

A HP-41 Bar Code Decoder

Martin Hepperle

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Bar codes are a low cost means to store data using printed labels. They can encode any kind of binary data and come in many flavors and have developed from the classical linear bar codes sequences to two dimensional QR code patterns. A wide variety of encoding schemes exists and for each encoding scheme a suitable decoder is required.

Therefore many different bar code readers are available. Today, most of these devices contain the optical scanner and the decoder software in a single unit. The decoder software is usually written to decode several standard bar code formats.

One example where the optical scanner device is separated from the decoder software is the HEDS-3000 wand and its derivatives. This wand is part of the HP-82153A wand system for the HP-41C. In this case the decoder software lives inside the ROM module in the plug that connects the wand to the calculator. The ROM routines were designed to decode the HP-specific bar codes for the HP-41C only. This is a bar code scheme where the white gaps between the bars have a constant width and only the bar width varies between two cases: "narrow" and "wide" to represent binary zeroes and ones. In addition to the encoded data additional checksums and flags are present as well as direction indicator bars. Commercially available bar code scanners cannot read this scheme because it is not one of the standard schemes.

Another example is the HP-82725A bar code reader module for the HP-75D, which used the HP-92267A or HP-92267B wand for input. Again the decoding was done with the help of a plug-in module. The code in this module was designed to decode several standard formats:

- Code 11 (USD-8)
- 3-of-9 Code (USD-3)
- Interleaved 2-of-5 Code (USD-1)
- Industrial 2-of-5 Code
- 2-of-7 Code (Codabar, USD-4)
- Universal Product Code (UPC A, UPC E)
- European Article Number (EAN 8, EAN 13)

Interestingly the HP-75D module cannot decode the HP specific bar codes used for the HP-41C.

Finally, a similar wand was available as a third-party product for the HP-71B. The ZENWAND was designed to read the same barcode types as the wand for the HP-75. Its ROM contained more useful routines including functions to print barcodes.

How does a Wand Work?

The articles [3] and [4] give very a good overview of the working of the HEDS-3000 and the HP-41 wand system. The wand contains a very sensitive optical sensor with amplifiers which detects whether a white (reflective) or black area is in front of the wands tip. The measuring area is a small dot of about 0.5 mm diameter. By sliding the tip of the wand across a strip of bar codes a time history corresponding to white and black bars can be recorded. The major difficulty in manual operation is the variable scanning speed, which leads to a variable duration of the same bar type. A decoding algorithm has to take this variable timing into account. For this purpose all white spaces in the HP-specific barcode scheme have the same width, thus serving as a timing reference. More difficulties arise from printing quality and tolerances. Therefore decoding barcodes can be a rather difficult process. Simple checksums allow for error checking but not error recovery. Multiple errors can even lead to a correct

Figure 1: Exploded view of a HEDS-3000 as used for the HP-41 wand system. The optical sensor is clearly visible at the left. The HP-41 variant used a black case.

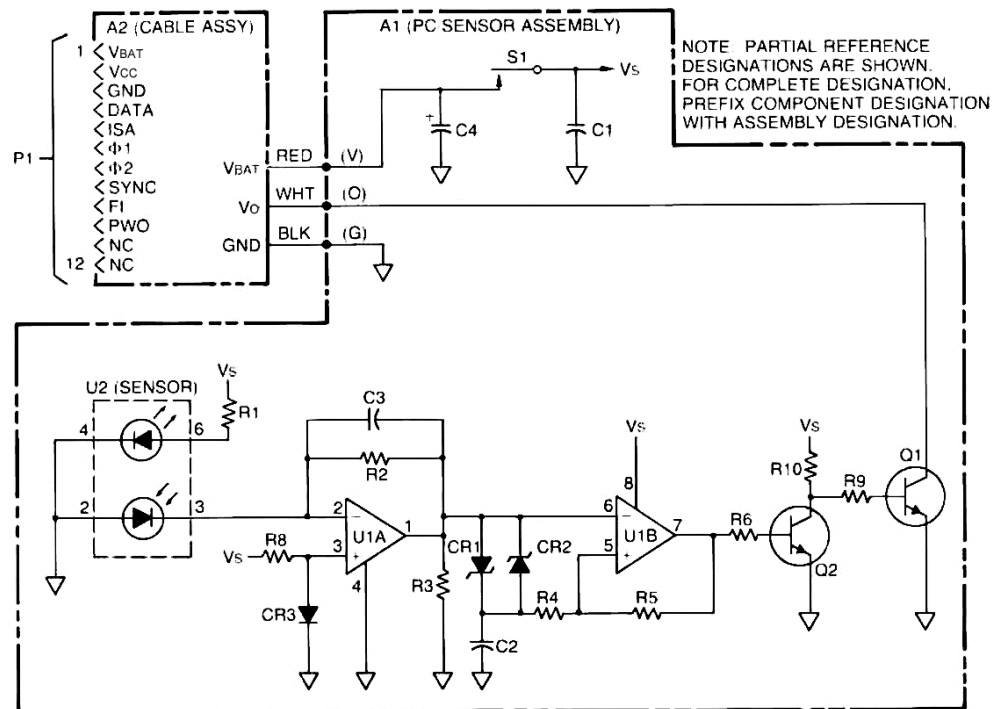


Figure 2: Schematic of the HEDS-3000 wand with interface to the HP-41 showing sensor and amplifier chain (image lifted from [5]).

The HEDS-3000 contains all the circuitry to deliver a well formed digital signal. Further processing must be done with additional hard- and software.

The wand has a switch so that it only draws power when switched on. This is useful because the optical sensor contains a power consuming LED to illuminate the barcode. In case of the HP-41 the switch can also trigger a wake-up of the calculator up if it was switched off.

