Cadetwriter

The following is a presentation about the Cadetwriter given at the Vintage Computer Festival West 2019. The actual presentation can be viewed at:

https://www.youtube.com/watch?v=f5bpK3Gou1Q

Developed as a by-product of the Computer History Museum's IBM 1620 Jr. project, the Cadetwriter is a general-purpose ASCII terminal. It can be connected via RS-232 or USB to any mini, micro, mainframe, or replica computer as a terminal device. A commercial quality IBM/Lexmark Wheelwriter 1000 was adapted by interposing a circuit board containing a Teensy 3.5 microcontroller between the typewriter's keyboard and motherboard. Custom firmware controls the typewriter and communicates with the host computer. To support the full ASCII character set, characters not on the printwheel are synthesized using overprinted characters and "period graphics". The Cadetwriter can print up to 16cps and is a reliable, low-maintenance, low-cost substitute for Teletype, DECWriter, Diablo, Spinwriter, ImageWriter, etc. teleprinters.

All of the plans, schematics, software, and documentation are being made freely available to the community so that anyone can build their own Cadetwriter for nominal cost and little effort. All of the information is available at:

https://github.com/IBM-1620/Cadetwriter/

Finally, there are several message boards available for users to be notified of updates, get information, ask questions, share experiences, make suggestions, etc. They are located at:

https://Cadetwriter.slack.com

Cadetwriter

A Wheelwriter-based Computer Terminal

IBM 1620 Jr. Team

Dave Babcock

Steve Casner

Joe Fredrick

Agenda

- Cadetwriter Description & History
- Reverse Engineering the Wheelwriter
- Adapting the Wheelwriter
- Firmware Highlights
- For More Information
- Q & A

