DataHolster project package

Dear Fluke 80 user:

Thank you for your interest in the DataHolster project as seen in the October 1993 issue of Circuit Cellar Ink. By now, you probably understand the power and versatility of the Fluke 80 series meters and want to further extend their capabilities into the realm of data acquisition. I am offering this information packet as a courtesy to Circuit Cellar readers in hopes that enthusiasts like you will find new and creative uses for the Fluke 80 series' ultrasonic output capabilities.

This packet should provide you with enough information to thoroughly understand the Fluke 80 series data format and how to use it. I have divided the information in this packet into five sections:

Main section:	Fluke 80 series data format explanation (you're reading page 1 of this section)
Appendix A:	Segment layouts and data format charts
Appendix B:	Sample data strings and display worksheets
Appendix C:	Software listings and memory map
Appendix D:	Schematics and parts list

After reading the Circuit Cellar article and this data packet, you should be able to construct and debug your own DataHolster and even extend the data logging capabilities beyond what appears in the article. This data package was written under the assumption that readers will have a basic understanding of microprocessors, communications systems, electronics, and the use of the Fluke 80 series meters.

I'm interested in hearing about your applications for this project. Please send correspondence, questions, and feedback to the E-mail address below. Good luck!

Derek Matsunaga

Disclaimers

(1) The John Fluke Mfg. Co., Inc. does not support the ultrasonic output on the Fluke 80 series meters. Please do not contact them with questions concerning this feature.

(2) The data presented in this package was obtained by reverse engineering and experimental methods. Although the author has made a considerable effort to assure its accuracy, the data is in no way guaranteed to be error free.

(3) This package contains copyrighted material. It may not be duplicated in any form, including by electronic means.

(4) The author offers no warranties, expressed or implied, as to the applicability or accuracy of this information for any purpose.

The basics of the "Ultrasonic Output" mode on the Fluke 80 series meters

The "Ultrasonic Output" mode is enable by pressing the meter's HOLD button for about two seconds while turning the meter on. A periodic "buzzing" noise will be heard when the meter is in this mode.

With the ultrasonic output enabled, the meter transmits the displayed data via its internal speaker. Naturally, all other audio indicators are non-functional when the meter is in this mode. The data output is heard as a "buzzing" noise which occurs about twice every second, depending on the measurement mode of the meter. When in Ultrasonic Output mode, the measurement rate of the meter is reduced by about half. Each occurrence of the "buzz" sound represents a string of 36 four bit words (nybbles) that contain information about which segments and annunciators (indicators) are lit-up on the meter's display.

The output signal is modulated on a carrier of about 16.6KHz. The bit time is approximately 1.3ms. Each four bit word is lead by a start bit (logical 1) and terminated by a stop bit (logical 0). This allows fairly accurate asynchronous detection because a word counter can be reset every time a start bit is received, thus eliminating timing error stack-up. A sample timing diagram is shown below:

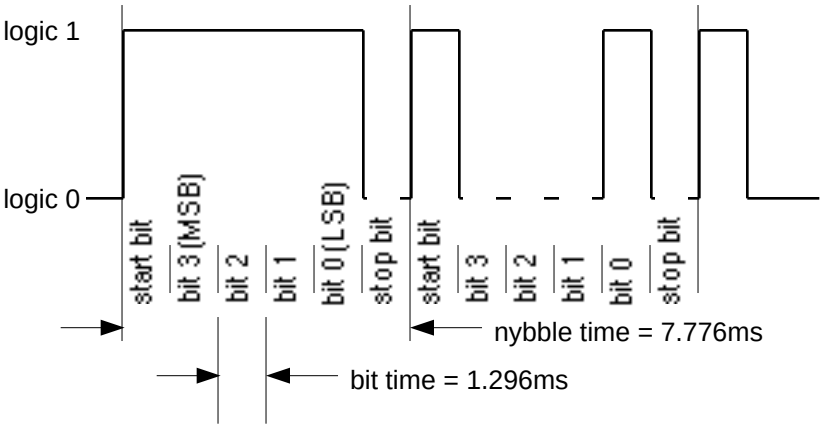


Figure 1: Nybble timing diagram

With the start bit, the stop bit, and four data bits each taking about 1.3ms, the total time to transmit a single word is 7.8ms. Since there are 36 words per data string, each string will require a total of about 280ms of transmission time. The time between data strings varies with the measurement mode of the meter, but it is always at least one word length (7.8ms).

Each string of data contains a three word header and a one word trailer, which leaves 32 words for actual measurement information. I'm not sure what the function of the header is, but the trailer word is a checksum for all previously transmitted words in the string.

Each bit of the 32 data words (128 bits total) indicates the status of a specific segment or annunciator on the meter's display. The bar graph segments are included in the transmission. An example of an entire record transmission is shown below:

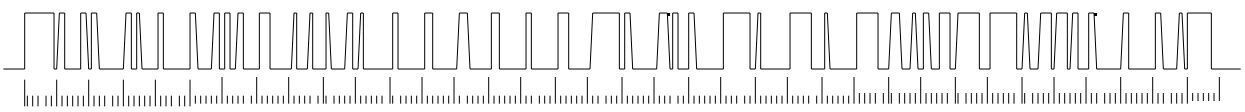


Figure 2: Example record

The large ticks on the scale represent the start bit for each nybble. The signal is representative of what would appear on U3B pin 7 (see the schematic in Appendix D) while acquiring a data record from the meter. It is then fed into the microprocessor for decoding, where the the microprocessor removes the start bits and stop bits and stores the data bits for later processing.

The data format

Once the microprocessor has acquired the data and stripped-off the start and stop bits, it must decode the data. Each data bit in the string represents the status of a specific segment on the meter's display. A logic 1 indicates that the segment is on while a logic zero indicates that the segment is off. So, the software must look for seven-segment "signatures" to decode the data.

The segment layouts and data formats are shown in Appendix A. Note that the data format for the 87 is different than that of the 83 and 85. Appendix B contains sample data strings and display worksheets so you can test your understanding of the data format. Using the data format charts to determine which segments are lit, fill-in the segments on the worksheet. The answers are on the last page of the Appendix B.

There are probably several ways in which to decode the numerical data, but one method is to combine the low and high segment nibbles into one 8 bit word and do comparisons with known "signatures". The software listings in Appendix C illustrate this method.

Using the checksum

The last nybble transmitted by the meter is a checksum derived from all previously transmitted nybbles. This number can be used to test the integrity of the received data.

The meter determines the checksum by adding-up all of the previously transmitted nybbles, masking-off everything but the lower four bits, and subtracting 1. For example, if the checksum nybble is 1100 (decimal 12), then the sum of all previously transmitted words would be 13. If the lower four bits of the sum is 0000 (decimal 0), then subtracting 1 should yield 1111 (decimal 15). The software makes this calculation (see code listings) and determines if the data is valid.

An actual example of this process is shown below. This example uses the Fluke 87: Sample #1 string from Appendix B.

nybble #	Segment register name	Binary value	Decimal value	Hex value
1	header 1	1111	15	$f
2	header 2	0001	1	$1
3	header 3	0000	0	$0
4	S0	1000	8	$8
5	S16	0000	0	$0
6	S1	0001	1	$1
7	S17	0100	4	$4
8	S2	1000	8	$8
9	S18	0000	0	$0
10	S3	0001	1	$1
11	S19	0000	0	$0
12	S4	0000	0	$0
13	S20	0000	0	$0
14	S5	1000	8	$8
15	S21	0000	0	$0
16	S6	0000	0	$0
17	S22	0000	0	$0
18	S7	1111	15	$f
19	S23	0000	0	$0
20	S8	1010	10	$a
21	S24	1000	8	$8
22	S9	1110	14	$e
23	S25	0000	0	$0
24	S10	1111	15	$f
25	S26	0000	0	$0

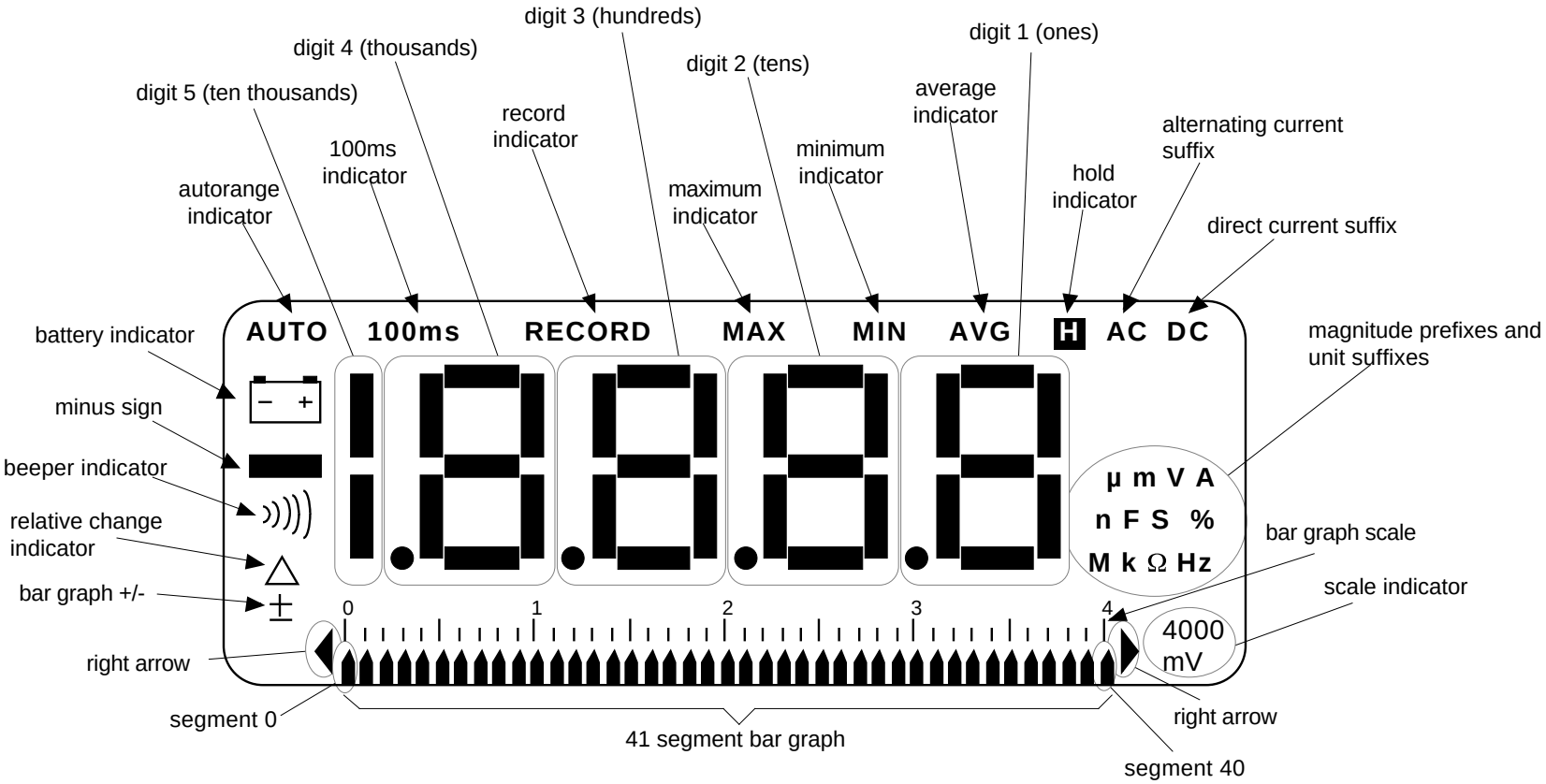
26	S11	1011	11	$b
27	S27	0000	0	$0
28	S12	0000	0	$0
29	S28	1100	12	$c
30	S13	1001	9	$9
31	S29	1101	13	$d
32	S14	0000	0	$0
33	S30	0000	0	$0
34	S15	0000	0	$0
35	S31	0001	1	$1
35	checksum	1001	9	$9
	total (minus checksum)	10011010	154	$9a

The total of all data words is 10011010 in 8 bit binary. To test the validity of the data, the upper four bits of the sum are masked (i.e. 10011010 • 00001111) to obtain the lower four bits of the sum. The four bit value of the sum is then 1010 (hex $0a, decimal 10). Now 1 is subtracted from this value to yield 1001 (hex $09, decimal 9). This value matches the checksum value (nybble 35) so the data is valid.