The BarcodeReader Software

The BARCODEREADER application was written in Java and is therefore useable on any platform for which a Java Virtual Machine (JVM) exists. It can be used for the following tasks:

- Decode program and data barcode information from scanned images. A scan resolution of at least 400 dpi in pure black and white quality is recommended. Grayscale images look good on screen but yield poor scanning results.
- Import programs in binary (.raw), binary (.p41) or hexadecimal (.dat) format.
- Save programs in different formats: binary (.raw), binary (.p41), hexadecimal (.dat), text (.txt)
- Save program bar codes as a Postscript program for converting to bitmap images or printing.
- Print programs in text or barcode form directly to the system printer.

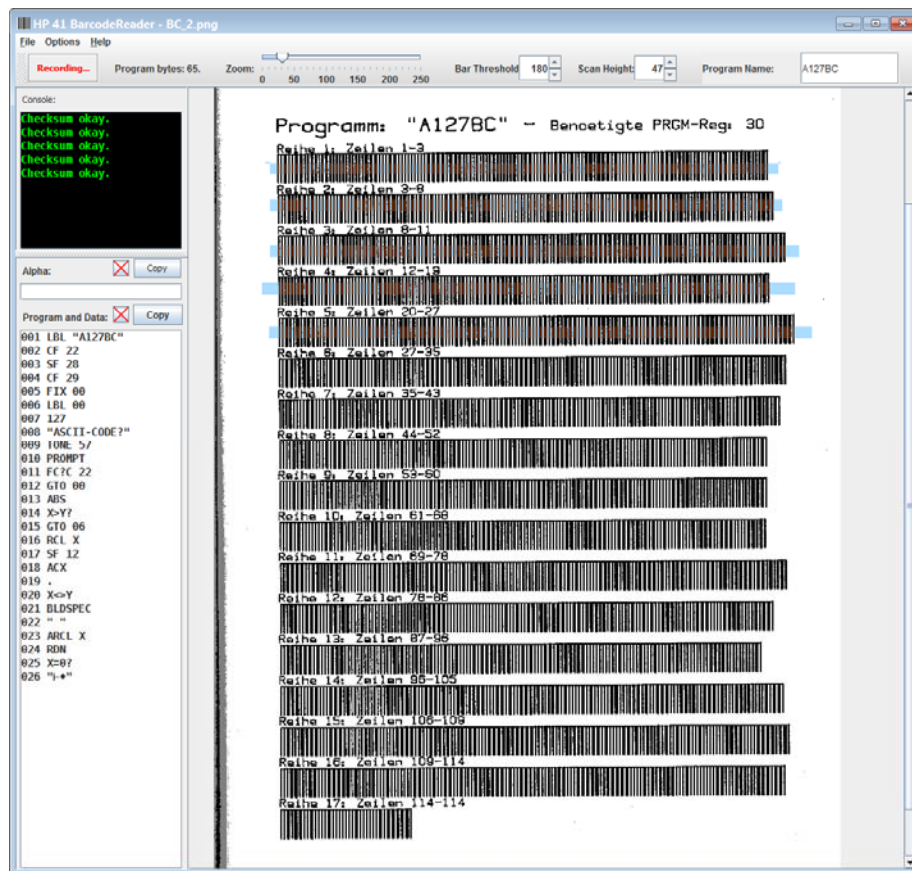


Figure 3: Application window with first rows of program barcodes in the image scanned.

Running the Application

The program is contained in a single .jar archive file and can be run using the following command:

```
java -jar barcodescanner.jar
```

If you do not want to open a command window, you can also create a shortcut or command file or even better associate all .jar files with the command

```
java -jar %1
```

So that the application can be run by activating the archive file by single or double click or by pressing the enter key.

Notes for Windows Users

Under Windows you can find out whether a file association for java archives exists by issuing the following commands in a command window. The “assoc” command checks whether a file type association for files with names ending in “.jar” exists:

```
C:\>assoc .jar  
.jar=jarfile
```

If no file type is associated, you can specify one by typing

```
C:\>assoc .jar=jarFile
```

Then the “ftype” command can be used to check which command is associated with files of this type (in this case with “jarFile”).

```
C:\>ftype jarFile  
jarFile="D:\Java\jre8\bin\javaw.exe" -jar "%1" %*
```

If no command is associated, you can define it by issuing the command

```
C:\> ftype jarFile="D:\Java\jre8\bin\javaw.exe" -jar "%1" %*
```

In Windows versions prior to version 7 you could easily perform these changes with the Windows GUI, but in later windows versions this option seems to have been “optimized” away.

Typical Application

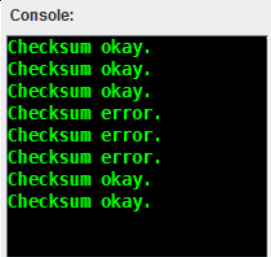

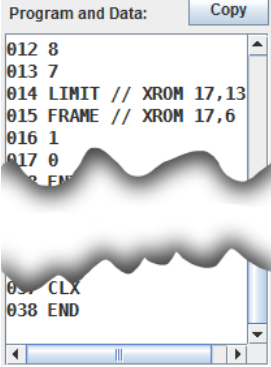
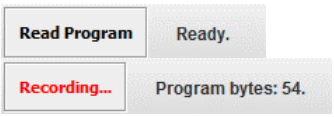
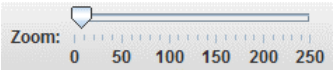


A typical application can be split in these steps:


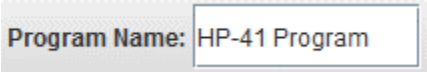
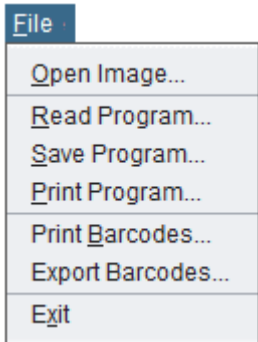
- 1) Opening a scanned image containing lines of barcodes,
- 2) To scan program bar codes you must initialize the line and checksum counter by pressing the **Read Program** button in the toolbar.
- 3A) To process each row resp. column:
 - a) Move the mouse pointer to the left (horizontal row) or above (vertical row) of the barcode,
 - b) press and hold the left mouse button,
 - c) drag the mouse pointer over the barcode row (a horizontal or vertical line will be drawn),
 - d) release the mouse button after the right end of the row
(note: you can repeat steps a) to d) if the line is not covering the whole barcode),
 - e) press the **a** key on the keyboard to **a**cquire the line.
- 3B) Simplification of 3A):
 - a) Move the mouse pointer to the left of the barcode row, no click is required,
 - b1) press the **a** key on the keyboard to search for a horizontal barcode row and to **a**cquire it,
or
 - b2) press the **v** key on the keyboard to search for a vertical barcode column and to **a**cquire it.

(Note that the automatic search for the barcode row resp. column may not work if text or another row of barcodes is immediately following the end of the barcode row. Then use the procedure according to step 3A).

- 4) When all lines are read (programs should end with an END instruction), the program can be exported or printed.

Controls and Options

	<p>Status and error messages are displayed in the console window.</p>
	<p>The alpha field shows the current content of the alpha register including any appended text strings. Its content can be copied to the clipboard.</p>
	<p>If <u>data barcodes</u> are scanned their values are collected in this field. Sequenced bar codes contain a prepended sequence number.</p> <p>If <u>program bar codes</u> are scanned the program lines read so far are shown in this field. A complete program should include its END.</p> <p>This field is for display purposes only. While you can edit the content of this field this will have no effect on the currently loaded or scanned program, i.e. you cannot edit a program and save the modified variant.</p> <p>The content of this field can be copied to the clipboard.</p>
<h3>Toolbar Items</h3>	
	<p>The record button resets the checksum and line count and prepares for reading multi-line program bar codes. For these bar codes the checksum is carried over from row to row, so that it must be reset before scanning the first row. While scanning a program the number of bytes read so far is updated for each line.</p>
	<p>The zoom factor only affects the display. The scanning operation is always performed on the full resolution of the image. Usually it is a good idea to adjust the zoom factor so that the whole width of the longest bars is visible.</p>
	<p>Rotates the current image 90° counter clockwise.</p>
	<p>This threshold defines the separation between narrow and wide bars. Following the documentation this value should be 150%, i.e. a wide bar is at least 150% times as wide as the white space between the bars. Depending on print quality this value can be set to values as high as 200%.</p>

	<p>Note that a self-adaptive algorithm has been implemented which starts with the value defined in this field. In case of checksum errors the algorithm adjusts the threshold based on the statistical distribution of the bars and spaces found in the scan area. After 6 readjustments the algorithm gives up.</p>
	<p>The scan height defines the height of the rectangle over which the pixels are averaged. In most cases values between 20 and 80 achieve a high success rate. In critical cases a lower value may reduce the error rate.</p>
	<p>The name of the current program as it will be exported respectively printed on barcode pages and program listings.</p>
Menu Items	
	<p>Open Image...</p> <ul style="list-style-type: none"> Open a bitmap file with barcodes. Scans should have about 400 dpi or better. Best results are obtained for pure black and white images (not grayscale). <p>Note: Instead of using this menu command you can also drag and drop image files of type PNG, BMP, JPG or GIF onto the BARCODEREADER window.</p> <p>Read Program...</p> <ul style="list-style-type: none"> Open a HP-41 program stored in a file. The file can be either in binary (raw or p41) or hexadecimal encoded (dat) format. <p>Note: Instead of using this menu command you can also drag and drop files of type RAW, P41, or DAT onto the BARCODEREADER window.</p> <p>Save Program...</p> <ul style="list-style-type: none"> Save a program in binary (raw or p41), hexadecimal encoded (dat), or plain text listing (txt) format. The export to a Postscript file produces one or more pages of barcode for conversion to PDF or printing to a postscript printer. These files can be converted with Adobe Acrobat or Ghostscript or other tools like CorelDraw. <p>Print Program...</p> <ul style="list-style-type: none"> Prints pages with the program listing to your system printer. <p>Print Barcodes...</p> <ul style="list-style-type: none"> Prints pages with barcodes to your system printer. <p>Export Barcodes...</p> <ul style="list-style-type: none"> Prints barcodes to a sequence of numbered image files. <p>Exit</p> <ul style="list-style-type: none"> Stores preferences and exits the program.