Cadetwriter

ASCII Terminal Emulation

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz
0123456789 !"#$%&'()*+,-./:;<=>? @[\]^_`{|}~
```

Specifications

- IBM/Lexmark Wheelwriter 1000 daisy wheel typewriter
- Custom Serial Interface Board with Teensy 3.5 (Arduino) microcontroller
- Jumper-selectable emulations: IBM 1620 Console Typewriter, ASCII Terminal, Stand-alone Typewriter, Customized Terminal
- Prints up to 16cps, ~4 page print buffer
- Serial interfaces: USB, RS232
- Flow control: RTS/CTS, RTR/CTS, XON/XOFF
- Baud rates: 1200 – 921,600
- Modes: 7 or 8 Data Bits, Even/Odd/No Parity, 1 or 2 Stop Bits

Cadetwriter

IBM 1620 Restoration

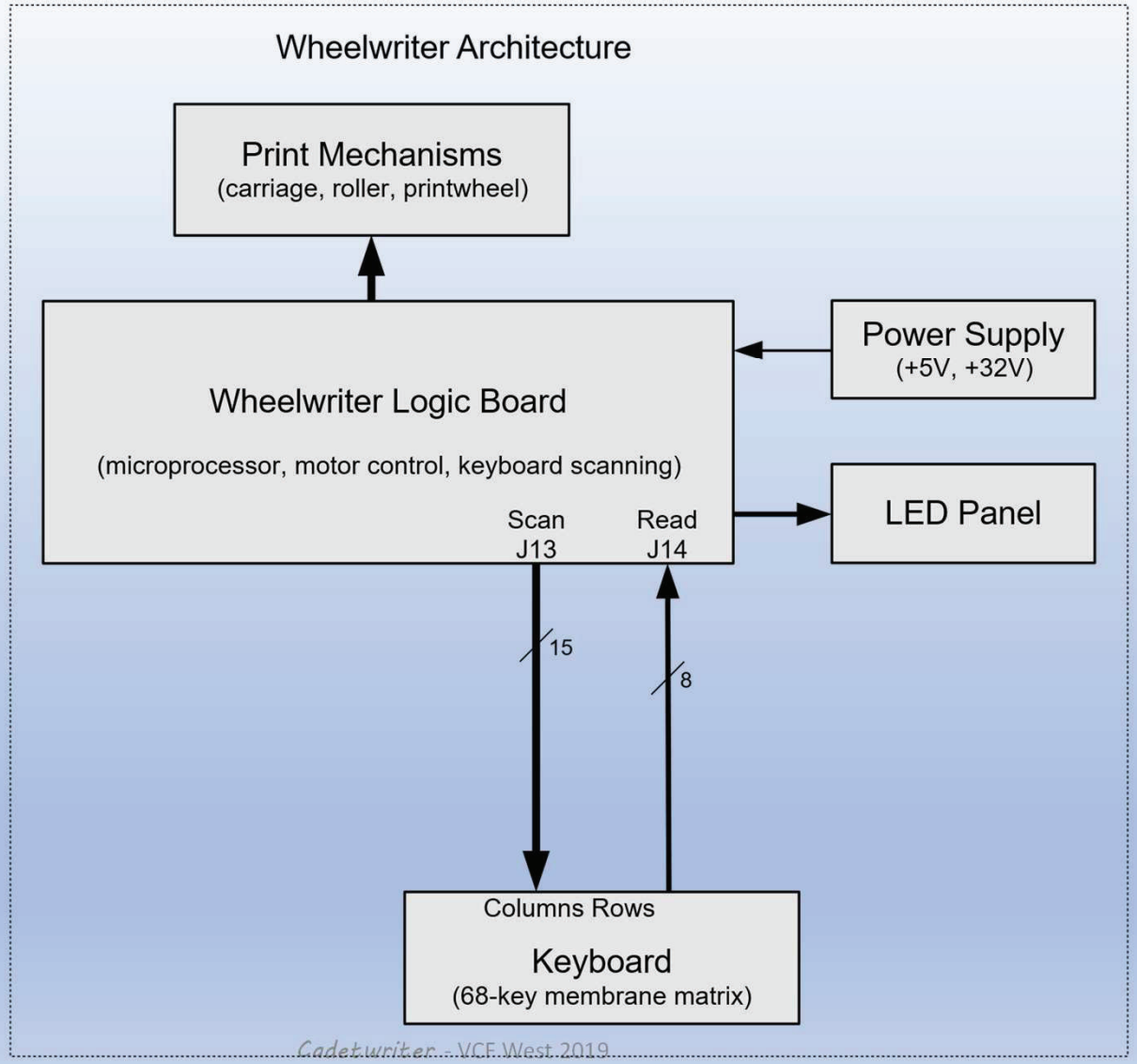
Background

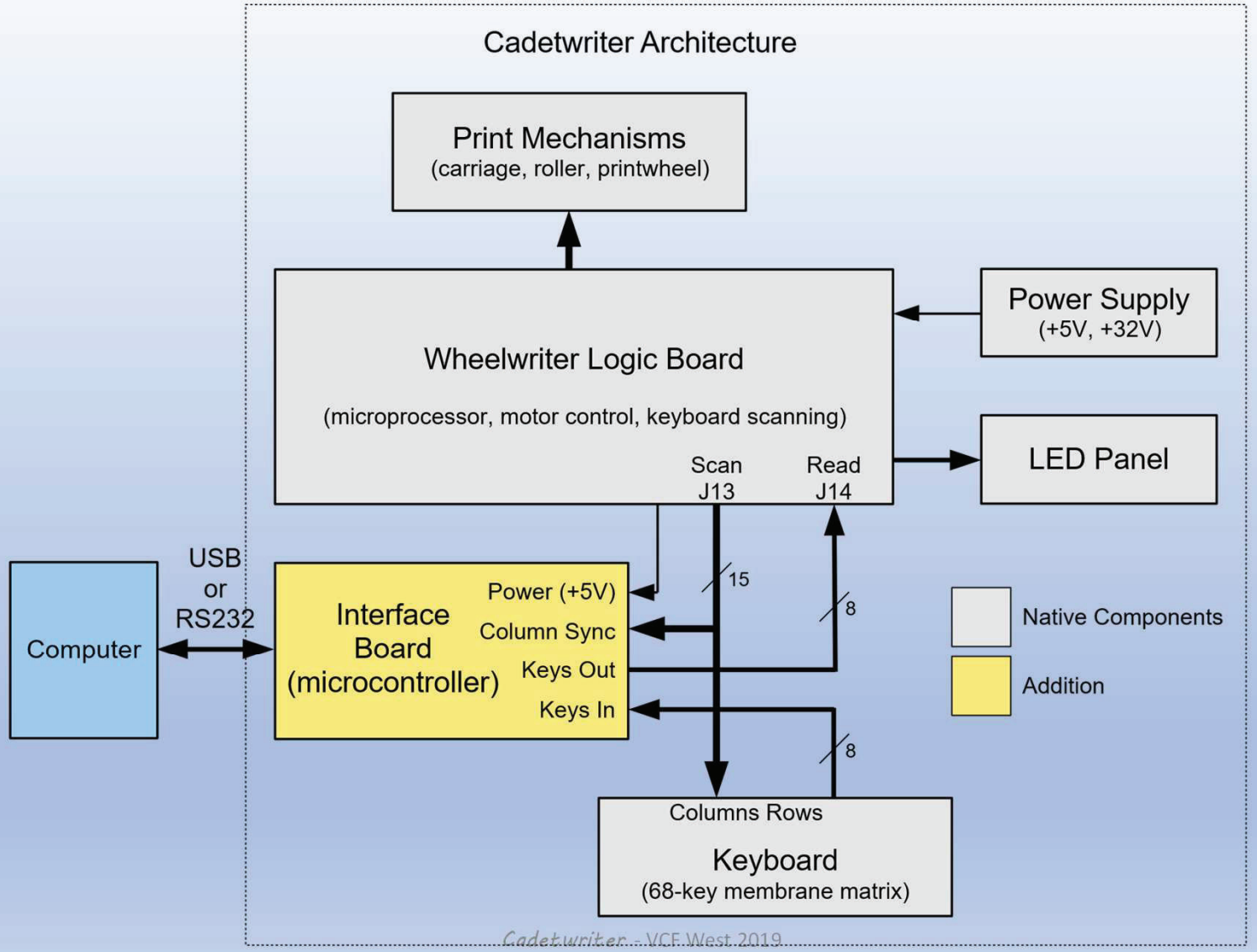
- IBM 1620 Jr. project – recreate the IBM 1620 with modern electronics
- The console typewriter was a crucial component of the IBM 1620
- Impractical to use either IBM Model B or Selectric typewriters
- Needed a solution using a robust, supportable typewriter that produces IBM 1620 looking output