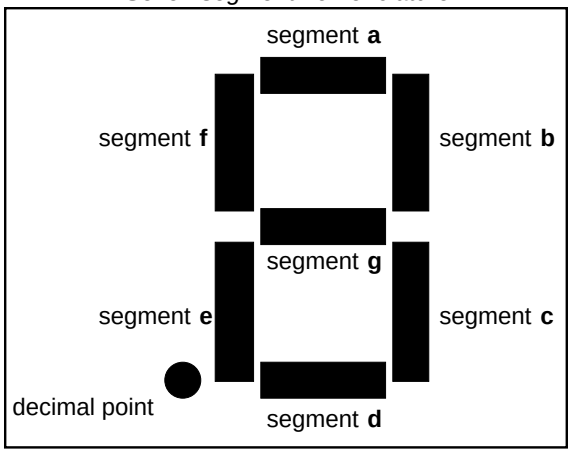
It should be noted that this checksum method is not bullet proof. It can only be guaranteed to detect a single fault in the data. However, other clever methods may be incorporated in the decoding software to increase the fault tolerance of the error detection. For instance, the software may check to determine if more than one units indicator is lit. If so, then the data is faulty. Similarly, the software may check for the presence of more than one magnitude indicator (such as kilo and nano at the same time). The software could also check for the presence of more than one decimal point, illegal seven segment signatures, etc.

Appendix A

Segment layouts and data format charts



Seven segment nomenclature



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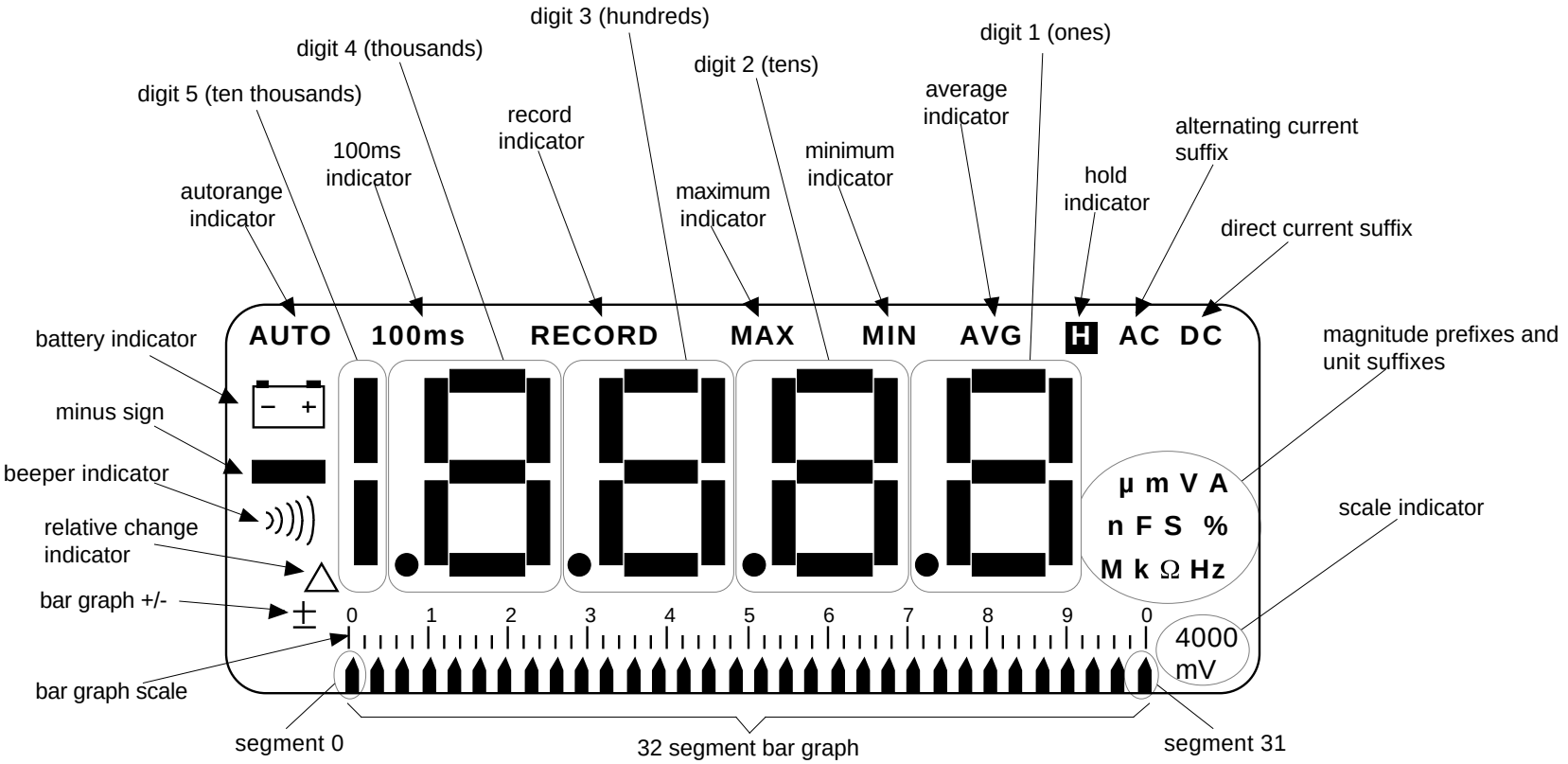
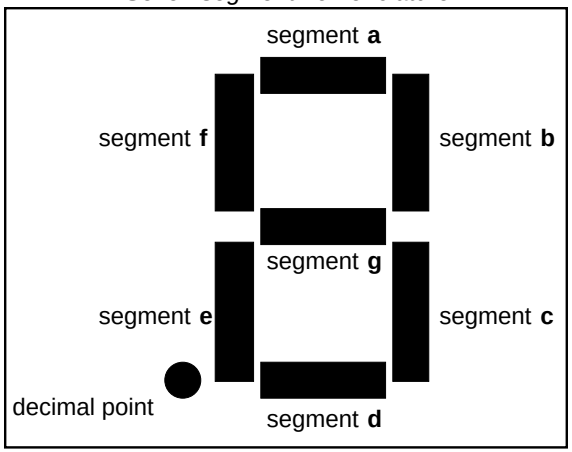
Nybble	Segment register name	Bit	Function
1	header 1	1	header (function unknown)
		2	header (function unknown)
		3	header (function unknown)
		4	header (function unknown)
2	header 2	5	header (function unknown)
		6	header (function unknown)
		7	header (function unknown)
		8	header (function unknown)
3	header 3	9	header (function unknown)
		10	header (function unknown)
		11	header (function unknown)
		12	header (function unknown)
4	S0	13	mV (scale millivolts indicator)
		14	4000 (scale indicator)
		15	DC (direct current suffix)
		16	AC (alternating current suffix)
5	S16	17	bar graph -
		18	Δ (relative change indicator)
		19	minus sign
		20	AUTO (autorange indicator)
6	S1	21	Hz (Hertz unit)
		22	% (percent indicator)
		23	A (Ampere unit)
		24	unused
7	S17	25	unused
		26	left arrow
		27	bar graph, segment 0
		28	unused
8	S2	29	Ω (Ohms unit)
		30	S (seconds unit)
		31	V (Volts unit)
		32	unused
9	S18	33	bar graph scale labels on/off
		34	bar graph, segment 1
		35	bar graph, segment 2
		36	bar graph, segment 3
10	S3	37	k (kilo prefix)
		38	F (Farads suffix)
		39	m (milli prefix)
		40	H (hold indicator)
11	S19	41	bar graph scale on/off
		42	bar graph, segment 6
		43	bar graph, segment 5
		44	bar graph, segment 4
12	S4	45	M (mega prefix)
		46	n (nano prefix)
		47	µ (micro prefix)
		48	AVG (average indicator)
13	S20	49	unused
		50	bar graph, segment 7
		51	bar graph, segment 8
		52	bar graph, segment 9
14	S5	53	unused
		54	unused
		55	MIN (minimum indicator)
		56	MAX (maximum indicator)
15	S21	57	unused
		58	bar graph, segment 12
		59	bar graph, segment 11
		60	bar graph, segment 10
16	S6	61	digit 1, segment d
		62	digit 1, segment c
		63	digit 1, segment b
		64	digit 1, segment a
17	S22	65	unused
		66	bar graph, segment 13
		67	bar graph, segment 14
		68	bar graph, segment 15
18	S7	69	digit 1, decimal point
		70	digit 1, segment e
		71	digit 1, segment g
		72	digit 1, segment f
19	S23	73	bar graph, segment 16
		74	bar graph, segment 19
		75	bar graph, segment 18
		76	bar graph, segment 17
20	S8	77	digit 2, segment d
		78	digit 2, segment c
		79	digit 2, segment b
		80	digit 2, segment a
21	S24	81	unused
		82	bar graph, segment 21
		83	bar graph, segment 20
		84	unused
22	S9	85	digit 2, decimal point
		86	digit 2, segment e
		87	digit 2, segment g
		88	digit 2, segment f
23	S25	89	unused
		90	bar graph, segment 22
		91	bar graph, segment 23
		92	bar graph, segment 24
24	S10	93	digit 3, segment d
		94	digit 3, segment c
		95	digit 3, segment b
		96	digit 3, segment a
25	S26	97	bar graph, segment 25
		98	bar graph, segment 28
		99	bar graph, segment 27
		100	bar graph, segment 26
26	S11	101	digit 3, decimal point
		102	digit 3, segment e
		103	digit 3, segment g
		104	digit 3, segment f
27	S27	105	unused
		106	bar graph, segment 29
		107	bar graph, segment 30
		108	unused
28	S12	109	digit 4, segment d
		110	digit 4, segment c
		111	digit 4, segment b
		112	digit 4, segment a
29	S28	113	bar graph, segment 34
		114	bar graph, segment 31
		115	bar graph, segment 32
		116	bar graph, segment 33
30	S13	117	digit 4, decimal point
		118	digit 4, segment e
		119	digit 4, segment g
		120	digit 4, segment f
31	S29	121	unused
		122	bar graph, segment 37
		123	bar graph, segment 36
		124	bar graph, segment 35
32	S14	125	digit 5, segments b and c
		126	100ms indicator digits "00"
		127	100ms indicator digits "ms"
		128	RECORD indicator
33	S30	129	bar graph, segment 38
		130	bar graph, segment 39
		131	bar graph, segment 40
		132	unused
34	S15	133	bar graph +
		134	beeper indicator
		135	battery indicator
		136	100ms indicator digit "1"
35	S31	137	4 (scale indicator)
		138	right arrow
		139	400 (scale indicator)
		140	40 (scale indicator)
36	checksum	141	checksum bit 3 (MSB)
		142	checksum bit 2
		143	checksum bit 1
		144	checksum bit 0 (LSB)