<div data-bbox="204 324 400 463"> <div>Edit</div> <div>Paste Image</div> <div>Paste Text</div> </div>	<div data-bbox="707 194 841 224">Paste Image</div> <ul style="list-style-type: none"> Pastes an image with barcodes from the clipboard. Scans should have at least 400 dpi and should be in pure black and white. <div data-bbox="707 365 866 394">Paste Program</div> <ul style="list-style-type: none"> Pastes a program from the clipboard. The program must be a text string in text hexadecimal encoded (dat) format, complete with header and checksum. Line breaks, tabs and spaces are ignored and can be used for grouping if desired. They will be ignored when parsing the string.
<div data-bbox="204 963 574 1256"> <div>Options</div> <div> <div>✓ Show Line Numbers</div> <div>✓ Show Statistics Window</div> <div>Decode XROM Functions</div> <div>Annotate XROM Functions</div> <div>Enter Raw Bar Codes...</div> <div>Options...</div> </div> </div>	<div data-bbox="707 607 933 636">Show Line Numbers</div> <ul style="list-style-type: none"> Three digits line numbers are prepended to each program line. <div data-bbox="707 741 973 770">Show Statistics Window</div> <ul style="list-style-type: none"> Display a window with the width of bars and spaces. <div data-bbox="707 844 991 873">Decode XROM Functions</div> <ul style="list-style-type: none"> For some known modules the XROM numbers are decoded and the function name is shown in human readable form. <div data-bbox="707 1014 1007 1043">Annotate XROM Functions</div> <ul style="list-style-type: none"> If XROM functions are decoded <ul style="list-style-type: none"> the ROM id and function is shown as a comment. Otherwise <ul style="list-style-type: none"> the decoded function name is shown as a comment. <div data-bbox="707 1288 968 1317">Enter Raw Bar Codes...</div> <ul style="list-style-type: none"> Opens a dialog where you can enter a sequence of “0” and “1” characters to read as a line of bar codes if the optical scanning process has repeatedly failed. You can insert spaces or dots to separate groups for readability. <div data-bbox="707 1491 821 1520">Settings...</div> <ul style="list-style-type: none"> Opens a dialog to specify options for printing and exporting.
<div data-bbox="422 1653 1201 1995"> <div>Raw Bar Code Entry</div> <div>Enter complete bar code consisting of '0' and '1', including leading and traili... You can include spaces for better readability.</div> <div>bar code (binary): 00 0000 0000 10</div> <div>ProcessClose</div> </div>	

Figure 4: The raw bar code entry dialog can be used as a last resort to enter a line which cannot be read from a scanned image of poor quality.

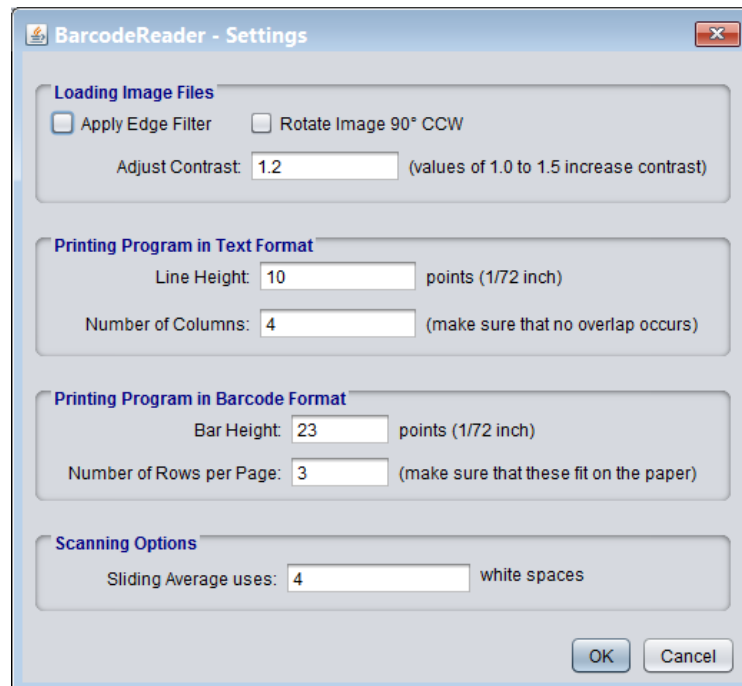


Figure 5: The Options dialog allows adjusting parameters for the loading of images and the printout of programs in text as well as in barcode form. It also contains some general parameters.

Help

About...

Shows the usual About dialog with the version number.

```
001 LBL "SET"
002 PINIT // XROM 17,25
003 6
004 ENTER
005 256
006 ENTER
007 7
008 ENTER
009 187
010 LIMIT // XROM 17,13
011 FRAME // XROM 17,6
012 10
013 ENTER
014 90
```

```
015 ENTER
016 10
017 ENTER
018 90
019 LOCATE // XROM 17,15
020 CLST
021 100
022 STO Z
023 SCALE // XROM 17,30
024 FRAME // XROM 17,6
025 FIX 00
026 DEG
027 CLX
028 END
```

Figure 6: Example program decoded from the image. Active options: ☒ Show Line Numbers , ☒ Decode XROM Functions , ☒ Annotate XROM Functions .