- Pursued a novel approach to adapt a Wheelwriter 1000 to computer operation

Cadetwriter

IBM 1620 Console Typewriter Emulation

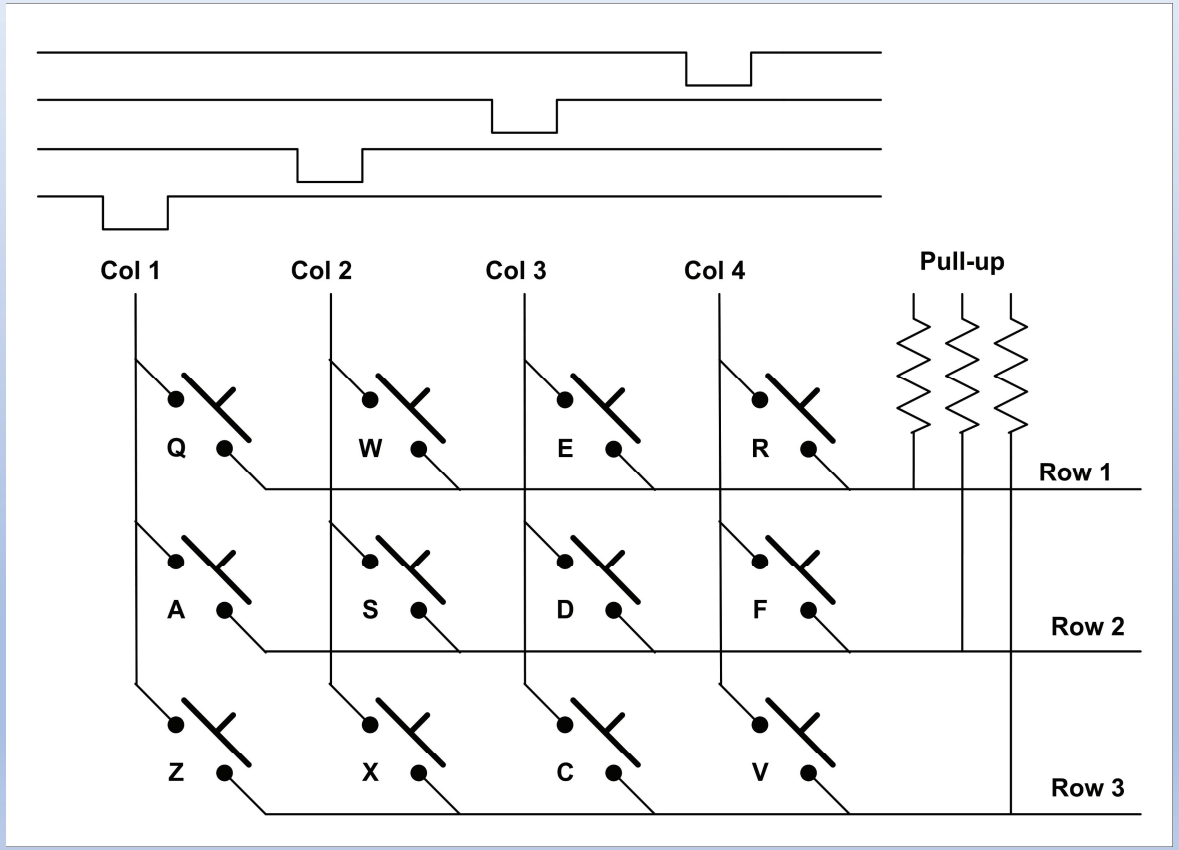
ABCDEFGHIJKLMNOPQRSTUVWXYZ Ø123456789 Ø̄1̄2̄3̄4̄5̄6̄7̄8̄9̄ $()+-*/=.,@ @̄ ‡‡‡‡ ✕ R̄S̄


Wheelwriter Architecture
Print Mechanisms
(carriage, roller, printwheel)
Wheelwriter Logic Board
(microprocessor, motor control, keyboard scanning)
Scan
J13
Read
J14
Power Supply
(+5V, +32V)
LED Panel
15
8
Columns Rows
Keyboard
(68-key membrane matrix)


Cadetwriter Architecture
Print Mechanisms
(carriage, roller, printwheel)
Wheelwriter Logic Board
(microprocessor, motor control, keyboard scanning)
Power Supply
(+5V, +32V)
LED Panel
Scan
J13
Read
J14
Computer
USB
or
RS232
Interface
Board
(microcontroller)
Power (+5V)
Column Sync
Keys Out
Keys In
15
8
8
Native Components
Addition
Columns Rows
Keyboard
(68-key membrane matrix)

Reverse Engineering Native Wheelwriter Function

A Simple Keyboard



Reverse Engineering Process

