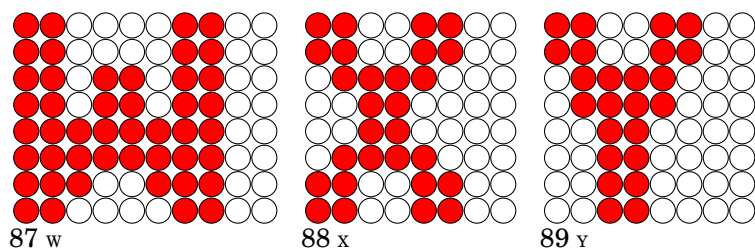
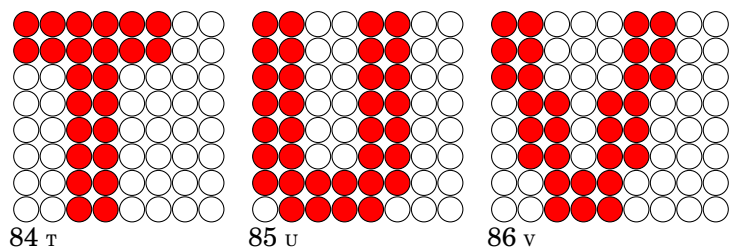
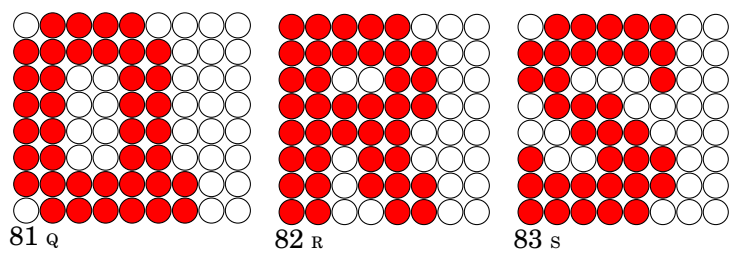
254 thorn