Fluke 83/85 Data Format Chart



Seven segment nomenclature



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Nybble	Segment register name	Bit	Function
1	header 1	1	header (function unknown)
		2	header (function unknown)
		3	header (function unknown)
		4	header (function unknown)
2	header 2	5	header (function unknown)
		6	header (function unknown)
		7	header (function unknown)
		8	header (function unknown)
3	header 3	9	header (function unknown)
		10	header (function unknown)
		11	header (function unknown)
		12	header (function unknown)
4	S0	13	AC (alternating current suffix)
		14	DC (direct current suffix)
		15	unused
		16	unused
5	S16	17	battery indicator
		18	minus sign
		19	beeper indicator
		20	digit 5, segments b and c
6	S1	21	A (Ampere unit)
		22	% (percent indicator)
		23	Hz (Hertz unit)
		24	4 (scale indicator)
7	S17	25	unused
		26	AUTO (autorange indicator)
		27	function unknown
		28	Δ (relative change indicator)
8	S2	29	V (Volts unit)
		30	S (seconds unit)
		31	Ω (Ohms unit)
		32	100ms record indicator
9	S18	33	unused
		34	bar graph -
		35	bar graph +
		36	unused
10	S3	37	m (milli prefix)
		38	F (Farads suffix)
		39	k (kilo prefix)
		40	bar graph scale on/off
11	S19	41	bar graph, segment 0
		42	bar graph, segment 1
		43	bar graph, segment 2
		44	bar graph, segment 3
12	S4	45	µ (micro prefix)
		46	n (nano prefix)
		47	M (mega prefix)
		48	DUTY (unused)
13	S20	49	bar graph, segment 7
		50	bar graph, segment 6
		51	bar graph, segment 5
		52	bar graph, segment 4
14	S5	53	H (hold indicator)
		54	unused
		55	unused
		56	unused
15	S21	57	bar graph, segment 8
		58	bar graph, segment 9
		59	bar graph, segment 10
		60	bar graph, segment 11
16	S6	61	AVG (average indicator)
		62	MIN (minimum indicator)
		63	MAX (maximum indicator)
		64	RECORD (record indicator)
17	S22	65	bar graph, segment 15
		66	bar graph, segment 14
		67	bar graph, segment 13
		68	bar graph, segment 12
18	S7	69	digit 1, segment c
		70	digit 1, segment d
		71	digit 1, segment a
		72	digit 1, segment b
19	S23	73	bar graph, segment 16
		74	bar graph, segment 17
		75	bar graph, segment 18
		76	bar graph, segment 19
20	S8	77	digit 1, segment e
		78	digit 1, decimal point
		79	digit 1, segment f
		80	digit 1, segment g
21	S24	81	bar graph, segment 23
		82	bar graph, segment 22
		83	bar graph, segment 21
		84	bar graph, segment 20
22	S9	85	digit 2, segment c
		86	digit 2, segment d
		87	digit 2, segment a
		88	digit 2, segment b
23	S25	89	bar graph, segment 24
		90	bar graph, segment 25
		91	bar graph, segment 26
		92	bar graph, segment 27
24	S10	93	digit 2, segment e
		94	digit 2, decimal point
		95	digit 2, segment f
		96	digit 2, segment g
25	S26	97	bar graph, segment 31
		98	bar graph, segment 30
		99	bar graph, segment 29
		100	bar graph, segment 28
26	S11	101	digit 3, segment c
		102	digit 3, segment d
		103	digit 3, segment a
		104	digit 3, segment b
27	S27	105	unused
		106	unused
		107	unused
		108	unused
28	S12	109	digit 3, segment e
		110	digit 3, decimal point
		111	digit 3, segment f
		112	digit 3, segment g
29	S28	113	unused
		114	unused
		115	unused
		116	unused
30	S13	117	digit 4, segment c
		118	digit 4, segment d
		119	digit 4, segment a
		120	digit 4, segment b
31	S29	121	unused
		122	unused
		123	unused
		124	unused
32	S14	125	digit 4, segment e
		126	digit 4, decimal point
		127	digit 4, segment f
		128	digit 4, segment g
33	S30	129	unused
		130	unused
		131	unused
		132	unused
34	S15	133	100ms indicator digit "1"
		134	100ms indicator digit "00"
		135	100ms indicator digit "m"
		136	100ms indicator digit "s"
35	S31	137	mV (scale millivolts indicator)
		138	4000 (scale indicator)
		139	400 (scale indicator)
		140	40 (scale indicator)
36	checksum	141	checksum bit 3 (MSB)
		142	checksum bit 2
		143	checksum bit 1
		144	checksum bit 0 (LSB)

Fluke 87 Data Format Chart

Appendix B

Sample data strings and display worksheets

Sample data strings

Fluke 87: Sample #1
1111 0001 0000 1000 0000 0001 0100 1000 0000 0001 0000 0000 0000 1000 0000 0000 0000 1111 0000 1010 1000 1110 0000 1111 0000 1011 0000 0000 1100 1001 1101 0000 0000 0000 0001 1001

Fluke 87: Sample #2
1111 0001 0000 0100 0100 0001 0100 1000 0100 0001 0100 0000 0000 0000 0000 0000 0000 1110 0000 1011 0000 1110 0000 0111 0000 1111 0000 1010 1100 1001 0111 0000 1111 0000 0001 0000

Fluke 87: Sample #3
1111 0001 0000 0100 0000 0001 0000 1000 0010 1001 0000 0000 0000 0000 0000 0000 0000 1111 0000 0101 0000 1110 0001 0011 0000 1111 0010 0011 1110 1111 1110 0001 0001 0000 1011 1001

Fluke 87: Sample #4
1111 0001 0000 0000 0000 0001 0100 0010 0010 0011 0001 0000 0000 1000 0000 0000 0000 1001 0000 0000 0000 1110 0000 1011 0000 1001 0010 0100 1110 0111 0000 1001 0001 0000 0000 0100

Fluke 87: Sample #5
1111 0001 0000 0000 0000 0000 0100 0000 0010 0100 0000 0100 0000 0000 0000 0000 0000 1110 0000 0011 0000 1111 0000 0101 0000 1111 1101 1010 0101 1111 0000 1010 0000 0000 0000 0110

Fluke 87: Sample #6
1111 0001 0000 0100 0000 1001 0100 0000 0010 1001 0100 0000 0000 1000 0000 0000 0000 0111 0000 1001 0000 1110 0000 0111 0000 1111 1000 1010 0110 1111 0000 1010 0000 0000 0001 1101

Fluke 87: Sample #7
1111 0001 0000 0100 0000 1001 0100 0000 0010 0001 0000 1000 0000 0000 0000 0000 0000 1001 1000 0011 0000 1001 0000 0000 0000 1110 0100 0011 0000 1111 0100 1010 0000 0000 0111 0001

Fluke 83/85: Sample #1
1111 0001 0000 0001 0001 0000 0010 0010 1111 0001 1111 0000 0111 0000 0111 1111 0111 0101 1001 1101 0000 1111 0000 0111 0000 0000 0000 0110 0000 0000 0000 0000 0000 0000 1001 1000

Fluke 83/85: Sample #2
1111 0001 0000 0010 1011 0000 0010 0010 1111 0000 1111 0000 0111 0000 0001 1101 0000 0111 0000 1101 0000 1011 0000 1111 0000 0101 0000 0110 0000 0000 0000 0000 0000 0000 1001 0101

Fluke 83/85: Sample #3
1111 0001 0000 1010 0000 0000 0010 0010 1111 0010 1111 0000 0111 0000 0111 1111 0111 1010 1111 1101 0110 0011 0111 1111 1111 0011 0110 1111 1111 0010 0111 0000 1100 1000 1011 0100

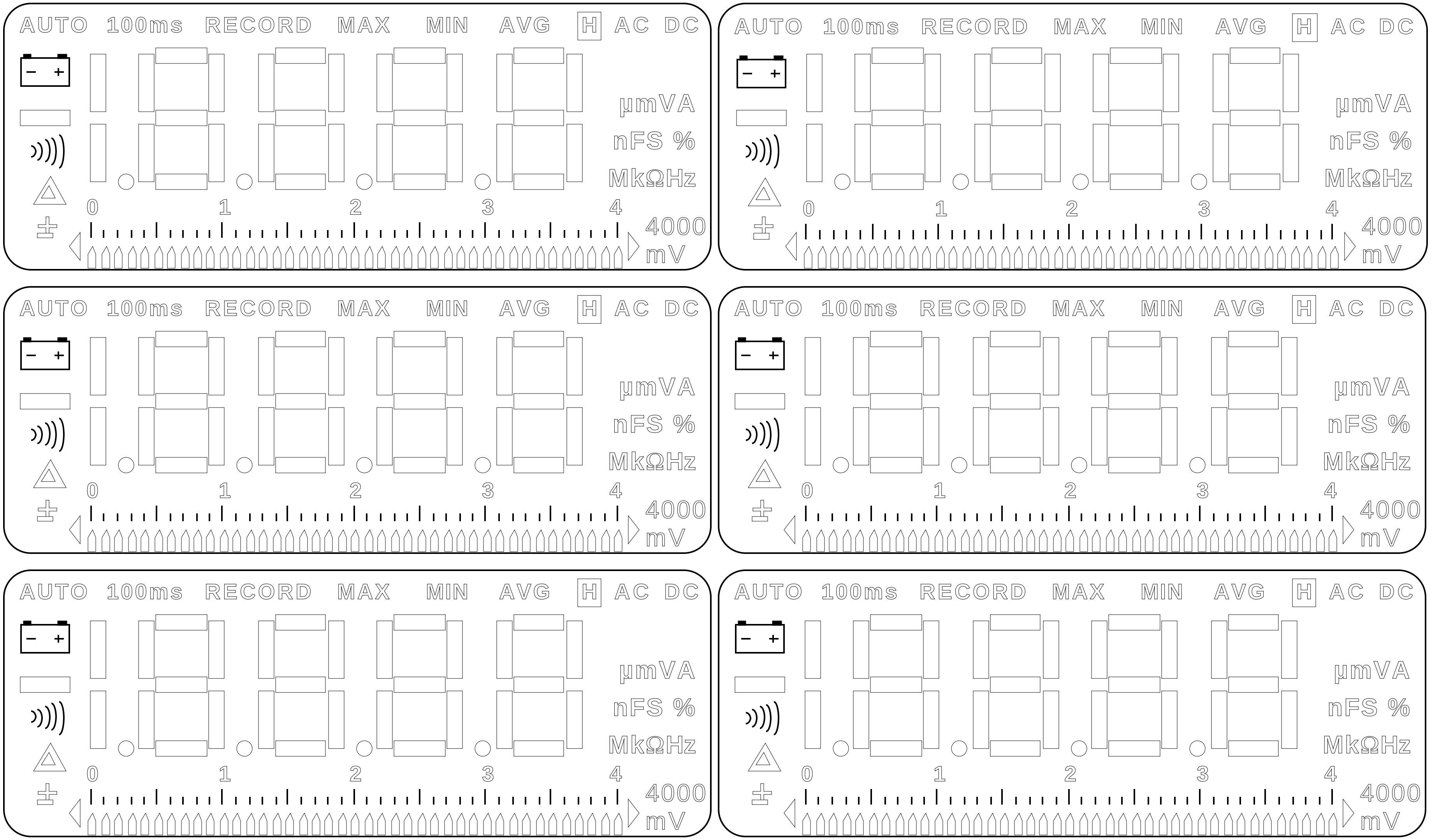
Fluke 83/85: Sample #4
1111 0001 0000 0000 0001 0000 0010 1000 1111 1001 1111 0000 0111 0000 0111 0110 0111 0000 1111 1101 0110 0111 0000 0110 0000 1000 0000 1011 0000 0110 0000 0000 0000 1000 1000 0100

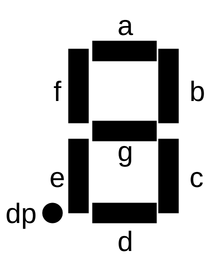
Fluke 83/85: Sample #5
1111 0001 0000 0000 0001 0000 0000 0000 0000 0100 0000 0100 0000 0000 0000 1101 0000 0011 0000 1111 0000 1010 0000 1111 0000 0101 0000 1111 0000 0101 0000 0000 0000 1000 0000 0001