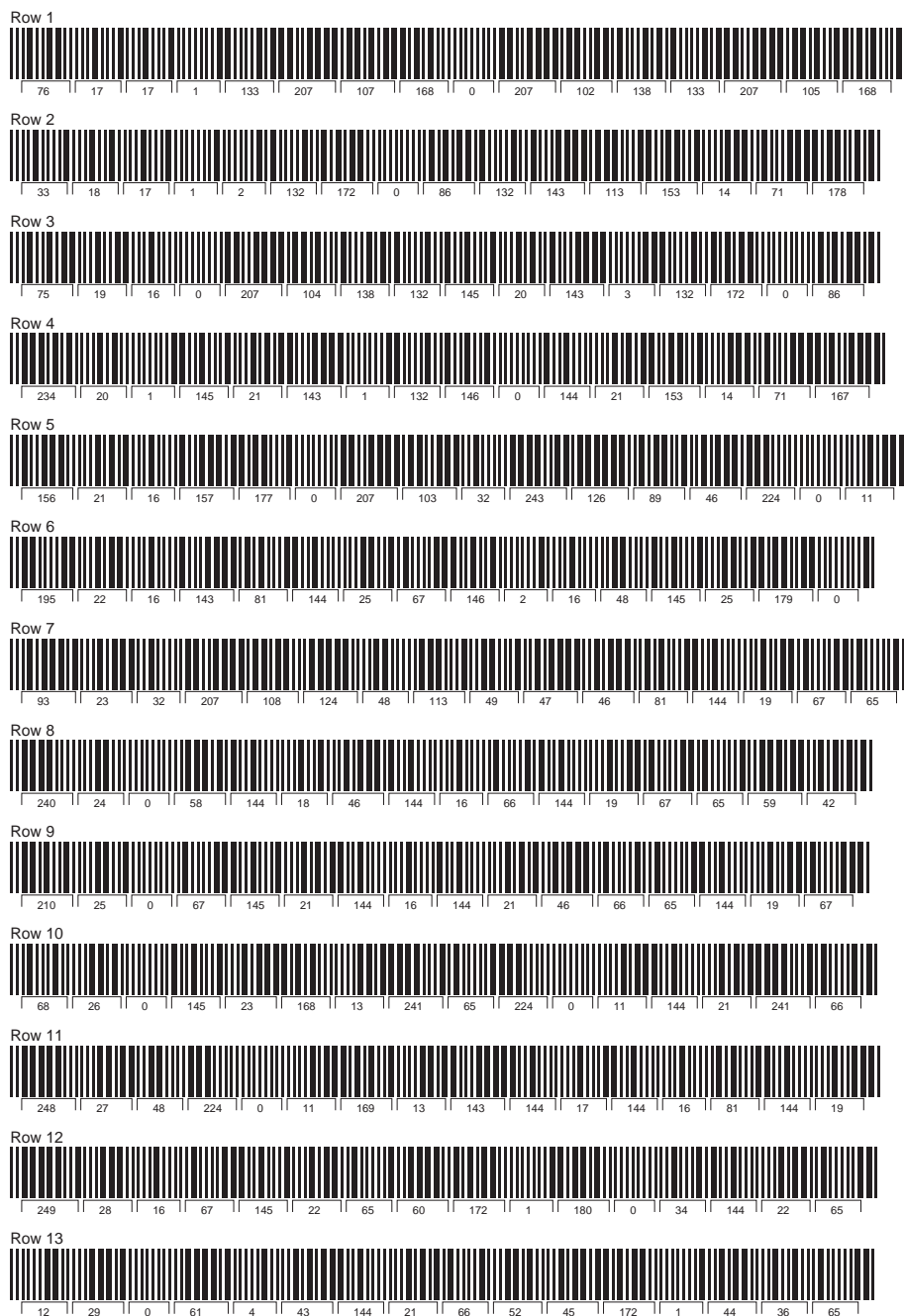
Fonts and Character Sets

In order to display an approximation of the HP-41 character set the BARCODEREADER application uses the font “DejaVu Sans Mono”. This freely available font contains suitable Unicode characters except for the “x with overbar” character (code #2), which I have replaced by an “x with dieresis”, i.e. an “x” with two dots above it. BARCODEREADER uses its own embedded font resource so that it is not necessary to install it on the target system.

dec	hex	char	dec	hex	char	dec	hex	char	dec	hex	char
0	0	◆	32	20		64	40	@	96	60	␣
1	1	×	33	21	!	65	41	A	97	61	a
2	2	×	34	22	"	66	42	B	98	62	b
3	3	←	35	23	#	67	43	C	99	63	c
4	4	α	36	24	\$	68	44	D	100	64	d
5	5	β	37	25	%	69	45	E	101	65	e
6	6	Γ	38	26	&	70	46	F	102	66	f
7	7	↓	39	27	'	71	47	G	103	67	g
8	8	Δ	40	28	(	72	48	H	104	68	h
9	9	σ	41	29	)	73	49	I	105	69	i
10	a	◆	42	2a	*	74	4a	J	106	6a	j
11	b	λ	43	2b	+	75	4b	K	107	6b	k
12	c	μ	44	2c	,	76	4c	L	108	6c	l
13	d	∠	45	2d	-	77	4d	M	109	6d	m
14	e	τ	46	2e	.	78	4e	N	110	6e	n
15	f	Φ	47	2f	/	79	4f	O	111	6f	o
16	10	θ	48	30	0	80	50	P	112	70	p
17	11	Ω	49	31	1	81	51	Q	113	71	q
18	12	δ	50	32	2	82	52	R	114	72	r
19	13	Å	51	33	3	83	53	S	115	73	s
20	14	å	52	34	4	84	54	T	116	74	t
21	15	Ä	53	35	5	85	55	U	117	75	u
22	16	ä	54	36	6	86	56	V	118	76	v
23	17	Ö	55	37	7	87	57	W	119	77	w
24	18	ö	56	38	8	88	58	X	120	78	x
25	19	Ü	57	39	9	89	59	Y	121	79	y
26	1a	ü	58	3a	:	90	5a	Z	122	7a	z
27	1b	Æ	59	3b	;	91	5b	[	123	7b	π
28	1c	œ	60	3c	<	92	5c	\	124	7c	
29	1d	≠	61	3d	=	93	5d	]	125	7d	→
30	1e	£	62	3e	>	94	5e	†	126	7e	Σ
31	1f	☒	63	3f	?	95	5f	—	127	7f	␣

Table 1: HP-41 character set as printed with the “DejaVu Sans Mono” font. Note that character 2 is represented by the character “x”.

HP-41 Program: "linreg.dat" size: 840 bytes = 120 registers



Page 1

Figure 7: First page of a program exported in Postscript format. The numbers below the bar code groups denote the decimal value of the corresponding byte.

```
0036C600F400534554A4591683121516831783111817A44DA4461110831910831110
831910A44F731110109171A45EA4469C008077C4072F16
```

Figure 8: Barcodes exported in hexadecimal format (.dat file extension). Note: the sequence is written as a single line without line breaks.