- No internal documentation for Wheelwriters available.
- First, use ohmmeter to map keyboard rows & columns -- 8 rows, 14 columns.

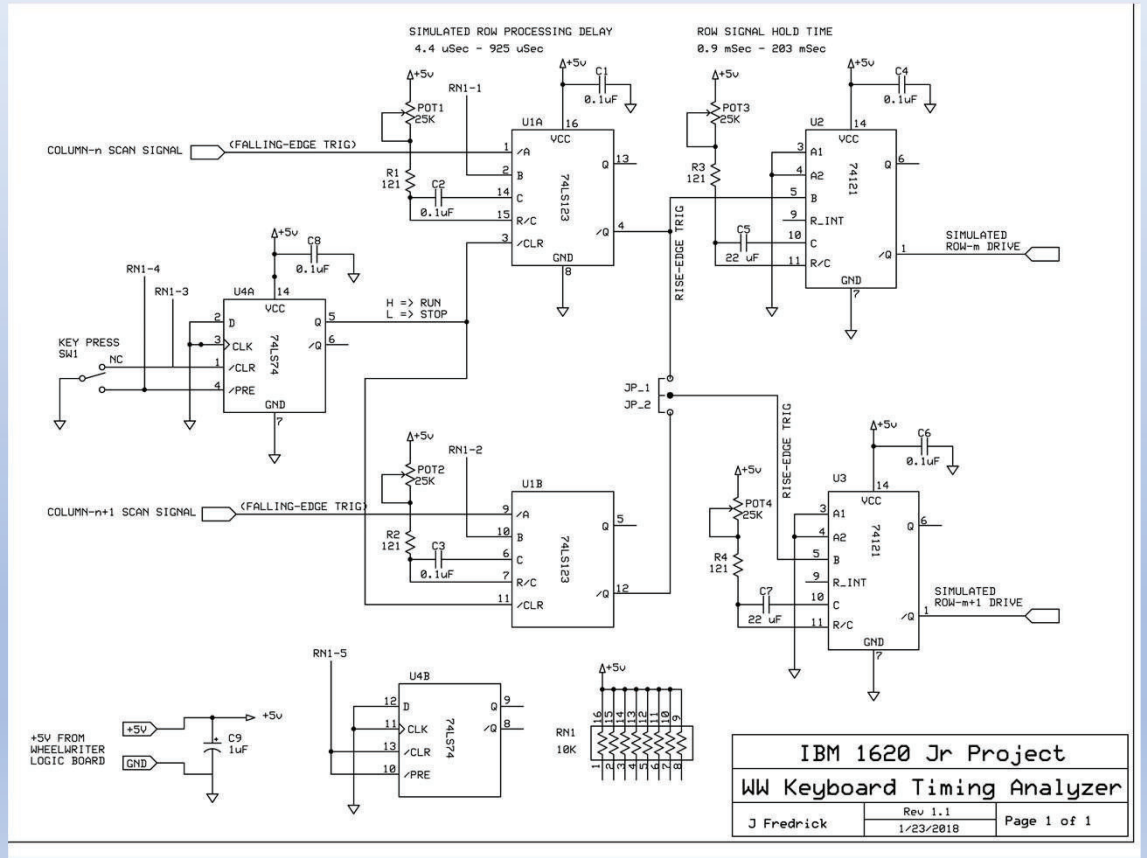
Wheel Writer 1000 (s/n 11TWT91) with Keyboard (dated 07 May 2001)															
	Keyboard "Column" Keyboard Left Flat Flex cable (J13 on Logic PCB)														
Keyboard "Row" Keyboard Right Flat Flex cable (J14 on Logic PCB)	**Left-most Pin 1**	**Pin 2**	**Pin 3**	**Pin 4**	**Pin 5**	**Pin 6**	**Pin 7**	**Pin 8**	**Pin 9**	**Pin 10**	**Pin 11**	**Pin 12**	**Pin 13**	**Pin 14**	**Right-most Pin 15**
Left -most Pin 15	Not Connected	T Clr 33 ohms	Open Circuit	Open Circuit	Open Circuit	Open Circuit	Open Circuit	G 31 ohms	H 1/2-down 32 ohms	Open Circuit	Open Circuit	" ' paragraph 41 ohms	C Rtn Ind Clr 47 ohms	down-arrow Line 50 ohms	Open Circuit
Pin 14	Not Connected	Open Circuit	T Set 30 ohms	Open Circuit	A 35 ohms	S 34 ohms	D Dec T 33 ohms	F 33 ohms	J 38 ohms	K 37 ohms	L Lang 39 ohms	: ; section	Open Circuit	Reloc Line Space	Open Circuit