Fluke 83/85: Sample #6
1111 0001 0000 0010 0001 0010 0010 0000 1000 0011 1000 0000 0000 0000 0000 1011 0000 0110 0000 1101 0000 1011 0000 1111 0000 0101 0000 1111 0000 0101 0000 0000 0000 1000 1001 1011

Fluke 83/85: Sample #7
1111 0001 0000 0110 0001 0010 0010 0000 1111 0000 1011 0010 0000 0000 0000 0110 0000 0011 0000 0110 0000 0000 0000 1101 0000 0011 0000 1111 0000 0101 0000 0000 0000 1000 1011 1100

Fluke 83/85: Sample #8
1111 0001 0000 0000 0001 0000 0010 1000 1111 0000 1111 1000 0111 0000 0111 0000 0111 0000 1111 1000 0110 1101 0111 1111 1111 0101 0110 0000 1111 0000 0111 0000 1110 0000 1101 0000





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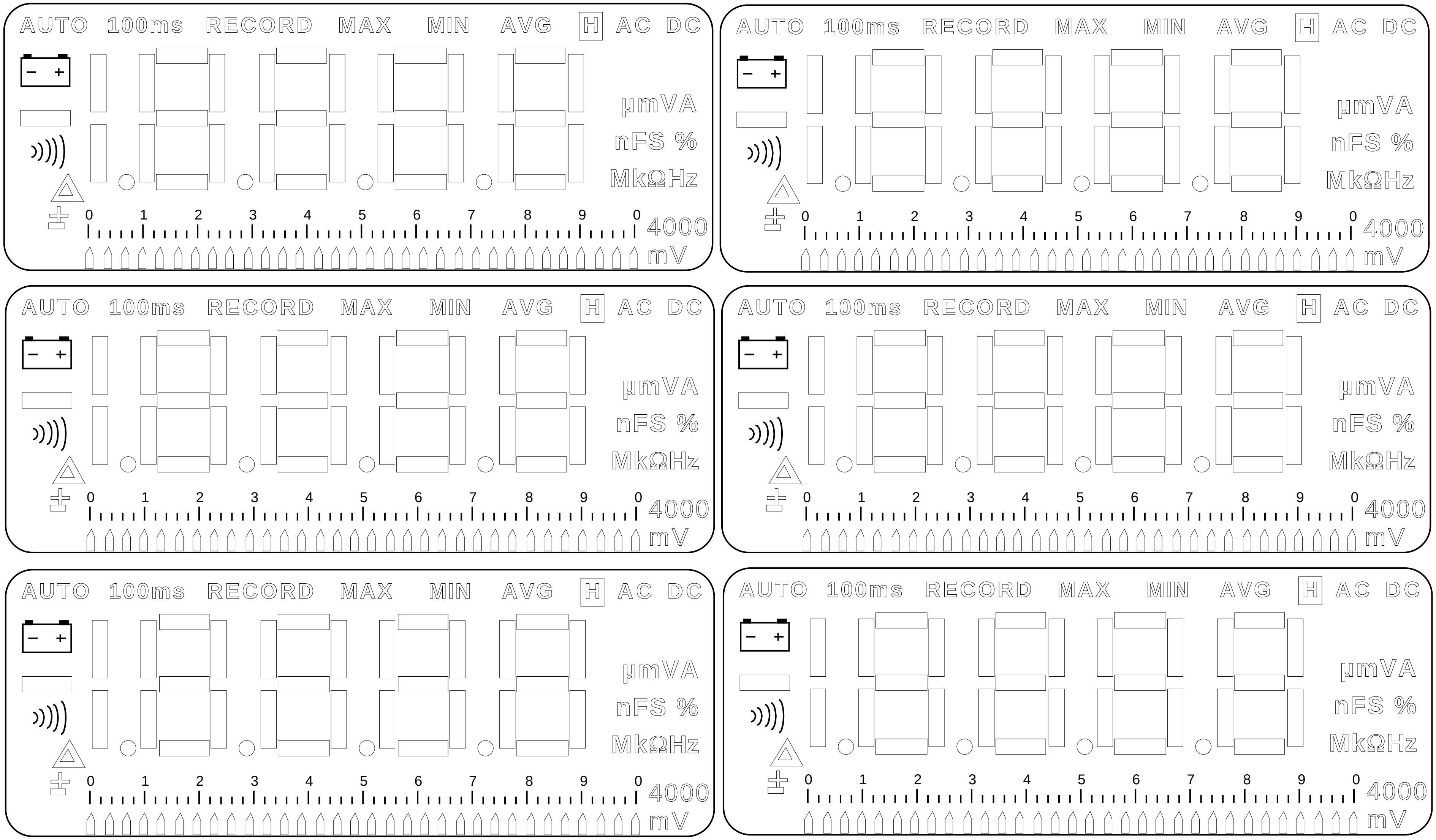

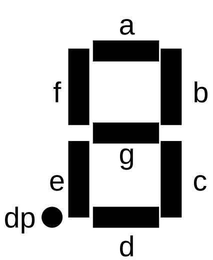

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Answers to sample data strings

Fluke 87: Sample #1
17.60VAC, HOLD, AUTO, bg 7.4, range 40

Fluke 87: Sample #2
-10.56VDC, AUTO, bg -.4, range 40

Fluke 87: Sample #3
395.3mvDC, AUTO, bg +8.8, range 400mV

Fluke 87: Sample #4
2.161kΩ, HOLD, AUTO, bg 1.0, range 4

Fluke 87: Sample #5
00.35nF, AUTO, bg+, no bar graph scale

Fluke 87: Sample #6
00.52mADC, HOLD, AUTO, bg+.4, range 40

Fluke 87: Sample #7
0514µADC, AUTO, bg +5.2, range 4000

Fluke 83/85: Sample #1
17.60VAC, HOLD, AUTO, bg 1.7, range 40

Fluke 83/85: Sample #2
-10.56VDC, AUTO, bg -1.0, range 40

Fluke 83/85: Sample #3
395.3mvDC, AUTO, bg +3.9, range 400mV

Fluke 83/85: Sample #4
2.161kΩ, AUTO, HOLD, bg +2.1, range 4

Fluke 83/85: Sample #5
00.35nF, AUTO, bg+, no bar graph scale

Fluke 83/85: Sample #6
00.52mADC, HOLD, AUTO, bg+0, range 40

Fluke 83/85: Sample #7
0514µADC, AUTO, bg+.5, range 4000

Fluke 83/85: Sample #8
OL, MΩ, AUTO, bg 4.0, range 40, right arrow

Appendix C

Software listings and memory map

DataHolster sourcecode RAM map

(see 68HC705K1 technical data for a complete system memory map)

Note: Some addresses are named more than once for code clarity (readability). This was done so that different functional sections of the sourcecode can refer to the same location by different (more meaningful) names than other sections. This memory map applies to both the Fluke 87 and Fluke 83/85 versions of the code.