HP-41 program: "linregr.raw"

001 LBL "REGR"	057 ST0 00	113 RCL 13
002 LBL a	058 X<>Y	114 FS? 01
003 CF 00	059 ST0 01	115 RCL 12
004 CF 01	060 RCL 15	116 RCL 04
005 RTN	061 RCL 14	117 -
006 LBL F	062 X^2	118 ST0 05
007 SF 00	063 RCL 19	119 XEQ 6
008 LBL A	064 /	120 RCL 05
009 CLREG	065 -	121 X<>Y
010 RTN	066 ST0 10	122 /
011 LBL D	067 RCL 18	123 ST0 06
012 SF 01	068 RCL 14	124 FS? 01
013 LBL 01	069 RCL 16	125 GT0 04
014 STOP	070 *	126 RCL 12
015 FS? 00	071 RCL 19	127 RCL 13
016 LOG	072 /	128 -
017 STOP	073 -	129 ST0 07
018 ADV	074 ST0 11	130 RCL 19
019 X<>Y	075 RCL 10	131 RCL 20
020 ΣREG 14	076 /	132 -
021 Σ+	077 ST0 21	133 ST0 08
022 GT0 01	078 RCL 16	134 /
023 LBL C	079 RCL 21	135 ST0 22
024 CLREG	080 RCL 14	136 LBL 04
025 STOP	081 *	137 ADV
026 ST0 20	082 -	138 "ANVA"
027 ADV	083 RCL 19	139 AVIEW
028 LBL 02	084 /	140 ADV
029 STOP	085 ST0 23	141 "REG."
030 FS? 00	086 SF 13	142 AVIEW
031 LOG	087 "A"	143 1
032 ST0 21	088 XEQ 11	144 "D.L."
033 ADV	089 RCL 21	145 XEQ 11
034 LBL 00	090 "B"	146 ST0 24
035 STOP	091 XEQ 11	147 RCL 04
036 ST0+ 00	092 CF 13	148 "S.C."
037 RCL 21	093 ADV	149 XEQ 11
038 ΣREG 14	094 RCL 17	150 "C.M."
039 Σ+	095 RCL 16	151 XEQ 11
040 7ISZ	096 X^2	152 RCL 06
041 GT0 00	097 RCL 19	153 /
042 LBL B	098 /	154 ST0 16
043 RCL 00	099 ST0 22	155 "F"
044 "ΣY."	100 -	156 XEQ 11
045 XEQ 11	101 ST0 12	157 XEQ 6
046 ADV	102 FS? 01	158 ST0 26
047 X^2	103 GT0 03	159 XEQ 10
048 RCL 25	104 RCL 02	160 "DEV."
049 /	105 RCL 22	161 AVIEW
050 ST0+ 02	106 -	162 XEQ 6
051 0	107 ST0 13	163 ST0 24
052 ST0 00	108 LBL 03	164 "D.L."
053 ST0 25	109 RCL 11	165 XEQ 11
054 GT0 02	110 RCL 21	166 RCL 05
055 LBL G	111 *	167 "S.C."
056 MEAN	112 ST0 04	168 XEQ 11

Figure 9: First page of a program as printed to via the "File"->"Print Program..." option.

How to Select the Scanning Resolution?

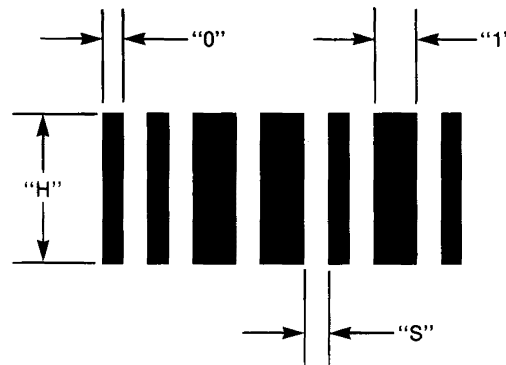
The nominal dimensions and tolerances are given in [1] and reprinted in Figure 10. The tolerances given in the HP specification correspond to a print resolution of about 300 dpi. At this resolution the tolerance amounts to approximately 1 dot and the suggested height equals 100 dots. A resolution of 300 dpi equals the then current laser printer technology.

Some tolerances are given relative to the unit width W , other tolerances are given in absolute values. The question arises how these tolerances add up and how we can safely distinguish between "0" and "1" values. We can apply the tolerances given in the documentation in a worst case sense. This means that we assume a narrow bar having its maximum width followed by a space having its minimum width and a wide bar having its minimum width followed by a space of the maximum width.

Taking all possible combinations of the nominal tolerances into account, the outcome is:

- a "0" should have between 60 and 111% of the space width,
- a "1" should have between 140 and 216% of the space width.

Any decoding software must be able to cope with these ranges to reliably recognize the barcode.



	WIDTH*	TOLERANCE	SUGGESTED VALUES
"S"	$W + .002''$	$\frac{W - 0.005''}{5}$	$0.022'' \pm 0.003''$
"0"	$W - .002''$	$\frac{W - 0.005''}{5}$	$0.018'' \pm 0.003''$
"1"	$2W - .002''$	$\frac{W - 0.005''}{5}$	$0.038'' \pm 0.003''$
"H"			$H > 0.35''$

*Bar widths are arbitrarily reduced by .002" to allow for the differences between bar width perception of the wand and the human eye.

Figure 10: Specification of barcodes dimensions according to [1].

More complications arise if we read barcodes from a scanned image. The given scanning resolution which leads to rounding of the sampled widths to the images raster with an additional tolerance of ± 0.5 pixels. If we take this additional tolerance into account we can determine whether we are safely able to distinguish between a narrow and a wide bar for a given image resolution and printed bar code width.