Pin 13	Not Connected	Open Circuit	Mar Rel RePrt 25 ohms	Open Circuit	Degree +/- 30 ohms	Open Circuit	Open Circuit	% 5 13 ohms	cent 6 12 ohms	+ = 32 ohms	Open Circuit	_ - 20 ohms	Backspace Bksp 1 27 ohms	Paper Up Micro 29 ohms	Open Circuit
Pin 12	Not Connected	Open Circuit	Open Circuit	Open Circuit	Exclaimation 1 Spell 42 ohms	@ 2 Add 35 ohms	# 3 Del 33 ohms	$ 4 Vol 31 ohms	& 7 28 ohms	* 8 28 ohms	(9 Stop 28 ohms	) 0 29 ohms	Open Circuit	Open Circuit	Open Circuit
Pin 11	Not Connected	L Mar 43 ohms	Tab IndL 41 ohms	Open Circuit	Q Impr 44 ohms	W 38 ohms	E 35 ohms	R A Rtn 34 ohms	U Cont 30 ohms	I Word 30 ohms	O R Flsh 31 ohms	P 31 ohms	Open Circuit	Paper Down Micro 31 ohms	Open Circuit
Pin 10	Not Connected	Open Circuit	RMar 52 ohms	Open Circuit	Open Circuit	Open Circuit	Open Circuit	T 38 ohms	Y 1/2-up 38 ohms	[ ] 3 44 ohms	Open Circuit	1/4 1/2 2 37 ohms	Open Circuit	Open Circuit	Open Circuit
Pin 9	Not Connected	Open Circuit	Lock 45 ohms	Right Shift 49 ohms	Z 48 ohms	X 42 ohms	C Ctr 40 ohms	V 38 ohms	M 35 ohms	, , 35 ohms	. . 35 ohms	Open Circuit	up-arrow Line 39 ohms	Open Circuit	Open Circuit