Address	Name	Function during acquisition	Function during decoding	Function during serial output
$00e0	temp1	"high" counting byte	digit information	(not used)
$00e1	lcount	number of low cycles detected	(variable name not used)	(not used)
	lowS	(variable name not used)	the low S register	(not used)
$00e2	hcount	number of high cycles detected	(variable name not used)	(not used)
	highS	(variable name not used)	the high S register	(not used)
$00e3	scount	(variable name not used)	offset of next S register	(variable name not used)
	bitcount	number of bits acquired	(variable name not used)	the number of serial bits sent
$00e4	bytecount	number of bytes acquired	offset of next ASCII string byte	the number of ASCII bytes sent
$00e5	firstbyte	Fluke header	the base address of S register RAM	(variable name not used)
	string	(variable name not used)	the base address of string RAM	the base address of the output string
$00e6		S0	(not used)	(not used)
$00e7		S16,S1	(not used)	(not used)
$00e8		S17,S2	(not used)	(not used)
$00e9		S18,S3	(not used)	(not used)
$00ea		S19,S4	(not used)	(not used)
$00eb		S20,S5	(not used)	(not used)
$00ec		S21,S6	(not used)	(not used)
$00ed		S22,S7	(not used)	(not used)
$00ee		S23,S8	(not used)	(not used)
$00ef		S24,S9	(not used)	(not used)
$00f0		S25,S10	(not used)	(not used)
$00f1		S26,S11	(not used)	(not used)
$00f2		S27,S12	ASCII output byte 11	ASCII output byte 11
$00f3		S28,S13	ASCII output byte 10	ASCII output byte 10
$00f4		S29,S14	ASCII output byte 9	ASCII output byte 9
$00f5		S30,S15	ASCII output byte 8	ASCII output byte 8
$00f6		S31,Fluke checksum	ASCII output byte 7	ASCII output byte 7
$00f7		data checksum	ASCII output byte 6	ASCII output byte 6
$00f8		(not used)	ASCII output byte 5	ASCII output byte 5
$00f9		(not used)	ASCII output byte 4	ASCII output byte 4
$00fa		(not used)	ASCII output byte 3	ASCII output byte 3
$00fb		(not used)	ASCII output byte 2	ASCII output byte 2
$00fc		(not used)	ASCII output byte 1	ASCII output byte 1
$00fd		(not used)	ASCII output byte 0	ASCII output byte 0
$00fe		(not used)	program counter	(not used)
$00ff		(not used)	program counter	(not used)

```
****************************************
* Fluke 83/85 Data Acquisition sourcecode *
*                                      *
*          Author: Derek Matsunaga     *
*        Revision: 2.283               *
*   Revision date: October 2, 1993     *
*       Processor: 68HC705K1           *
*                                      *
*         ©1993 Derek Matsunaga        *
*                                      *
*   Revision 2.2 corrects serial timing.  *
****************************************

* Set-up 68HC05K1 equate table.

porta                equ          $0000                          ;Port a address.
portb                equ          $0001                          ;Port b address.
ddra                 equ          $0004                          ;Data direction register a.
ddrb                 equ          $0005                          ;Data direction register b.

* Define RAM locations.

                     org          $00e0                          ;The beginning of RAM.
temp1                equ          $00e0                          ;A general purpose temporary register.
lcount               equ          $00e1                          ;The register which keeps track of low time.
lowS                 equ          $00e1                          ;The low "S" register from the meter.
hcount               equ          $00e2                          ;The register which keeps track of high time.
highS                equ          $00e2                          ;The high "S" register from the meter.
scount               equ          $00e3                          ;The "S" register counter.
bitcount             equ          $00e3                          ;The number of bits per byte received.
bytecount            equ          $00e4                          ;The number of 8 bit bytes received (#18 max).
firstbyte            equ          $00e5                          ;The location of the first byte in the record.
string               equ          $00e5                          ;The start of the output string.
checksum             equ          $00f8                          ;The checksum register.


* Define vector table.

                     org          vectors
                     fdb          rom
                     fdb          rom
                     fdb          rom
                     fdb          reset

* Initialize ports and registers.

                     org          $0200                          ;The beginning of program ROM.
reset                lda          #$ff
                     sta          ddra                           ;Configure all porta pins as outputs.
                     sta          porta                          ;Write all ones to porta.
                     clr          ddrb                           ;Configure both portb pins as inputs.
                     clr          bytecount                      ;Initialize counting registers.
                     clr          bitcount
                     clr          checksum                       ;Clear the checksum register.

* Since each nibble begins with a "1" as a start bit, the deadtime during
* valid data transmission will not exceed the 7.8ms nibble time
* (1.3ms/bit * 6 bits).  So, a complete record of data has just been sent if deadtime
* exceeds the 7.8ms nibble time.  Use about 11ms of dead time to prevent false record triggering
* (for noise immunity).

* Look for about 11ms of deadtime before reading data.  Due to the length of the
* deadtime, a 16 bit counter is needed.  The "temp1" location is used to store the
* "high" byte (upper 8 bits) of the 16 bit counter.  The X register is used to store the "low"
* byte.

start                clrx                                        ;Clear the X register.
                     stx          temp1                          ;Clear the "high" byte of X.

loop                 brset        0,portb,start                  ;Loop & clear X until portb0 goes low.

                     decx                                        ;Decrement the X register.
                     bne          loop                           ;If X>0, go to top of loop.

                     inc          temp1                          ;Directly increment the high byte of the counter.
                     lda          temp1                          ;Load the new high byte into the accumulator.
                     cmp          #$08                           ;Temp1 will be 8 when about 11.3ms of
                                                                 ;   deadtime has occurred.
                     bne          loop

* About 11.3ms of deadtime has been detected at portb0.  We are now ready
* to start reading the data from the meter.  The beginning of the actual
* data occurs with a low to high transition following the deadtime.

* Wait until deadtime is over (a high is detected at portb0).
* Each nibble is started with a 1.3ms high (a startbit).

getstart             brclr        0,portb,getstart               ;Read portb0 until it goes high.

* When the high at portb0 is detected, initialize the timer locations.

nextbit              ldx          #$91                           ;Initialize the X register with the bit time.
                     clr          lcount                         ;Initialize the low count register.
                     clr          hcount                         ;Initialize the high count register.

timer                decx                                        ;Decrement X register to keep track of time.
```

```
                    beq         timeout                     ;Check portb until X=0 (the timer has expired).

chkport             brset       0,portb,high                ;Check for a high at portb0.

low                 inc         lcount                      ;Increment the low count location.
                    bra         timer                       ;Go back to timer.

high                inc         hcount                      ;Increment the high count location.
                    bra         timer                       ;Go back to timer.

timeout             lda         bitcount                    ;Load the bit counter.
                    cmp         #$00                        ;Determine if it is the start bit of the 1st nibble.
                    beq         housekeep                   ;Ignore this bit if it is the start bit.
                    cmp         #$05                        ;Determine if it is the start bit of the 2nd nibble.
                    beq         housekeep                   ;Ignore this bit if it is the start bit.

                    lda         lcount                      ;Load the number of low counts.
                    sub         hcount                      ;Subtract the number of high counts.
                                                            ;C will be set if there were more highs than lows.
                    ldx         bytecount                   ;Load the record pointer into X.
                    rol         firstbyte,x                 ;Roll the carry bit onto the current record byte.

housekeep           inc         bitcount                    ;Increment the number of bits read.
                    lda         bitcount                    ;Load the incremented value into A.
                    cmp         #$05                        ;If bitcount is #5, get ready for next nibble.
                    beq         add_chksum
                    cmp         #$0a                        ;If bitcount is #10, get ready for next byte.
                    bne         nextbit

add_chksum          lda         firstbyte,x
                    and         #$0f
                    add         checksum
                    sta         checksum

                    lda         bitcount
                    cmp         #$05
                    beq         getstart

nextbyte            inc         bytecount                   ;Increment the number of bytes read.
                    lda         bytecount                   ;Load the incremented number into A.
                    cmp         #$12                        ;Determine if #18 bytes have been read.
                    beq         cs_test                     ;Start processing data if #18 bytes have been read.
                    clr         bitcount                    ;Reset bitcount to zero.
                    bra         getstart                    ;Wait for the next start bit.

* The integrity of the received data is determined by cs_test.  The received data is considered
* good if the received checksum correlates with the calculated checksum.
* The checksum location contains the least significant nibble of the sum of all all nibbles received,
* including the meter's checksum nibble.  Because of this, the meter's checksum nibble must be
* subtracted from the calculated checksum prior to comparison.
* The meter's checksum is 1 less than the calculated checksum.  (i.e. a calculated checksum
* of $0f corresponds to a received checksum of $0e).

cs_test             lda         firstbyte+$11               ;Load S31 and the meter's checksum into A.
                    and         #$0f                        ;Remove S31.
                    sta         temp1                       ;Store the meter's checksum in temp1.

                    lda         checksum                    ;Load the calculated checksum into A.
                    sub         temp1                       ;Subtract the meter's checksum nibble.
                    deca                                    ;Subtract 1.
                    and         #$0f                        ;Knock-off the high nibble.

                    ldx         #$18                        ;Load the output string offset into X.
                    stx         bytecount                   ;Bytecount now points to the output string character.

                    cmp         temp1                       ;See if the calculated checksum matches the meter's
checksum.
                    beq         ol_test                     ;If so, procede with decoding.
                                                            ;If the checksums do not match, send an exclamation point
to
                                                            ;   indicate a checksum error.
                    lda         #$21                        ;Load the ASCII value for an exclamation point (!).
                    sta         string,x                    ;Store it as the first character in the output string.
                    decx                                    ;Decrement the string pointer.
                    jmp         sendstring                  ;Send the exclamation point and restart the program.

* The following code segment, ol_test, determines if the overload message is on the
* display.  To accomplish this, the tens digit is checked for an "L".  If the "L" exists,
* then it is not necessary to process anything else.  If not, then proceed with the
* numeric decoding.  Note: the bottom leg of the "L" character is unique in S9 so it is used
* to check for the entire "L".

ol_test             lda         firstbyte+$09               ;Load S8.
                    and         #$0f                        ;Knock-off the high nibble.
                    cmp         #$08                        ;Check for the bottom leg of the "L" character.
                    bne         sign                        ;Go to the sign routine if the "L" does not exist.
                    jmp         overload                    ;Go to the overload routine if the "L" exists.

* No overload has been detected so now we can decode the display digits.

* The sign routine checks the acquired data for a minus sign.  If the minus sign is present, the routine
* stores the ASCII value of a minus sign as the first byte of the output string.  If not, the program proceeds
* to decode the ten-thousands digit.

sign                brclr       5,firstbyte+$02,ten_k       ;See if the sign bit is clear.
                    lda         #$2d                        ;Load the ASCII value for a minus sign.
```



```
                    jsr         outbyte                         ;Store a minus sign as the first byte in the output.

* The only digit that can appear in the ten-thousands place is a "1".  The ten_k routine checks for the presence
* of a "1".  Note that this digit will only be filled when the meter is in four digit mode.  If a "1" exists, it is
* stored as the next character in the output string.  If not, the program proceeds to decode the remaining four
* digits.

ten_k               brclr       3,firstbyte+$0f,start_thou      ;See if there is a 1 in the ten-thousands place.
                    lda         #$31                            ;Load the ASCII value for a "1".
                    jsr         outbyte                         ;Store the "1" in the output string.

* Start_thou is the beginning of the decoding routine for the remaining four display digits.


start_thou          stx         bytecount                       ;Store the output string pointer.
                    ldx         #$0e                            ;Load X with the offset of the first S register.
                    stx         scount                          ;Store it in scount.

thousands           ldx         scount                          ;Load the current scount value into X.
                    cpx         #$06                            ;See if it is the last S register.
                    bne         continue                        ;If it is the last S register, decode the magnitude.
                    bra         magnitude

continue            lda         firstbyte,x                     ;Load S13 the 1st time, S11, S9, S7.
                    sta         highS                           ;Store it in highS.
                    decx                                        ;Decrement scount.
                    lda         firstbyte,x                     ;Load S12 the 1st time, S10, S8, S6.
                    sta         lowS                            ;Store it in lowS.
                    decx                                        ;Decrement scount.
                    stx         scount                          ;Store scount.
                    ldx         bytecount                       ;Load the current output string offset into X.

display             lda         highS                           ;Load the high S register.
                    asla                                        ;Move the 4 LSBs to the MSBs.
                    asla
                    asla
                    asla
                    sta         temp1                           ;Store it in temp1.
                    lda         lowS                            ;Load the low S register.
                    and         #$0f                            ;Knock-off the 4MSBs.
                    ora         temp1                           ;Now we have a byte which represents the digit.
                    sta         temp1                           ;Store this byte in temp1.

* The dptest routine checks the digit to see if the decimal point is lit.  If it is, dptest stores the
* ASCII value of a decimal point at the current output string location.  If not, it proceeds to decode the
* numerals.

dptest              brclr       7,temp1,numerals                ;Test for a decimal point.
                    lda         #$2e                            ;The ASCII value for a period (decimal point).
                    jsr         outbyte                         ;Store it in the current output string location.

numerals            lda         temp1                           ;Load the digit information into A.
                    and         #$7f                            ;Get rid of the decimal point bit.
                    stx         bytecount                       ;Store the output string offset because the X register
                                                                ;   is needed for numeric decoding.

                    clrx
compare             cmp         #$5f                            ;Test for a "0".
                    beq         storechar                       ;If a "0" is present, go to the storechar routine.
                    incx                                        ;Increment X if a zero is not present.
                    cmp         #$06                            ;Test for a "1".
                    beq         storechar                       ;If a "1" is present, go to the storechar routine.
                    incx                                        ;Increment X if a one is not present.
                    cmp         #$6b                            ;Test for a "2".
                    beq         storechar                       ;If a "2" is present, go to the storechar routine.
                    incx                                        ;Increment X if a two is not present.
                    cmp         #$2f                            ;Test for a "3".
                    beq         storechar                       ;If a "3" is present, go to the storechar routine.
                    incx                                        ;Increment X if a three is not present.
                    cmp         #$36                            ;Test for a "4".
                    beq         storechar                       ;If a "4" is present, go to the storechar routine.
                    incx                                        ;Increment X if a four is not present.
                    cmp         #$3d                            ;Test for a "5".
                    beq         storechar                       ;If a "5" is present, go to the storechar routine.
                    incx                                        ;Increment X if a five is not present.
                    cmp         #$7d                            ;Test for a "6".
                    beq         storechar                       ;If a "6" is present, go to the storechar routine.
                    incx                                        ;Increment X if a six is not present.
                    cmp         #$07                            ;Test for a "7".
                    beq         storechar                       ;If a "7" is present, go to the storechar routine.
                    incx                                        ;Increment X if a seven is not present.
                    cmp         #$7f                            ;Test for an "8".
                    beq         storechar                       ;If an "8" is present, go to the storechar routine.
                    incx                                        ;Increment X if an eight is not present.
                    cmp         #$3f                            ;Test for a "9".
                    bne         thousands                       ;If an "9" is present, go to the storechar routine.
                                                                ;All numeric possibilities have been tested for.  If none
of them
                                                                ;  exist, proceed to decode the next digit.

storechar           txa                                         ;Transfer the X register to A.  The X register contains
                                                                ;A value indicative of the numeral on the display.
                    add         #$30                            ;Add X to the ASCII value for a "0".
                    ldx         bytecount                       ;Load X with a current output string offset.
                    sta         string,x                        ;Store the ASCII value of the displayed numeral at the
current
```



```
                                                        ;   output string position.
                    dec         bytecount               ;Decrement the output string pointer.
                    bra         thousands               ;Repeat the numeric decoding process for the remaining
digits.

* The overload routine stores the ASCII values for "OL" at the current output string location.

overload            lda         #$4f                    ;The ASCII value of an "O"
                    jsr         outbyte                 ;Store it in the current output string location.
                    lda         #$4c                    ;The ASCII value of an "L"
                    jsr         outbyte                 ;Store it in the current output string location.
                    lda         #$20                    ;The ASCII value of a space
                    jsr         outbyte                 ;Store it in the current output string location.
                    stx         bytecount               ;Store the current output string offset.

* The magnitude routine checks the appropriate S registers for magnitude indicators such as mega, kilo, milli, etc.
* Each magnitude designator has its own ASCII storage routine similar to that of the overload routine.

magnitude           ldx         bytecount
                    brset       1,firstbyte+$05,micro   ;Check S4 for a "micro" sign.
                    brset       2,firstbyte+$05,nano    ;Check S4 for a "nano" sign.
                    brset       3,firstbyte+$05,mega    ;Check S4 for a "mega" sign.
                    brset       1,firstbyte+$04,milli   ;Check S3 for a "milli" sign.
                    brset       3,firstbyte+$04,kilo    ;Check S3 for a "kilo" sign
                    bra         units                   ;Go to the units routine if no magnitude designators
                                                        ;   are detected.

* The outbyte subroutine stores the contents of the accumulator at the current output string location.
* On entry, the X register must contain the offset relative to the string location (see equate table).
* The X register is decremented to prepare for the next output string byte.

outbyte             sta         string,x                ;Store the accumulator at string+x.
                    decx                                ;Decrement X.
                    rts                                 ;Return to caller.

* The following routines store the ASCII values of the magnitude designators.  These routines are entered
* from the magnitude routine.

micro               lda         #$75                    ;Load the ASCII values for a "u".
                    bra         storemag                ;Go to the magnitude storing routine.
nano                lda         #$6e                    ;Load the ASCII values for an "n".
                    bra         storemag                ;Go to the magnitude storing routine.
mega                lda         #$4d                    ;Load the ASCII values for an "M".
                    bra         storemag                ;Go to the magnitude storing routine.
milli               lda         #$6d                    ;Load the ASCII values for an "m".
                    bra         storemag                ;Go to the magnitude storing routine.
kilo                lda         #$4b                    ;Load the ASCII values for a "K".

storemag            jsr         outbyte                 ;Go to the ASCII byte storing subroutine.

* The units routine checks the appropriate S registers for unit indicators such as farads, volts, ohms, etc.
* Each unit designator has its own ASCII storage routine similar to that of the overload routine.

units               brset       2,firstbyte+$04,farads  ;Check S3 for a farads indicator.