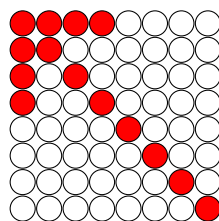


255 y umlaut

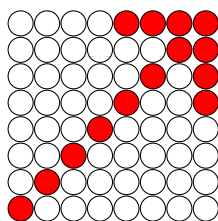
Font #2 symbol.font

65 _A66 _B67 _C68 _D69 _E70 _F71 _G72 _H73 _I74 _J75 _K76 _L77 _M78 _N79 _O80 _P

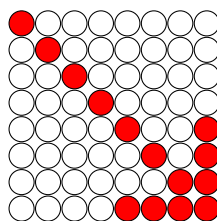




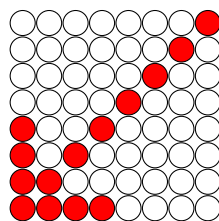
101 NW arrow



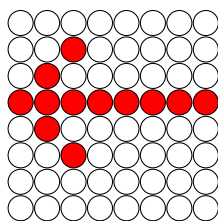
102 NE arrow



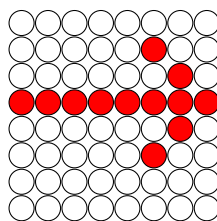
103 SE arrow



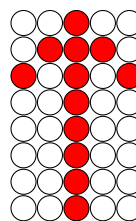
104 SW arrow



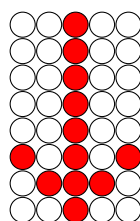
105 W arrow



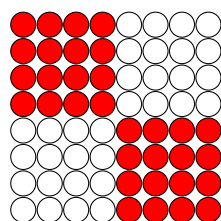
106 E arrow



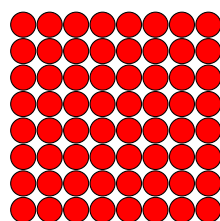
107 N arrow



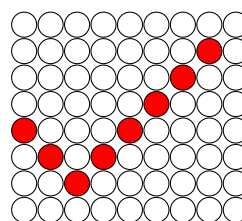
108 S arrow



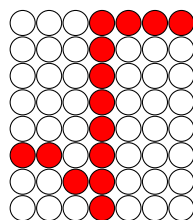
109 checkerboard



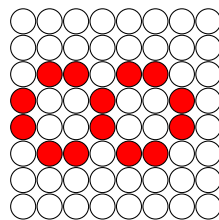
110 solid block



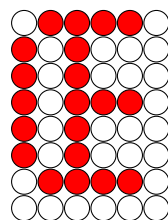
112 check



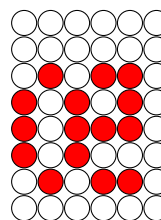
113 radical



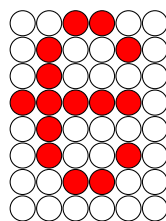
114 infinity



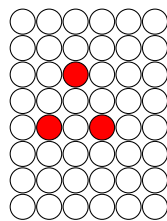
115 OE



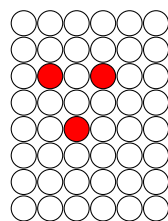
116 oe



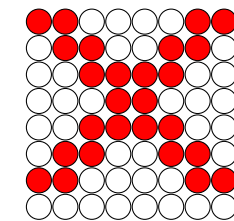
117 Euro



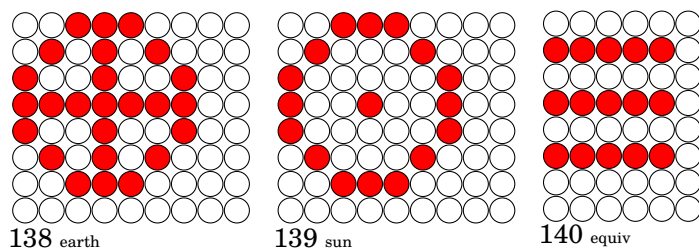
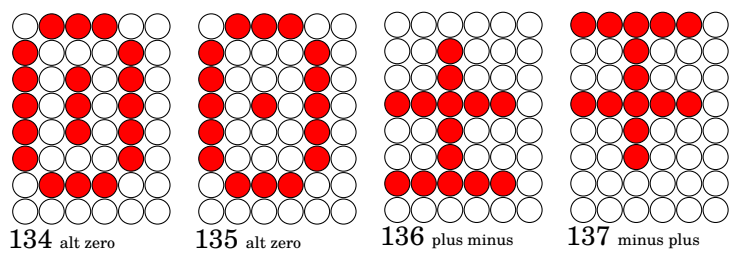
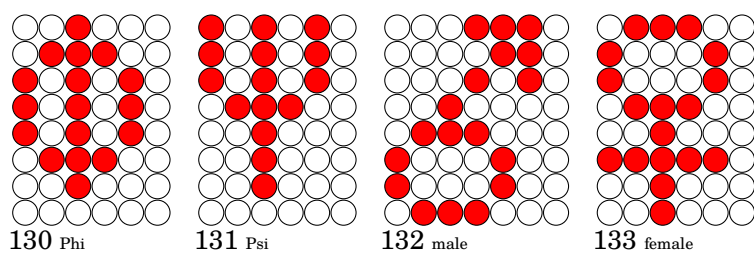
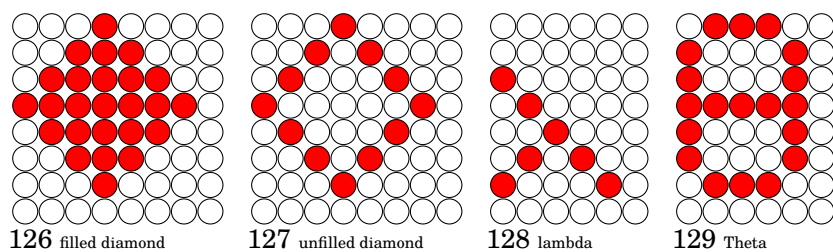
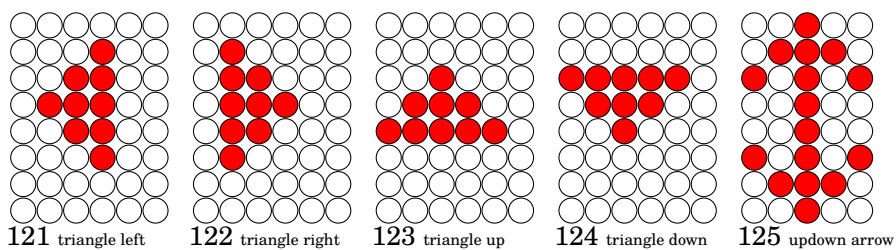
118 three dots up