Pin 8	Not Connected	Space Bar 50 ohms	<X Word 47 ohms	Left Shift 43 ohms	Open Circuit	Open Circuit	Open Circuit	B Bold 34 ohms	N Caps 35 ohms	Open Circuit	Open Circuit	? / 33 ohms	left-arrow Word 39 ohms	right-arrow Word 34 ohms	Code 57 ohms
Right-most Pin 1 (Pins 7 through 1)	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited	Short Circuited

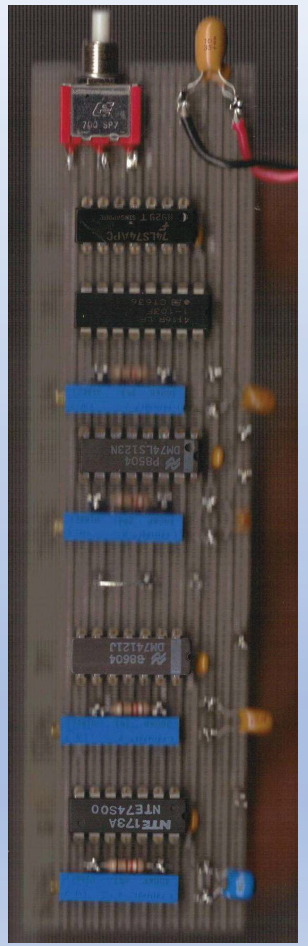
Reverse Engineering Process

- Second, insert break-out board between keyboard and motherboard.
- Examined keyboard column & row signals with logic analyzer, oscilloscope and one-shot test circuits to determined keyboard timing and motherboard behavior. (The heavy-lift.)
- Monitor one column signal and assert one row drive signal.

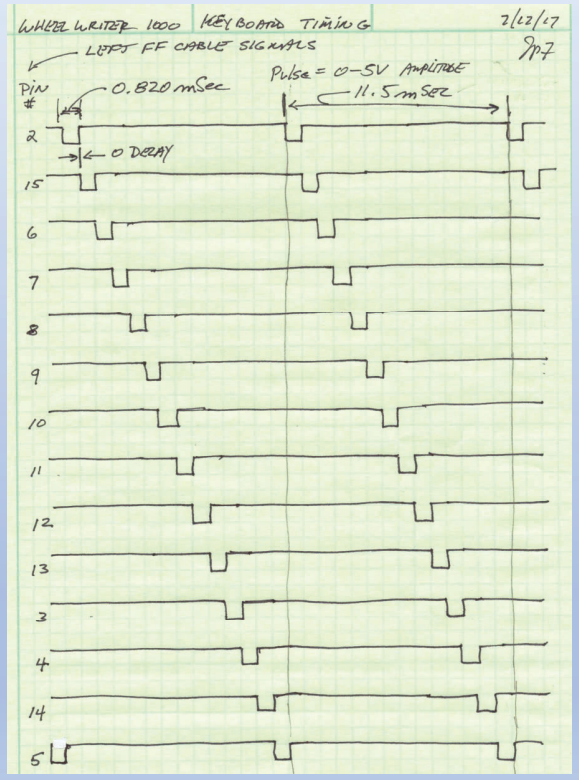
Cadetwriter

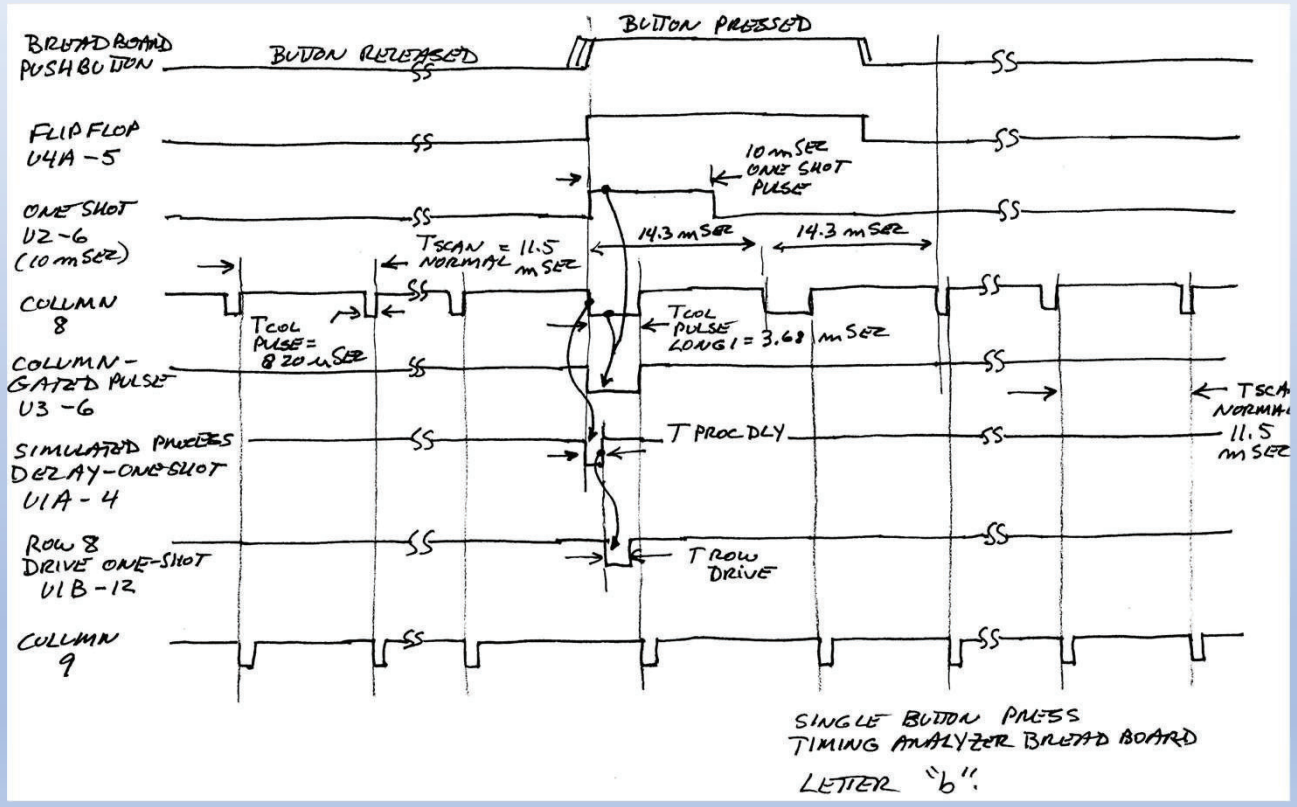
Key Press Timing Test Circuit



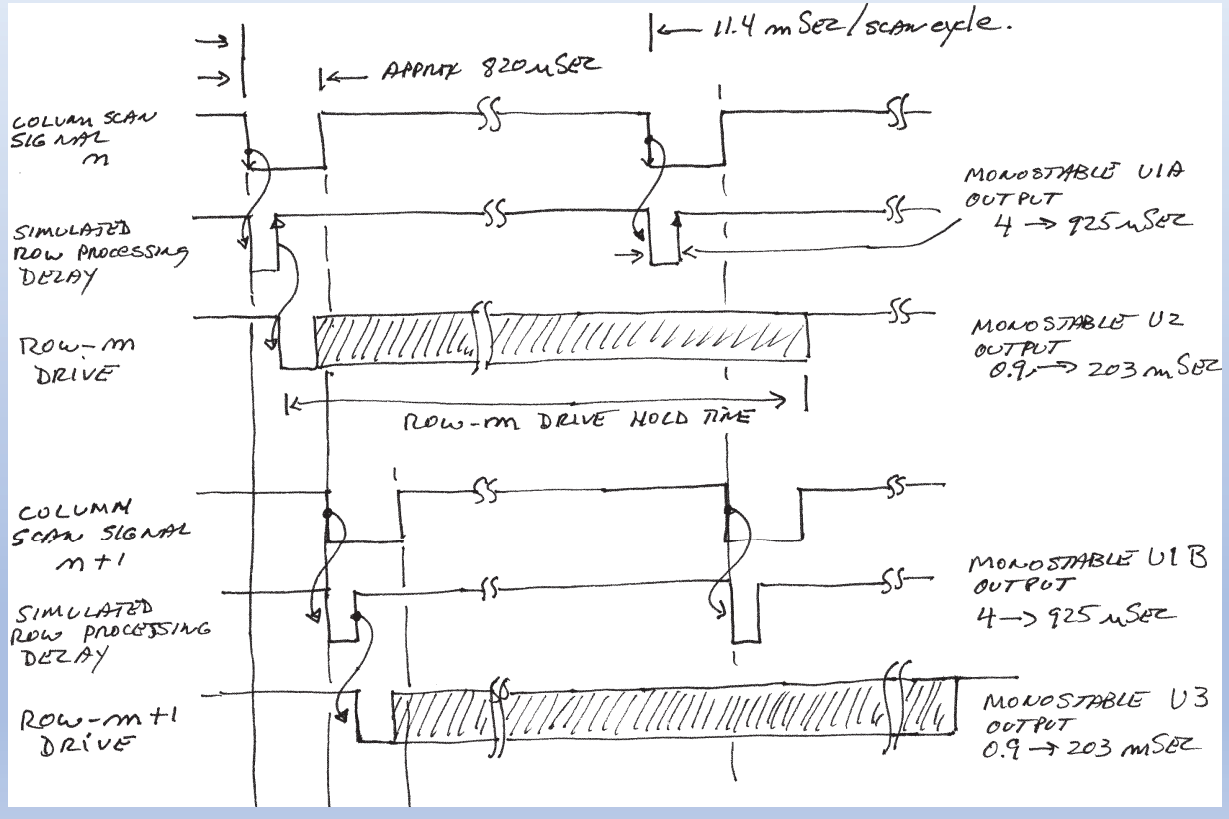


Timing Diagrams