                    brset       1,firstbyte+$03,volts   ;Check S2 for a volts indicator.
                    brset       2,firstbyte+$03,seconds ;Check S2 for a seconds indicator.
                    brset       3,firstbyte+$03,ohms    ;Check S2 for a ohms indicator.
                    brset       1,firstbyte+$02,amps    ;Check S1 for a amps indicator.
                    brset       2,firstbyte+$02,percent ;Check S1 for a percent indicator.
                    brset       3,firstbyte+$02,hertz   ;Check S1 for a hertz indicator.
                    bra         comments                ;Jump to the comments routine if no units indicators were
                                                        ;   detected.

* The following routines store the ASCII values of the units designators.  These routines are entered
* from the unit routine.

farads              lda         #$46                    ;The ASCII value of "F".
                    bra         storeunit
volts               lda         #$56                    ;The ASCII value of "V".
                    bra         storeunit
seconds             lda         #$73                    ;The ASCII value of "s".
                    bra         storeunit
ohms                lda         #$6f                    ;The ASCII value of "o".
                    jsr         outbyte
                    lda         #$68                    ;The ASCII value of "h".
                    jsr         outbyte
                    lda         #$6d                    ;The ASCII value of "m".
                    jsr         outbyte
                    bra         seconds                 ;Pluralize "ohm" using the "s" from the seconds routine to
                                                        ;   save ROM space.
amps                lda         #$41                    ;The ASCII value of "A".
                    bra         storeunit
percent             lda         #$25                    ;The ASCII value of "%".
                    bra         storeunit
hertz               lda         #$48                    ;The ASCII value of "H".
                    jsr         outbyte
                    lda         #$7a                    ;The ASCII value of "z".

storeunit           jsr         outbyte

* The comments routine detects the "AC" and "DC" annunciators.

comments            brset       0,firstbyte+$01,alternate ;Check S0 for the alternating current annunciator.
                    brset       1,firstbyte+$01,direct  ;Check S0 for the direct current annunciator.
                    bra         sendstring              ;Jump to the serial output routine if neither of these
exist.
```



```
alternate       lda     #$41                    ;The ASCII value of "A".
                jsr     outbyte                 ;Store the "A" at the current output string location.
                bra     current                 ;Jump to the routine to store a "C".
direct          lda     #$44                    ;The ASCII value of "D".
                jsr     outbyte                 ;Store the "D" at the current output string location.
current         lda     #$43                    ;The ASCII value of "C".
                jsr     outbyte                 ;Store the "D" at the current output string location.

* The sendstring routine terminates the output string with a <CR> and sends the output string, in serial format at
* 9600bps 8N1, to porta bit 0 (where the MAX 232A serial driver is connected).

sendstring      lda     #$0d                    ;The ASCII value of a <CR>.
                sta     string,x                ;Store the <CR> at the current output string location.  The
<CR>
                                                ;   provides a carriage return and serves as the output
string
                                                ;   terminator.

                lda     #$18                    ;Load the offset of the first character in the output
string.
                sta     bytecount               ;Store it in bytecount.

serstart        ldx     #$08                    ;The number of bits in a byte.
                stx     bitcount                ;Store it in bitcount.

startbit        clr     porta                   ;Send a start bit.
                ldx     #$1e                    ;Load X as a countdown register with the serial bit time.
startdly        decx
                bne     startdly                ;Loop until the serial bit time has expired.

                ldx     bytecount               ;Load X with the current output string offset.
                lda     string,x                ;Load A with the current output string character.

sendbit         sta     porta                   ;The bit of interest is stored at porta bit 0.
                ldx     #$1e                    ;Load X as a countdown register with the serial bit time.
bitdelay        decx
                bne     bitdelay                ;Loop until the serial bit time has expired.
                rora                            ;Rotate the data byte to get the next bit of interest into
                                                ;   the LSB of A.
                dec     bitcount                ;Decrement bitcount.
                bne     sendbit                 ;Repeat the bit shifting if eight data bits have not yet
been sent.

stopbit         bset    0,porta                 ;Send a stop bit.

bytedelay       decx                            ;Delay before next character. (X is $00 on entry)
                bne     bytedelay               ;Loop until the interbyte delay has expired.
                ldx     bytecount               ;Load X with the current output string offset.
                lda     string,x                ;Load the current output string character into A.
                cmp     #$0d                    ;See if it is the <CR> termination character.
                beq     end                     ;If it is the termination character, exit the sendserial
routine.
                dec     bytecount               ;Update the current output string offset.
                bra     serstart                ;Send the next byte in the output string.

end             jmp     reset                   ;Go to the beginning of the program and start the entire
                                                ;   process again.
```



```
**************************************
* Fluke 87 Data Acquisition sourcecode *
*                                    *
*        Author: Derek Matsunaga     *
*      Revision: 2.2                 *
* Revision date: October 2, 1993     *
*     Processor: 68HC705K1           *
*                                    *
*        ©1993 Derek Matsunaga       *
*                                    *
* Revision 2.2 corrects serial timing. *
**************************************

* Set-up 68HC05K1 equate table.

porta                equ          $0000                          ;Port a address.
portb                equ          $0001                          ;Port b address.
ddra                 equ          $0004                          ;Data direction register a.
ddrb                 equ          $0005                          ;Data direction register b.

* Define RAM locations.

                     org          $00e0                          ;The beginning of RAM.
temp1                equ          $00e0                          ;A general purpose temporary register.
lcount               equ          $00e1                          ;The register which keeps track of low time.
lowS                 equ          $00e1                          ;The low "S" register from the meter.
hcount               equ          $00e2                          ;The register which keeps track of high time.
highS                equ          $00e2                          ;The high "S" register from the meter.
scount               equ          $00e3                          ;The "S" register counter.
bitcount             equ          $00e3                          ;The number of bits per byte received.
bytecount            equ          $00e4                          ;The number of 8 bit bytes received (#18 max).
firstbyte            equ          $00e5                          ;The location of the first byte in the record.
string               equ          $00e5                          ;The start of the output string.
checksum             equ          $00f8                          ;The checksum register.

* Define vector table.

                     org          vectors
                     fdb          rom
                     fdb          rom
                     fdb          rom
                     fdb          reset

* Initialize ports and registers.

                     org          $0200                          ;The beginning of program ROM.
reset                lda          #$ff
                     sta          ddra                           ;Configure all porta pins as outputs.
                     sta          porta                          ;Write all ones to porta.
                     clr          ddrb                           ;Configure both portb pins as inputs.
                     clr          bytecount                      ;Initialize counting registers.
                     clr          bitcount
                     clr          checksum                       ;Clear the checksum register.

* Since each nibble begins with a "1" as a start bit, the deadtime during
* valid data transmission will not exceed the 7.8ms nibble time
* (1.3ms/bit * 6 bits, see explanation diagram).  So, a complete record of
* data has just been sent if deadtime exceeds the 7.8ms nibble time.  Use
* about 11ms of dead time to prevent false record triggering (for noise immunity).

* Look for about 11ms of deadtime before reading data.  Due to the length of the
* deadtime, a 16 bit counter is needed.  The "temp1" location is used to store the
* "high" byte (upper 8 bits) of the 16 bit counter.  The X register is used to store the "low"
* byte.  See sourcecode validation for detailed timing information.

start                clrx                                        ;Clear the X register.
                     stx          temp1                          ;Clear the "high" byte of X.

loop                 brset        0,portb,start                  ;Loop & clear X until portb0 goes low.

                     decx                                        ;Decrement the X register.
                     bne          loop                           ;If X>0, go to top of loop.

                     inc          temp1                          ;Directly increment the high byte of the counter.
                     lda          temp1                          ;Load the new high byte into the accumulator.
                     cmp          #$08                           ;Temp1 will be 8 when about 11.3ms of
                                                                 ;   deadtime has occurred.
                     bne          loop

* About 11.3ms of deadtime has been detected at portb0.  We are now ready
* to start reading the data from the meter.  The beginning of the actual
* data occurs with a low to high transition following the deadtime.

* Wait until deadtime is over (a high is detected at portb0).
* Each nibble is started with a 1.3ms high (a startbit).

getstart             brclr        0,portb,getstart               ;Read portb0 until it goes high.

* When the high at portb0 is detected, initialize the timer locations.

nextbit              ldx          #$91                           ;Initialize the X register with the bit time.
                     clr          lcount                         ;Initialize the low count register.
                     clr          hcount                         ;Initialize the high count register.

timer                decx                                        ;Decrement X register to keep track of time.
                     beq          timeout                        ;Check portb until X=0 (the timer has expired).
```

```
chkport         brset   0,portb,high            ;Check for a high at portb0.

low             inc     lcount                  ;Increment the low count location.
                bra     timer                   ;Go back to timer.

high            inc     hcount                  ;Increment the high count location.
                bra     timer                   ;Go back to timer.

timeout         lda     bitcount                ;Load the bit counter.
                cmp     #$00                    ;Determine if it is the start bit of the 1st nibble.
                beq     housekeep               ;Ignore this bit if it is the start bit.
                cmp     #$05                    ;Determine if it is the start bit of the 2nd nibble.
                beq     housekeep               ;Ignore this bit if it is the start bit.

                lda     lcount                  ;Load the number of low counts.
                sub     hcount                  ;Subtract the number of high counts.
                                                ;C will be set if there were more highs than lows.
                ldx     bytecount               ;Load the record pointer into X.
                rol     firstbyte,x             ;Roll the carry bit onto the current record byte.

housekeep       inc     bitcount                ;Increment the number of bits read.
                lda     bitcount                ;Load the incremented value into A.
                cmp     #$05                    ;If bitcount is #5, get ready for next nibble.
                beq     add_chksum
                cmp     #$0a                    ;If bitcount is #10, get ready for next byte.
                bne     nextbit

add_chksum      lda     firstbyte,x
                and     #$0f
                add     checksum
                sta     checksum

                lda     bitcount
                cmp     #$05
                beq     getstart

nextbyte        inc     bytecount               ;Increment the number of bytes read.
                lda     bytecount               ;Load the incremented number into A.
                cmp     #$12                    ;Determine if #18 bytes have been read.
                beq     cs_test                 ;Start processing data if #18 bytes have been read.
                clr     bitcount                ;Reset bitcount to zero.
                bra     getstart                ;Wait for the next start bit.

* The integrity of the received data is determined by cs_test.  The received data is considered
* good if the received checksum correlates with the calculated checksum.
* The checksum location contains the least significant nibble of the sum of all all nibbles received,
* including the meter's checksum nibble.  Because of this, the meter's checksum nibble must be
* subtracted from the calculated checksum prior to comparison.
* The meter's checksum is 1 less than the calculated checksum.  (i.e. a calculated checksum
* of $0f corresponds to a received checksum of $0e).

cs_test         lda     firstbyte+$11           ;Load S31 and the meter's checksum into A.
                and     #$0f                    ;Remove S31.
                sta     temp1                   ;Store the meter's checksum in temp1.

                lda     checksum                ;Load the calculated checksum into A.
                sub     temp1                   ;Subtract the meter's checksum nibble.
                deca                            ;Subtract 1.
                and     #$0f                    ;Knock-off the high nibble.

                ldx     #$18                    ;Load the output string offset into X.
                stx     bytecount               ;Bytecount now points to the output string character.

                cmp     temp1                   ;See if the calculated checksum matches the meter's
checksum.
                beq     ol_test                 ;If so, procede with decoding.
                                                ;If the checksums do not match, send an exclamation point
to
                                                ;   indicate a checksum error.
                lda     #$21                    ;Load the ASCII value for an exclamation point (!).
                sta     string,x                ;Store it as the first character in the output string.
                decx                            ;Decrement the string pointer.
                jmp     sendstring              ;Send the exclamation point and restart the program.

* The following code segment, ol_test, determines if the overload message is on the
* display.  To accomplish this, the tens digit is checked for an "L".  If the "L" exists,
* then it is not necessary to process anything else.  If not, then proceed with the
* numeric decoding.  Note: the bottom leg of the "L" character is unique in S9 so it is used
* to check for the entire "L".

ol_test         lda     firstbyte+$0a           ;Load S9.
                and     #$0f                    ;Knock-off the high nibble.
                cmp     #$04                    ;Check for the bottom leg of the "L" character.
                bne     sign                    ;Go to the sign routine if the "L" does not exist.
                jmp     overload                ;Go to the overload routine if the "L" exists.

* No overload has been detected so now we can decode the display digits.

* The sign routine checks the acquired data for a minus sign.  If the minus sign is present, the routine
* stores the ASCII value of a minus sign as the first byte of the output string.  If not, the program proceeds
* to decode the ten-thousands digit.

sign            brclr   6,firstbyte+$02,ten_k   ;See if the sign bit is clear.
                lda     #$2d                    ;Load the ASCII value for a minus sign.
                jsr     outbyte                 ;Store a minus sign as the first byte in the output.
```



```
* The only digit that can appear in the ten-thousands place is a "1".  The ten_k routine checks for the presence
* of a "1".  Note that this digit will only be filled when the meter is in four digit mode.  If a "1" exists, it is
* stored as the next character in the output string.  If not, the program proceeds to decode the remaining four
* digits.

ten_k                brclr       4,firstbyte+$02,start_thou      ;See if there is a 1 in the ten-thousands place.
                     lda         #$31                            ;Load the ASCII value for a "1".
                     jsr         outbyte                         ;Store the "1" in the output string.

* Start_thou is the beginning of the decoding routine for the remaining four display digits.


start_thou           stx         bytecount                       ;Store the output string pointer.
                     ldx         #$0f                            ;Load X with the offset of the first S register.
                     stx         scount                          ;Store it in scount.

thousands            ldx         scount                          ;Load the current scount value into X.
                     cpx         #$07                            ;See if it is the last S register.
                     bne         continue                        ;If it is the last S register, decode the magnitude.
                     bra         magnitude

continue             lda         firstbyte,x                     ;Load S14 the 1st time, S12, S10, S8.
                     sta         highS                           ;Store it in highS.
                     decx                                        ;Decrement scount.
                     lda         firstbyte,x                     ;Load S13 the 1st time, S11, S9, S7.
                     sta         lowS                            ;Store it in lowS.
                     decx                                        ;Decrement scount.
                     stx         scount                          ;Store scount.
                     ldx         bytecount                       ;Load the current output string offset into X.

display              lda         highS                           ;Load the high S register.
                     asla                                        ;Move the 4 LSBs to the MSBs.
                     asla
                     asla
                     asla
                     sta         temp1                           ;Store it in temp1.
                     lda         lowS                            ;Load the low S register.
                     and         #$0f                            ;Knock-off the 4MSBs.
                     ora         temp1                           ;Now we have a byte which represents the digit.
                     sta         temp1                           ;Store this byte in temp1.

* The dptest routine checks the digit to see if the decimal point is lit.  If it is, dptest stores the
* ASCII value of a decimal point at the current output string location.  If not, it proceeds to decode the
* numerals.

dptest               brclr       6,temp1,numerals                ;Test for a decimal point.
                     lda         #$2e                            ;The ASCII value for a period (decimal point).
                     jsr         outbyte                         ;Store it in the current output string location.

numerals             lda         temp1                           ;Load the digit information into A.
                     and         #$bf                            ;Get rid of the decimal point bit.
                     stx         bytecount                       ;Store the output string offset because the X register
                                                                 ;   is needed for numeric decoding.

                     clrx
compare              cmp         #$af                            ;Test for a "0".
                     beq         storechar                       ;If a "0" is present, go to the storechar routine.
                     incx                                        ;Increment X if a zero is not present.
                     cmp         #$09                            ;Test for a "1".
                     beq         storechar                       ;If a "1" is present, go to the storechar routine.
                     incx                                        ;Increment X if a one is not present.
                     cmp         #$97                            ;Test for a "2".
                     beq         storechar                       ;If a "2" is present, go to the storechar routine.
                     incx                                        ;Increment X if a two is not present.
                     cmp         #$1f                            ;Test for a "3".
                     beq         storechar                       ;If a "3" is present, go to the storechar routine.
                     incx                                        ;Increment X if a three is not present.
                     cmp         #$39                            ;Test for a "4".
                     beq         storechar                       ;If a "4" is present, go to the storechar routine.
                     incx                                        ;Increment X if a four is not present.
                     cmp         #$3e                            ;Test for a "5".
                     beq         storechar                       ;If a "5" is present, go to the storechar routine.
                     incx                                        ;Increment X if a five is not present.
                     cmp         #$be                            ;Test for a "6".
                     beq         storechar                       ;If a "6" is present, go to the storechar routine.
                     incx                                        ;Increment X if a six is not present.
                     cmp         #$0b                            ;Test for a "7".
                     beq         storechar                       ;If a "7" is present, go to the storechar routine.
                     incx                                        ;Increment X if a seven is not present.
                     cmp         #$bf                            ;Test for an "8".
                     beq         storechar                       ;If an "8" is present, go to the storechar routine.
                     incx                                        ;Increment X if an eight is not present.
                     cmp         #$3f                            ;Test for a "9".
                     bne         thousands                       ;If an "9" is present, go to the storechar routine.
                                                                 ;All numeric possibilities have been tested for.  If none
of them
                                                                 ;  exist, proceed to decode the next digit.

storechar            txa                                         ;Transfer the X register to A.  The X register contains
                                                                 ;A value indicative of the numeral on the display.
                     add         #$30                            ;Add X to the ASCII value for a "0".
                     ldx         bytecount                       ;Load X with a current output string offset.
                     sta         string,x                        ;Store the ASCII value of the displayed numeral at the
current
                                                                 ;   output string position.
```