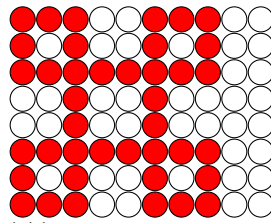


119 three dots down

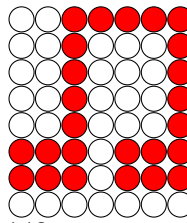


120 large cross

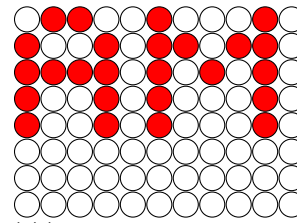




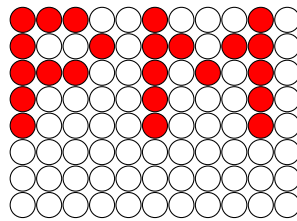
141 clover



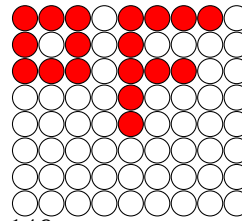
142 notes



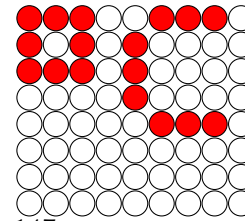
144 AM



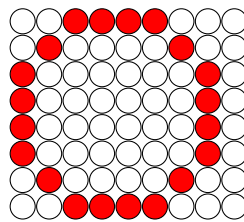
145 PM



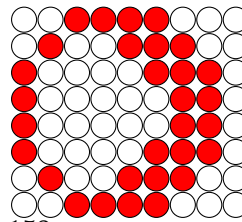
146 degrees F



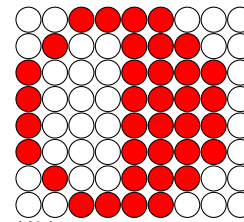
147 degrees C



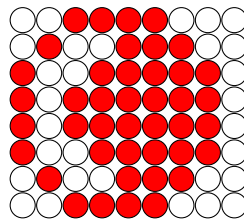
152 new moon



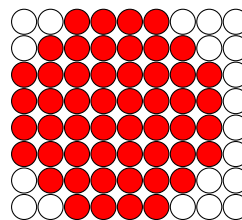
153 waxing crescent



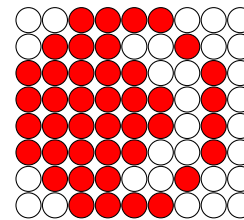
154 first quarter



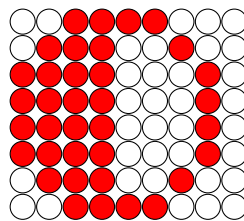
155 waxing gibbous



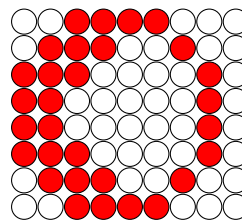
156 full moon



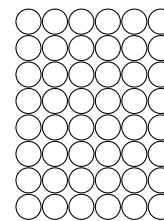
157 waning gibbous



158 third quarter



159 waning crescent



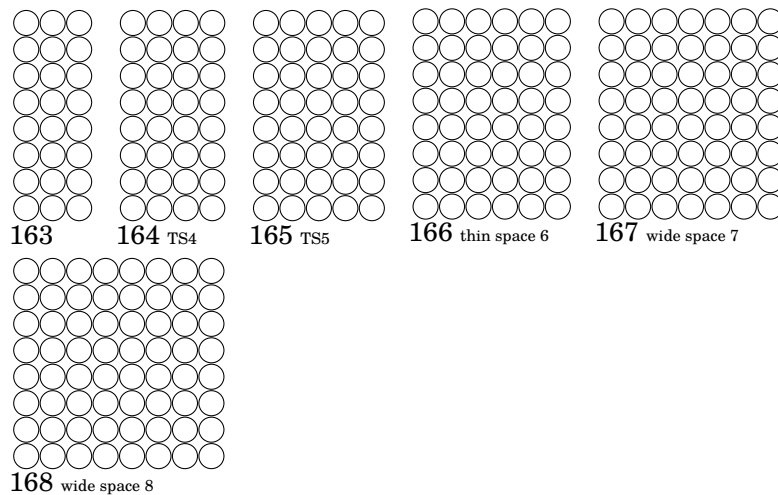
160 (unicode space)



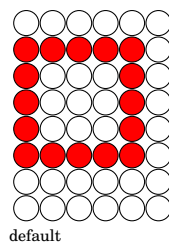
161



162



Default Glyph



Font Definition Files

In the `firmware/readerboard` directory there are a set of files with `.font` suffixes, which define the fonts that the readerboard can employ when writing text to the matrix. If you edit these files, or add more fonts, make the appropriate adjustments to the `Makefile` and run `make` in that directory to regenerate the glyph images on the preceding pages of this document, and the source files where the glyphs are actually stored in the device firmware. Then recompile the firmware image and flash it onto the hardware devices.