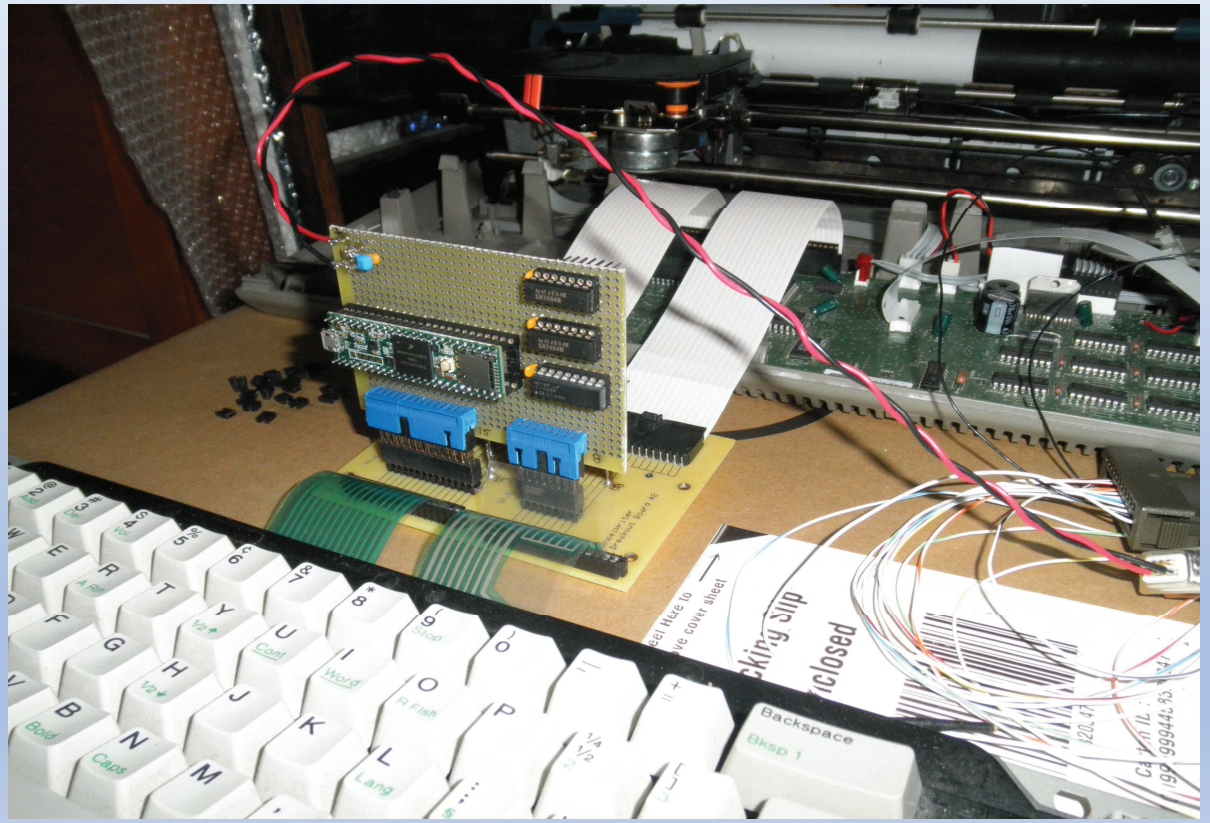
Timing Diagrams (cont.)



Reverse Engineering Process

- Finally, breadboard prototype Serial Interface Board with Teensy 3.5 connected to all column & row signals.
- Write test programs for Teensy to exercise typewriter functionality:
  - Monitor column signals with firmware interrupt function,
  - For keyboard (key press) input, check each row signal, translate column & row coordinates to key-code and send out USB port.
  - For printer output, receive key-code input on USB port and translate to column & row coordinates and assert corresponding row signal to emulate key press.

Serial Interface Prototype



Results

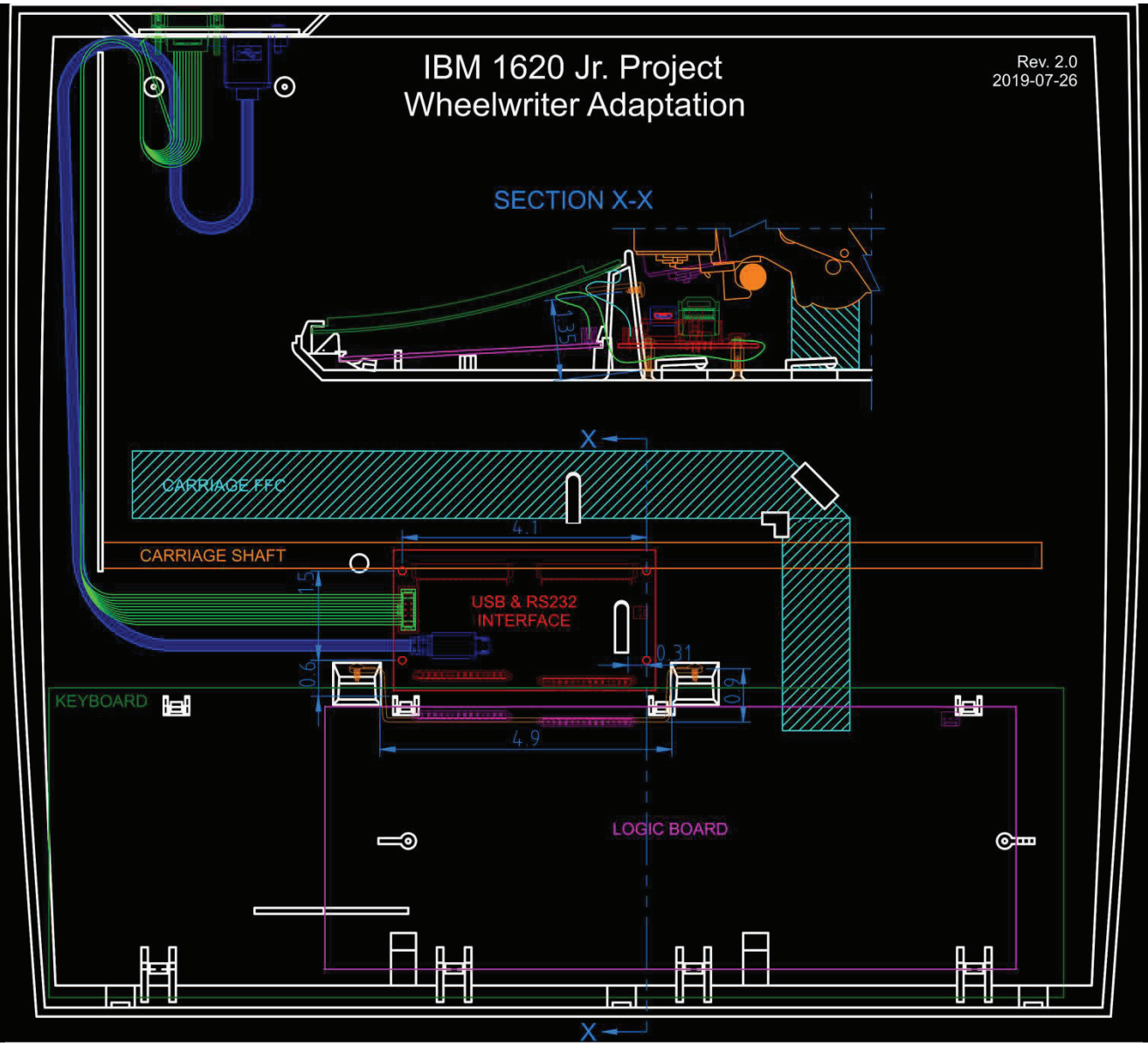
- Motherboard scans columns in a [mostly] consistent, but not strictly physical keyboard, order
- Column scan pulse amplitude: 0 – 5v TTL logic levels
- Column scan pulse width:
  - 820 usec if no new key is pressed or released
  - 3.68 msec if a key is pressed or released for the first time