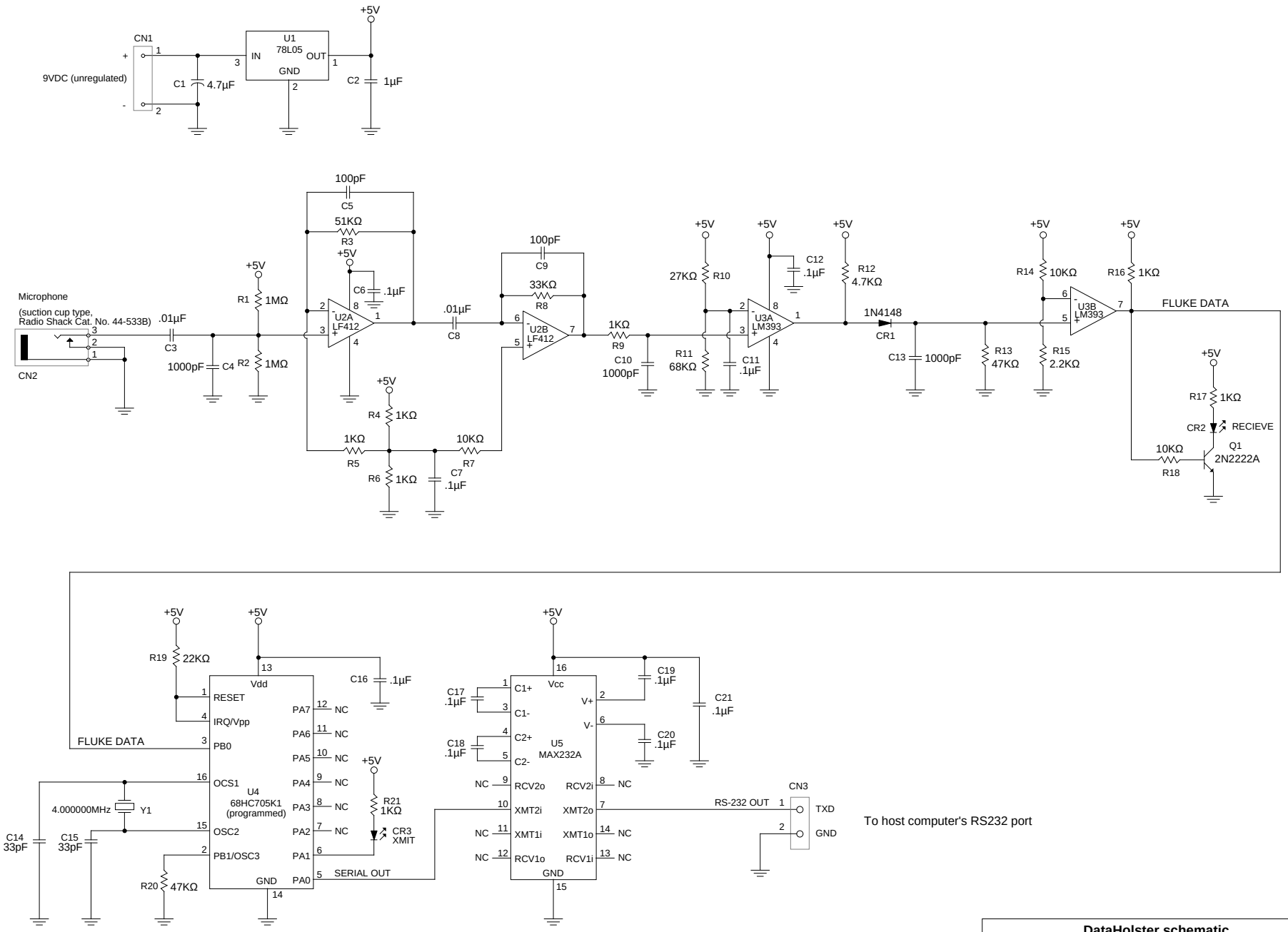
```
                    dec         bytecount                   ;Decrement the output string pointer.
                    bra         thousands                   ;Repeat the numeric decoding process for the remaining
digits.

* The overload routine stores the ASCII values for "OL" at the current output string location.

overload            lda         #$4f                        ;The ASCII value of an "O"
                    jsr         outbyte                     ;Store it in the current output string location.
                    lda         #$4c                        ;The ASCII value of an "L"
                    jsr         outbyte                     ;Store it in the current output string location.
                    lda         #$20                        ;The ASCII value of a space
                    jsr         outbyte                     ;Store it in the current output string location.
                    stx         bytecount                   ;Store the current output string offset.

* The magnitude routine checks the appropriate S registers for magnitude indicators such as mega, kilo, milli, etc.
* Each magnitude designator has its own ASCII storage routine similar to that of the overload routine.

magnitude           ldx         bytecount
                    brset       3,firstbyte+$05,micro       ;Check S4 for a "micro" sign.
                    brset       2,firstbyte+$05,nano        ;Check S4 for a "nano" sign.
                    brset       1,firstbyte+$05,mega        ;Check S4 for a "mega" sign.
                    brset       3,firstbyte+$04,milli       ;Check S3 for a "milli" sign.
                    brset       1,firstbyte+$04,kilo        ;Check S3 for a "kilo" sign
                    bra         units                       ;Go to the units routine if no magnitude designators
                                                            ;   are detected.

* The outbyte subroutine stores the contents of the accumulator at the current output string location.
* On entry, the X register must contain the offset relative to the string location (see equate table).
* The X register is decremented to prepare for the next output string byte.

outbyte             sta         string,x                    ;Store the accumulator at string+x.
                    decx                                    ;Decrement X.
                    rts                                     ;Return to caller.

* The following routines store the ASCII values of the magnitude designators.  These routines are entered
* from the magnitude routine.

micro               lda         #$75                        ;Load the ASCII values for a "u".
                    bra         storemag                    ;Go to the magnitude storing routine.
nano                lda         #$6e                        ;Load the ASCII values for an "n".
                    bra         storemag                    ;Go to the magnitude storing routine.
mega                lda         #$4d                        ;Load the ASCII values for an "M".
                    bra         storemag                    ;Go to the magnitude storing routine.
milli               lda         #$6d                        ;Load the ASCII values for an "m".
                    bra         storemag                    ;Go to the magnitude storing routine.
kilo                lda         #$4b                        ;Load the ASCII values for a "K".

storemag            jsr         outbyte                     ;Go to the ASCII byte storing subroutine.

* The units routine checks the appropriate S registers for unit indicators such as farads, volts, ohms, etc.
* Each unit designator has its own ASCII storage routine similar to that of the overload routine.

units               brset       2,firstbyte+$04,farads      ;Check S3 for a farads indicator.
                    brset       3,firstbyte+$03,volts       ;Check S2 for a volts indicator.
                    brset       2,firstbyte+$03,seconds     ;Check S2 for a seconds indicator.
                    brset       1,firstbyte+$03,ohms        ;Check S2 for a ohms indicator.
                    brset       3,firstbyte+$02,amps        ;Check S1 for a amps indicator.
                    brset       2,firstbyte+$02,percent     ;Check S1 for a percent indicator.
                    brset       1,firstbyte+$02,hertz       ;Check S1 for a hertz indicator.
                    bra         comments                    ;Jump to the comments routine if no units indicators were
                                                            ;   detected.

* The following routines store the ASCII values of the units designators.  These routines are entered
* from the unit routine.

farads              lda         #$46                        ;The ASCII value of "F".
                    bra         storeunit
volts               lda         #$56                        ;The ASCII value of "V".
                    bra         storeunit
seconds             lda         #$73                        ;The ASCII value of "s".
                    bra         storeunit
ohms                lda         #$6f                        ;The ASCII value of "o".
                    jsr         outbyte
                    lda         #$68                        ;The ASCII value of "h".
                    jsr         outbyte
                    lda         #$6d                        ;The ASCII value of "m".
                    jsr         outbyte
                    bra         seconds                     ;Pluralize "ohm" using the "s" from the seconds routine to
                                                            ;   save ROM space.
amps                lda         #$41                        ;The ASCII value of "A".
                    bra         storeunit
percent             lda         #$25                        ;The ASCII value of "%".
                    bra         storeunit
hertz               lda         #$48                        ;The ASCII value of "H".
                    jsr         outbyte
                    lda         #$7a                        ;The ASCII value of "z".

storeunit           jsr         outbyte

* The comments routine detects the "AC" and "DC" annunciators.

comments            brset       3,firstbyte+$01,alternate   ;Check S0 for the alternating current annunciator.
                    brset       2,firstbyte+$01,direct      ;Check S0 for the direct current annunciator.
                    bra         sendstring                  ;Jump to the serial output routine if neither of these
exist.
```



```
alternate           lda         #$41                        ;The ASCII value of "A".
                    jsr         outbyte                     ;Store the "A" at the current output string location.
                    bra         current                     ;Jump to the routine to store a "C".
direct              lda         #$44                        ;The ASCII value of "D".
                    jsr         outbyte                     ;Store the "D" at the current output string location.
current             lda         #$43                        ;The ASCII value of "C".
                    jsr         outbyte                     ;Store the "D" at the current output string location.

* The sendstring routine terminates the output string with a <CR> and sends the output string, in serial format at
* 9600bps 8N1, to porta bit 0 (where the MAX 232A serial driver is connected).

sendstring          lda         #$0d                        ;The ASCII value of a <CR>.
                    sta         string,x                    ;Store the <CR> at the current output string location.  The
<CR>
                                                            ;   provides a carriage return and serves as the output
string
                                                            ;   terminator.

                    lda         #$18                        ;Load the offset of the first character in the output
string.
                    sta         bytecount                   ;Store it in bytecount.

serstart            ldx         #$08                        ;The number of bits in a byte.
                    stx         bitcount                    ;Store it in bitcount.

startbit            clr         porta                       ;Send a start bit.
                    ldx         #$20                        ;Load X as a countdown register with the serial bit time.
startdly            decx
                    bne         startdly                    ;Loop until the serial bit time has expired.

                    ldx         bytecount                   ;Load X with the current output string offset.
                    lda         string,x                    ;Load A with the current output string character.


sendbit             sta         porta                       ;The bit of interest is stored at porta bit 0.
                    ldx         #$20                        ;Load X as a countdown register with the serial bit time.
bitdelay            decx
                    bne         bitdelay                    ;Loop until the serial bit time has expired.
                    rora                                    ;Rotate the data byte to get the next bit of interest into
                                                            ;   the LSB of A.
                    dec         bitcount                    ;Decrement bitcount.
                    bne         sendbit                     ;Repeat the bit shifting if eight data bits have not yet
been sent.

stopbit             bset        0,porta                     ;Send a stop bit.

bytedelay           decx                                    ;Delay before next character. (X is $00 on entry)
                    bne         bytedelay                   ;Loop until the interbyte delay has expired.
                    ldx         bytecount                   ;Load X with the current output string offset.
                    lda         string,x                    ;Load the current output string character into A.
                    cmp         #$0d                        ;See if it is the <CR> termination character.
                    beq         end                         ;If it is the termination character, exit the sendserial
routine.
                    dec         bytecount                   ;Update the current output string offset.
                    bra         serstart                    ;Send the next byte in the output string.

end                 jmp         reset                       ;Go to the beginning of the program and start the entire
                                                            ;   process again.
```