Each file defines up to 256 glyphs with codepoint values 0–255. The firmware will not allow some codepoints to be printed (see above, Tables 2.3, 2.7, and 2.8 on pp. 13–18), so to avoid reserved codes we recommend using codepoints ≥ 32 .

Any line which begins (possibly after leading whitespace) with a semi-colon (`;`) is a comment and is ignored completely.

Each glyph definition begins with a line enclosed in square brackets, in the form

[*<codepoint>* *<description>*]

Where *<codepoint>* is either the codepoint expressed as a decimal integer (e.g., “42”) or a dollar sign followed by the codepoint as a hex integer (e.g., “\$2B”), and *<description>* is an arbitrary text description of the character being defined.

For example:

```
[$25 percent]
```

```
@@..@|
```

```
@@..@|
```

```
...@.|
```

```
..@..|
```

```
.@...|
```

```
@..@@|
```

```
@..@@|
```

```
[$2E period]
```

```
..||||
```

```
..||||
```

```
..||||
```

```
..||||
```

```
..||||
```

```
@@||||
```

```
@@||||
```

As a special case, a glyph introduced with the heading

[default]

is defined to be the default glyph to be used if the user tries to print a glyph that is not defined in the font. Only one default glyph may be defined in the entire set of fonts.

The non-blank lines which follow the bracketed header line define the bitmap for the glyph. In this definition, positions which are off are noted with ‘.’ or ‘|’, while positions where the LED is on are noted with ‘@’.

Any completely blank columns to the right of all lit pixels should be represented by ‘|’ rather than ‘.’. This will make note of the drawn width of the character but the columns to the right which consist of ‘|’ characters are not actually stored in the firmware bitmap image, thus conserving ROM space.

If fewer than eight rows are specified, it is assumed that the rows that are present start at the top of the display, and the remaining unspecified rows are all off.

Character Aliases

If a character glyph is to be identical to another glyph, there is no point in storing two or more identical bitmaps in the ROM. In such a case, rather than presenting the duplicate bitmap, the character definition is simply

->⟨*codepoint*⟩
or
->⟨*codepoint*⟩,⟨*font index*⟩

In the first case, the glyph for the indicated codepoint will be reused for this character, such as the case in Font #0 where the prime character (hex \$87) looks identical to the single-quote character (hex \$27). Only the single-quote glyph is actually specified in `standard.font`, so the prime character is defined only as

```
[$87 prime]  
->$27
```

In the second case, the glyph to be duplicated comes from a different font file entirely. For example, many characters in Font #1 (`standard_variable.font`) have the same glyphs as Font #0, such as:

```
[$23 pound sign]  
->$23,0
```


PREPARING AND UPDATING FIRMWARE IMAGES

The firmware that runs on the readerboard hardware (or, more precisely, the Arduino single-board computer attached to the circuit board) is located in the `firmware/readerboard` directory of the readerboard project repository.

After updating the code from the repository if necessary, perform the following steps to configure and prepare the firmware image:

Step 1: Configuration. Edit a few lines near the top of `readerboard.h`:

```
// BEGIN CONFIGURATION SECTION
// TODO: Set these before compiling for a particular hardware
//      configuration
#define HW_MODEL (MODEL_3xx_RGB)
#define HW_MC (HW_MC_DUE)
#define HAS_I2C_EEPROM (false)
```

These values should come already set up for the latest hardware model (in this example, the revision 3 RGB models which incorporate the Arduino directly onto the main circuit board). If your hardware uses a different design, such as one of the older legacy boards, `HW_MODEL` needs to be changed to another hardware name, provided that name is actually supported (and supported correctly) in the rest of the firmware.

Also, `HW_MC` needs to be set to the model of Arduino microcontroller you will be using to control this unit.