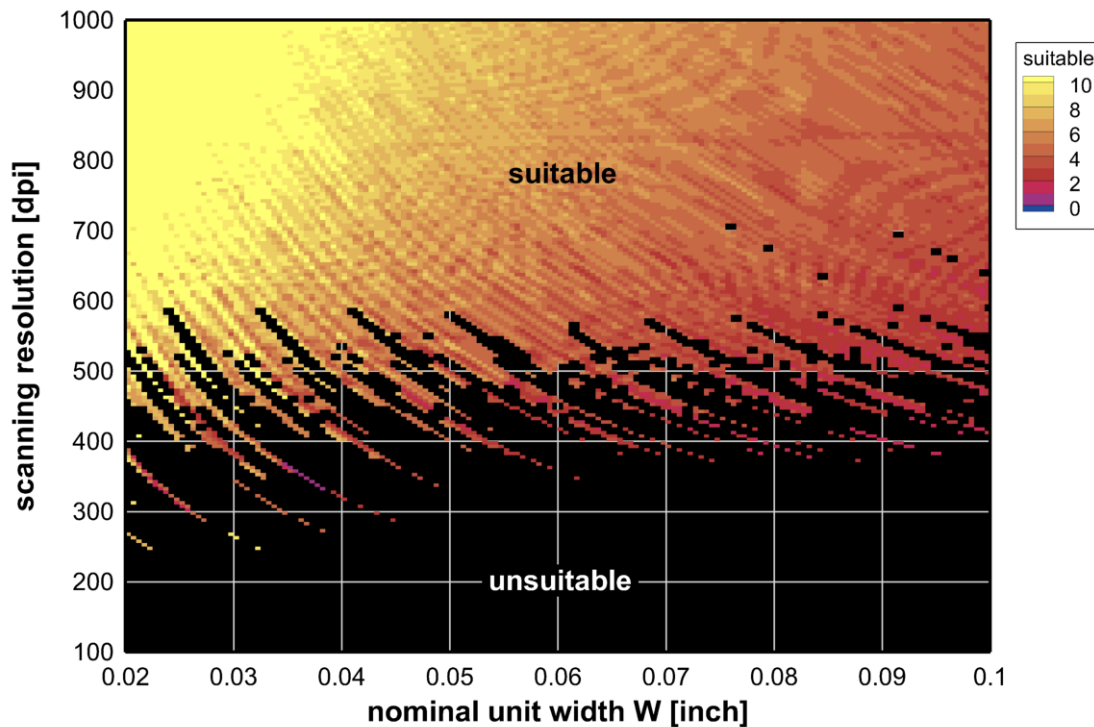
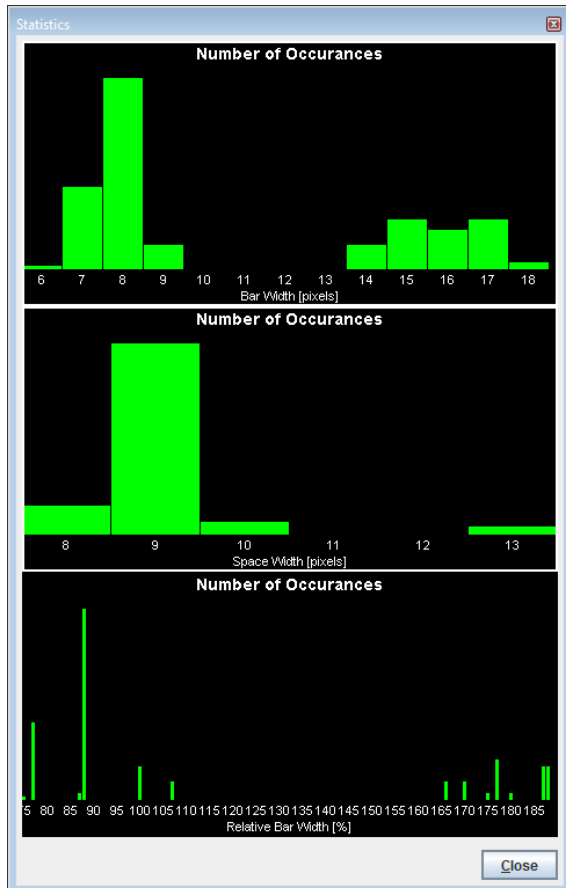


Figure 11: Capability to distinguish between narrow and wide bars depending on scan resolution and bar code unit width. The results represent a worst case scenario, typical results should be better.

Figure 11 shows a color coding of the difference between narrow and wide bars relative to the associated space width in percent. A value of zero means that we cannot distinguish between the two widths. Negative values mean that a wide bar appears narrower than a narrow bar – these regions are blanked out in black. We can see that a minimum resolution of about 600 dpi should almost always lead to satisfactory results. On the other hand resolutions below 300 dpi would almost always lead to problems. It is interesting that we obtain streaked patterns which are due to the discrete sampling (Mr. Shannon sends his best wishes). Note also that this is the worst case when all tolerances are in the most unfortunate combination.

In practical application I obtained acceptable results with 400 dpi black and white scans. For such images the tolerances amount to ± 1.2 dots, while a scan at 600 dpi results in tolerances of ± 1.8 dots. If we assume that our scanning process adds or drops one column of dots from the edge of a bar, a 400 dpi scan should be sufficient for recognition, albeit with no additional margin. Lower resolution scans cannot be safely decoded. However, they work if created accurately on a raster basis (one width unit exactly fits into the raster) so that no antialiasing occurs.

Statistical Properties of Bar Width Distributions



In the ideal case we would find only two bar widths: narrow and wide. However, the variation due to the printing and scanning processes leads to a spread of the bar widths. The distribution of the widths should show two narrow peaks, one centered on the narrow and one around the wide bars.

If the scan is of lower quality, the distributions will be wider and less focused. Such distributions make the recognition process more difficult because a variation exist for the spaces between the bars as well and a worst case combination can lead to the incorrect identification of a bar width.

Figure 12: Typical distribution of the bar and space width as obtained from a relatively poor print of a program line. The widths of bars and spaces show a considerable variation. The lowest chart shows the relative bar width, i.e. the ratio of bar width to the width of the immediately following space, expressed in percent. Due to integer math we see gaps between the bars.

In almost all cases errors are detected by comparing with the checksum. Often it is sufficient to rescan the bar at a slightly different position.