Appendix D

Schematics and parts list



DataHolster schematic	
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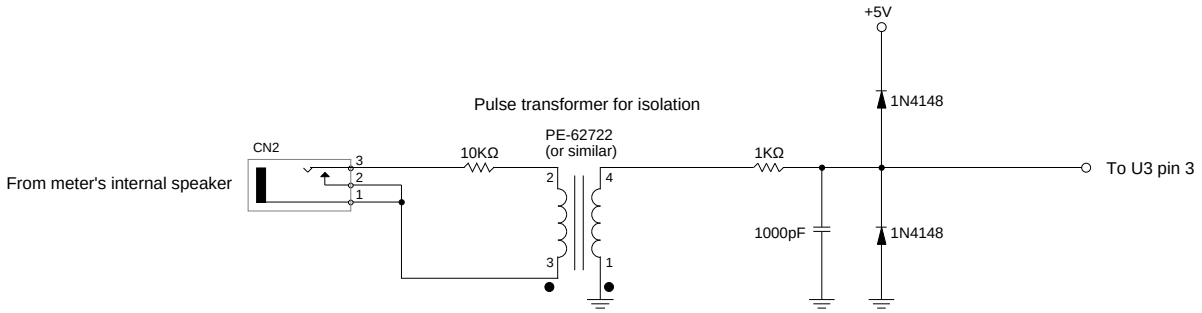
Alternate construction for hardwire interface. Eliminate amplifier front-end from page 1 and replace it with the circuit below. R10 and R11 may need to be adjusted depending on the turns ratio of the transformer.



Component list

Designator	Component	Type	Value
C1	capacitor	tantalum	4.7µF
C2	capacitor	ceramic	1µF
C3	capacitor	ceramic	.01µF
C4	capacitor	ceramic	1000pF
C5	capacitor	ceramic	100pF
C6	capacitor	ceramic	.1µF
C7	capacitor	ceramic	.1µF
C8	capacitor	ceramic	.01µF
C9	capacitor	ceramic	100pF
C10	capacitor	ceramic	1000pF
C11	capacitor	ceramic	.1µF
C12	capacitor	ceramic	.1µF
C13	capacitor	ceramic	1000pF
C14	capacitor	ceramic	33pF
C15	capacitor	ceramic	33pF
C16	capacitor	ceramic	.1µF
C17	capacitor	ceramic	.1µF
C18	capacitor	ceramic	.1µF
C19	capacitor	ceramic	.1µF
C20	capacitor	ceramic	.1µF
C21	capacitor	ceramic	.1µF
CN1	connector	DC adapter	2 pin
CN2	connector	1/8" phone	2 pin
CN3	connector	3/32" phone	2 pin
CR1	diode	general purpose	1N4148
CR2	LED	T1 3/4	red
CR3	LED	T1 3/4	red
Q1	transistor	NPN	2N2222A

Designator	Component	Type	Value
R1	resistor	1/4 watt, 5%	1MΩ
R2	resistor	1/4 watt, 5%	1MΩ
R3	resistor	1/4 watt, 5%	51kΩ
R4	resistor	1/4 watt, 5%	1kΩ
R5	resistor	1/4 watt, 5%	1kΩ
R6	resistor	1/4 watt, 5%	1kΩ
R7	resistor	1/4 watt, 5%	10kΩ
R8	resistor	1/4 watt, 5%	33kΩ
R9	resistor	1/4 watt, 5%	1kΩ
R10	resistor	1/4 watt, 5%	27kΩ
R11	resistor	1/4 watt, 5%	68kΩ
R12	resistor	1/4 watt, 5%	4.7kΩ
R13	resistor	1/4 watt, 5%	47kΩ
R14	resistor	1/4 watt, 5%	10kΩ
R15	resistor	1/4 watt, 5%	2.2kΩ
R16	resistor	1/4 watt, 5%	1kΩ
R17	resistor	1/4 watt, 5%	1kΩ
R18	resistor	1/4 watt, 5%	10kΩ
R19	resistor	1/4 watt, 5%	22kΩ
R20	resistor	1/4 watt, 5%	47kΩ
R21	resistor	1/4 watt, 5%	1kΩ
U1	voltage regulator	100mA	78L05
U2	op amp	dual JFET	LF412
U3	comparator	dual open collector	LM393
U4	microcontroller	16 pin, programmed	68HC705K1
U5	RS-232 driver	16 pin, 5V only	MAX232A
Y1	crystal		4.000000MHz