Values for HW_MODEL (Readerboard Hardware Model):	
MODEL_3xx_RGB	PCB revision 3.0 and later with RGB LEDs installed.
MODEL_3xx_MONOCHROME	PCB revision 3.0 and later with single-color LEDs installed with their anodes soldered into pin 4 (the blue circuit).
Values for HW_MC (Microcontroller Installed):	
HW_MC_MEGA_2560	Arduino Mega 2560.
HW_MC_DUE	Arduino Due.

Table 8.1: Firmware Configuration Values

If using an EEPROM chip or module external to the Arduino via the I²C bus, such as chip U16 which is recommended for use with the Arduino Due, then set HAS_I2C_EEPROM to true. If using no EEPROM or the one built-in to the Arduino, leave this set to false.

The supported values for these two configuration settings are listed in Table 8.1.

```
// TODO: Set these default settings (this will be the "factory
// default settings"). On Due-based systems without
// external EEPROM, this is the only way to make these
// settings at all. On every other model, this is just
// the default that can be overridden by configuring the
// unit since the new configuration values can be saved
// in EEPROM.
//
// Default baud rate. Allowed values are '0'=300, '1'=600,
// '2'=1200, '3'=2400, '4'=4800, '5'=9600, '6'=14400,
// '7'=19200, '8'=28800, '9'=31250, 'A'=38400, 'B'=57600,
// 'C'=115200.
#define EE_DEFAULT_USB_SPEED ('5')
#define EE_DEFAULT_485_SPEED ('5')
```

These values determine the default baud rate to use for the USB direct connection and RS-485 network. Note that the value is a character literal.

```
// Default device address (may be any value from 0-63 except
// the global address, or EE_ADDRESS_DISABLED if you won't be
// using RS-485 at all.)
#define EE_DEFAULT_ADDRESS (EE_ADDRESS_DISABLED)
```



```
//
// Default global device address (may be any value from 0-15).
#define EE_DEFAULT_GLOBAL_ADDRESS (15)
```

With `EE_DEFAULT_ADDRESS` set to `EE_ADDRESS_DISABLED`, the RS-485 interface will be disabled. Otherwise the value set for this symbol is an integer in the range 0–63 which will be the device address recognized in commands received over the RS-485 network.

Set `EE_DEFAULT_GLOBAL_ADDRESS` to the default global device address you wish the unit to recognize. This must be in the range 0–15.

```
//
// TODO: Adjust these for the colors of discrete status LEDs on
//       this unit. These can be used for color values in
//       commands sent to the device.
#define STATUS_LED_COLOR_L0 ('G')
#define STATUS_LED_COLOR_L1 ('y')
#define STATUS_LED_COLOR_L2 ('Y')
#define STATUS_LED_COLOR_L3 ('r')
#define STATUS_LED_COLOR_L4 ('R')
#define STATUS_LED_COLOR_L5 ('b')
#define STATUS_LED_COLOR_L6 ('B')
#define STATUS_LED_COLOR_L7 ('W')
```

These are set for the standard color assignments for the discrete status LEDs, allowing for the use of these single-letter color codes to refer to the status LEDs. If you build a unit with different colors, you may assign appropriate color codes here.

```
#define BANNER_HARDWARE_VERS "HW 3.2.3  "
#define BANNER_FIRMWARE_VERS "FW 0.0.0  "
#define BANNER_SERIAL_NUMBER "S/N RBXXXX"
#define SERIAL_VERSION_STAMP "V3.2.3$R0.0.0$SRBXXXX$"
//
//           \---/  \---/  \---/
//           |      |      |
//           Hardware version  |
//           Firmware version  |
//           Serial number
```

The `BANNER_FIRMWARE_VERS` value should match the version of the firmware source code you are compiling.

Likewise, `BANNER_HARDWARE_VERS` gives the revision of the PCB in use.

Set the `BANNER_SERIAL_NUMBER` value to the serial number for your specific device. Serial numbers under 300 are reserved for the project author's use. If building your own device, assign a serial number that makes sense to you. It will help you manage your collection of devices best if you give them unique serial numbers since those can be queried by software.

These should be 10-character text strings. They will be displayed briefly when the sign is booted.

Set the `SERIAL_VERSION_STAMP` value to match the previous three values while still preserving the format "V...\$R...\$S...\$". This string will be sent verbatim as part of the device's response to being queried for its configuration and status.

Step 2: Make. Run the make program. This will build the font tables from the various *.font files into the firmware code so the target device will be able to generate characters from those fonts.