If this does not work it may be helpful to change the height of the scanning rectangle, sometimes a lower, sometimes a higher rectangle improves the recognition performance.

It is also helpful to align the barcode properly on the scanner or photocopier plate to minimize the effect of jagged edges.

Bar Width Distribution

For exporting in postscript format we define the nominal widths of the spaces and bars in default 1/72 inch units in accordance with [1] as:

```
/space 1.6 def
/narrow 1.3 def
/wide 2.7 def
/height 26 def
```

These values can be found in the exported Postscript files.

If we decode the barcode using a hand held scanner, the actual time resolution depends on the variable scanning speed. Therefore the width of a space has to be constantly recalculated. Only then can we determine whether we have seen a narrow or a wide bar.

If we have just scanned a narrow bar + space pair, we can calculate the nominal space width from

$$\text{spacewidth} = (\text{barwidth} + \text{spacewidth}) * 40 / 73$$

and if the current pair contained a wide bar we use

$$\text{spacewidth} = (\text{barwidth} + \text{spacewidth}) * 16 / 43$$

These equations yield a good approximation using only integer arithmetic. They allow for resolutions of up to 4800 dpi without exceeding the range of 16 bit integers. This is important if we want to implement a fast algorithm in a small microcontroller.

A technique useful to improve decoding reliability was the application of a slight relaxation to the space timing so that spurious noise is filtered out. The aim here is to track the variable timing but to avoid too large fluctuations. The BARCODEREADER application applies a sliding average over 4 samples of the space widths to reduce the risk of misinterpretation of single very short or long spaces.

Another measure to improve the reliability proved to be very useful: during the evaluation of the timing the distribution of bar widths is collected so that a probability distribution results. This allows to automatically re-adjust the detection threshold between narrow and wide bars. If decoding fails another pass over the already collected timing data can be started with the adjusted threshold value. This process can be repeated several times. In the BARCODEREADER application a maximum of five iterations is performed before the scan is declared unreadable.

Type		Header Length	Total Length	Description
Program	1	3	4+	non private program
Program	2	3	4+	private program
Execute	4	2	3+	direct execution of command
Data	6	1.5	3+	numeric to X register, BCD digits packed in nibbles, filled to minimum length resp. to next byte boundary with NULL nibbles
Data	7	2	3+	alphanumeric replace alpha register, 1 byte per character
Data	8	2	3+	alphanumeric append to alpha register, 1 byte per character
Data	9	3	4+	sequenced numeric to X register
Data	10	3	4+	sequenced alphanumeric replace alpha register
Data	11	3	4+	sequenced alphanumeric append to alpha register
Keyboard			1 or 2	alphanumeric characters, programmable and non-programmable functions, XROM functions

Table 2: Summary of bar code types recognized by BARCODEREADER. All lengths are in bytes.

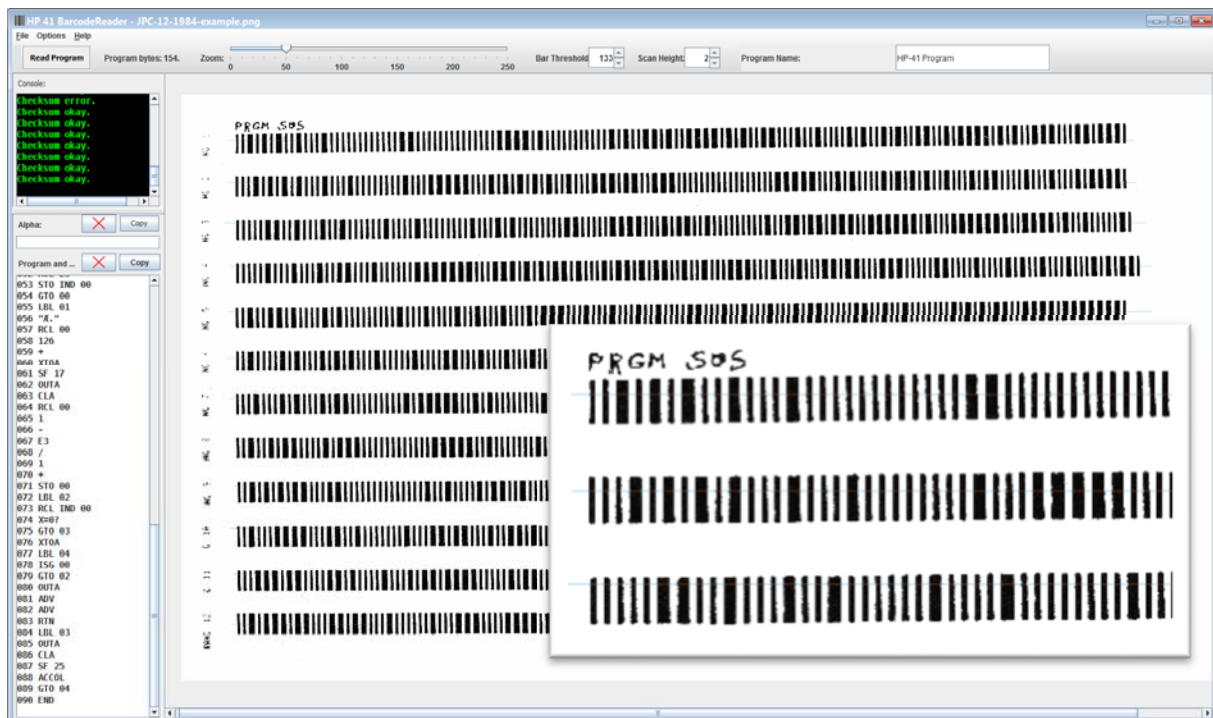


Figure 7: Example of successful scan of barcodes of very poor quality. Inset shows enlarged view of upper left corner of image. Parameter settings: threshold 133, scan height 2 pixels.

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