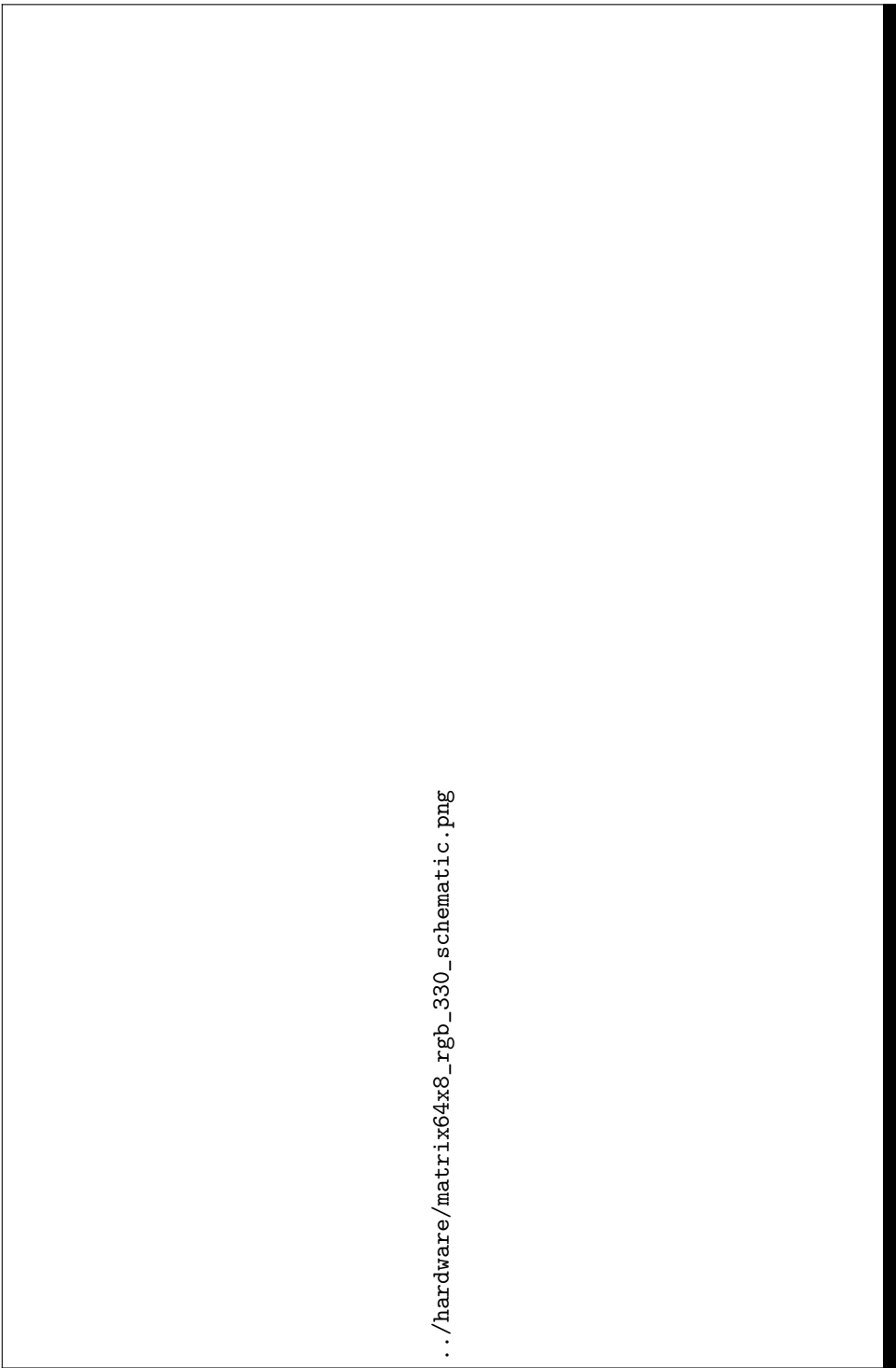
Customizing and extending the fonts is described in Chapter 7.

Step 3: Compile. Using your Arduino compiler tools, compile the `readerboard.ino` file and upload it to your readerboard hardware. This step assumes you have set up your own Arduino development environment and is beyond the scope of this document to help you with.

CHAPTER 9

SCHEMATICS AND DIAGRAMS

The following pages include the schematics for the current 3.3.0 version of the readerboard PCB and the board assembly diagram, showing where the components are placed.



../hardware/matrix64x8_rgb_330_schematic.png