  - Up to 2 sec if keyboard input buffer (32 characters) is full
  - Up to 5.1 sec if “too many” carriage movements in a short period of time
- Key press must be asserted within 265 usec of start of column scan
- Keys only need to be pressed for 1 column scan to register

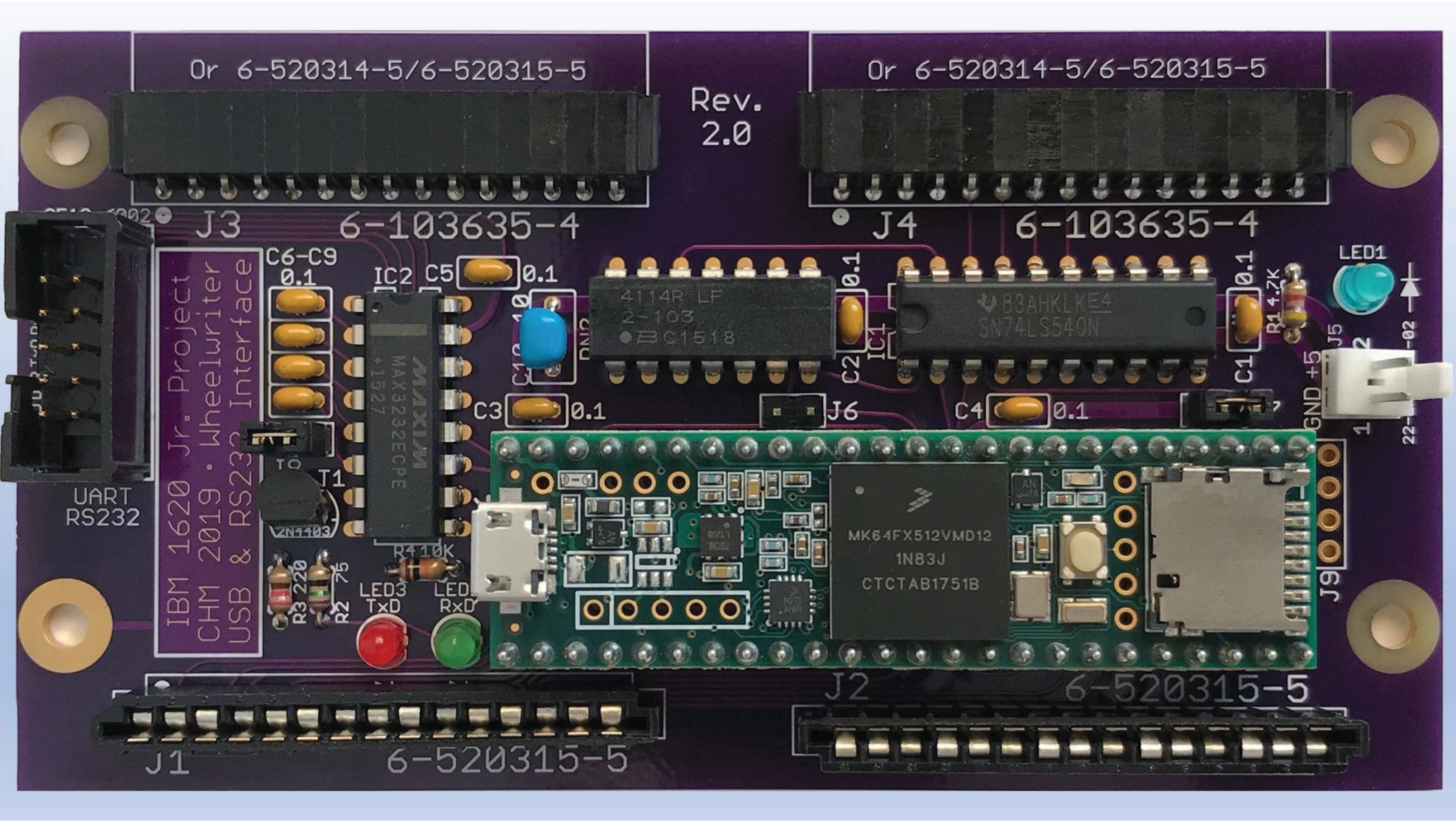
Adapting the Wheelwriter

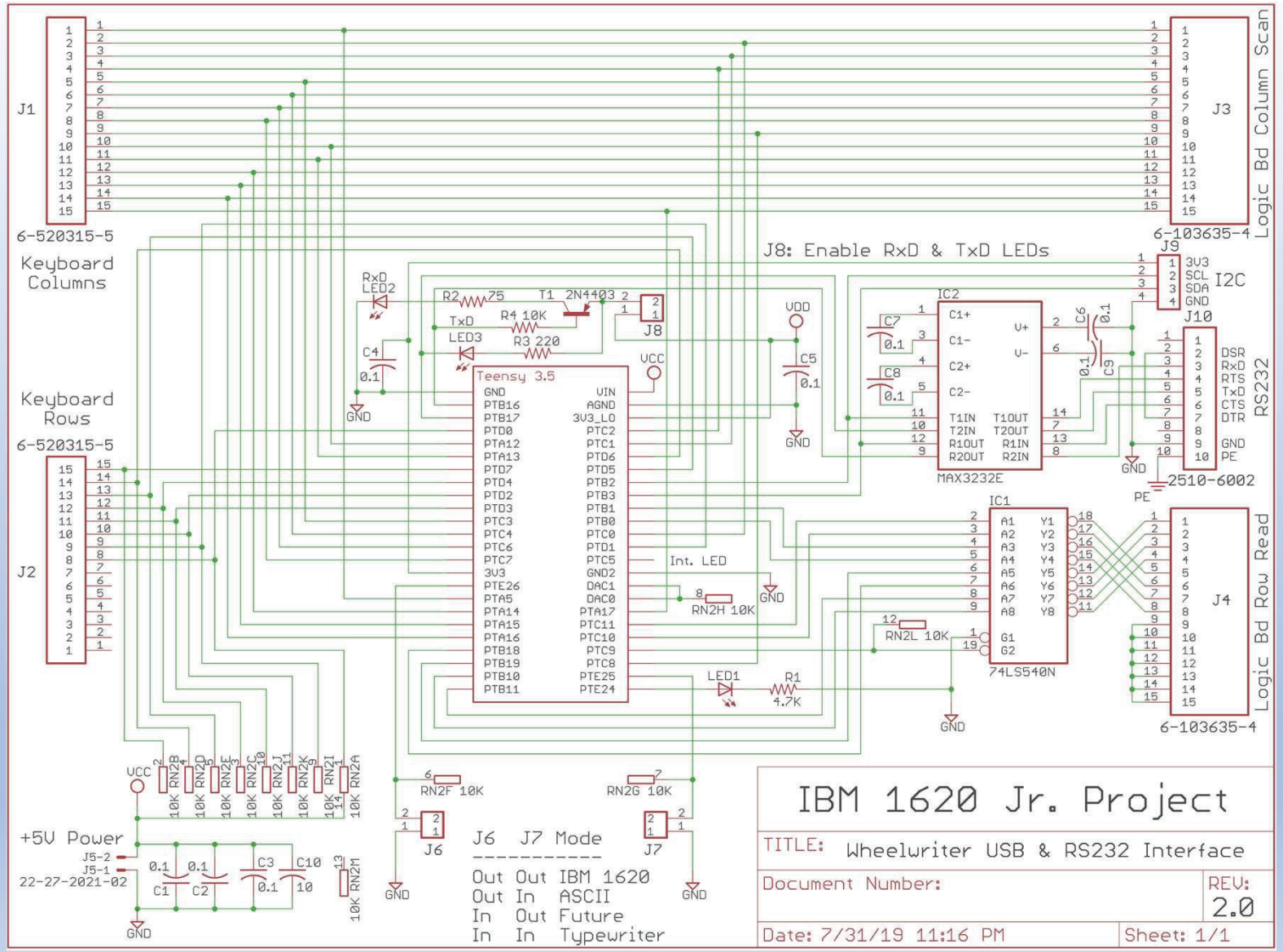
Wheelwriter Modifications

- Solder power connector to typewriter motherboard
- Drill 4 mounting holes in typewriter base for Serial Interface Board
- Drill 2 mounting holes for flex cable depression bracket
- Cut openings for USB-B and DE-9 connectors in back of typewriter
- Build and install Serial Interface Board and cables
- Bend and install flex cable depression bracket

A step-by-step adaptation guide with photos is available

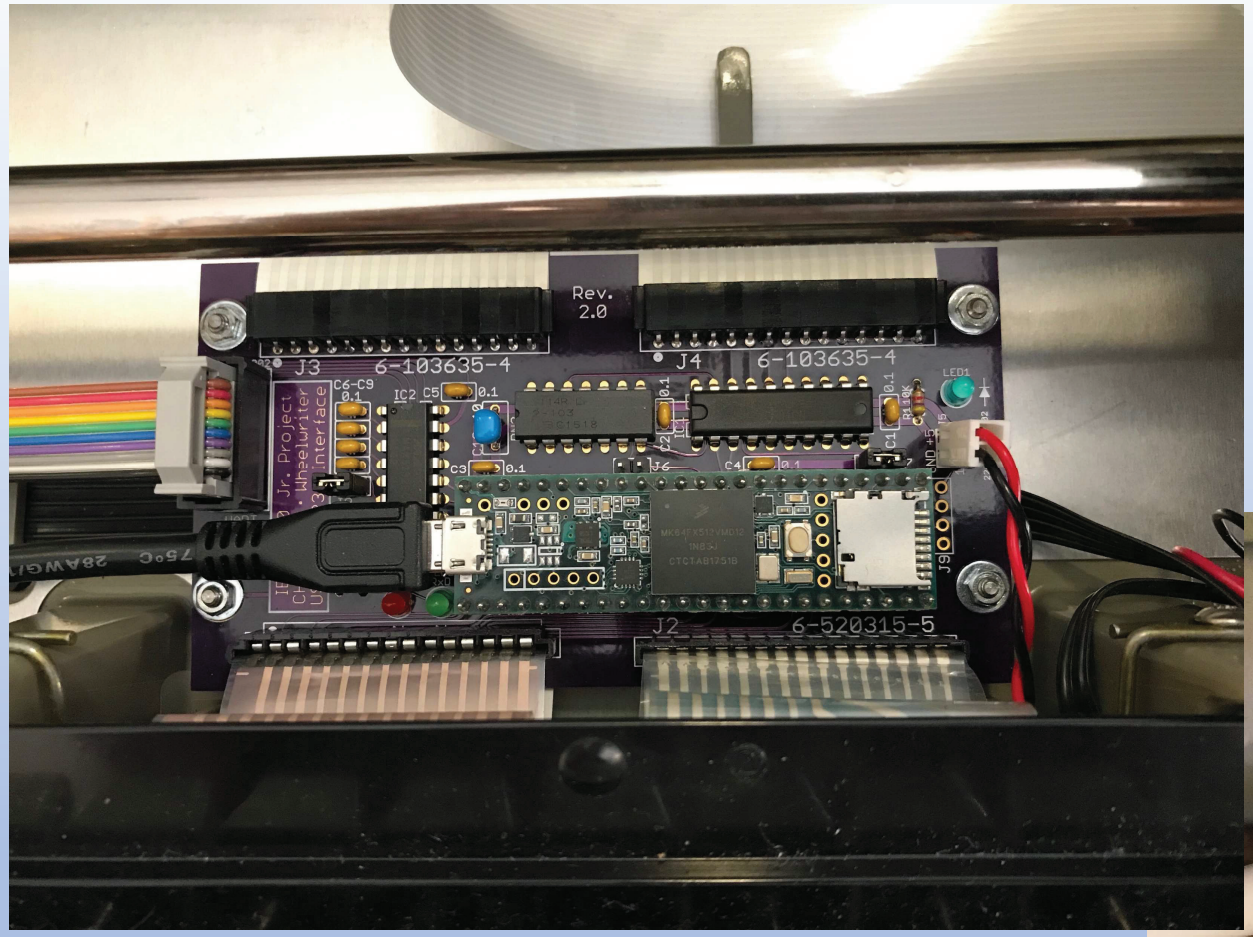

IBM 1620 Jr. Project
Wheelwriter Adaptation
Rev. 2.0
2019-07-26
SECTION X-X
1.35
X
CARRIAGE FFC
4.1
CARRIAGE SHAFT
1.5
USB & RS232
INTERFACE
0.31
0.6
0.6
KEYBOARD
4.9
LOGIC BOARD
X

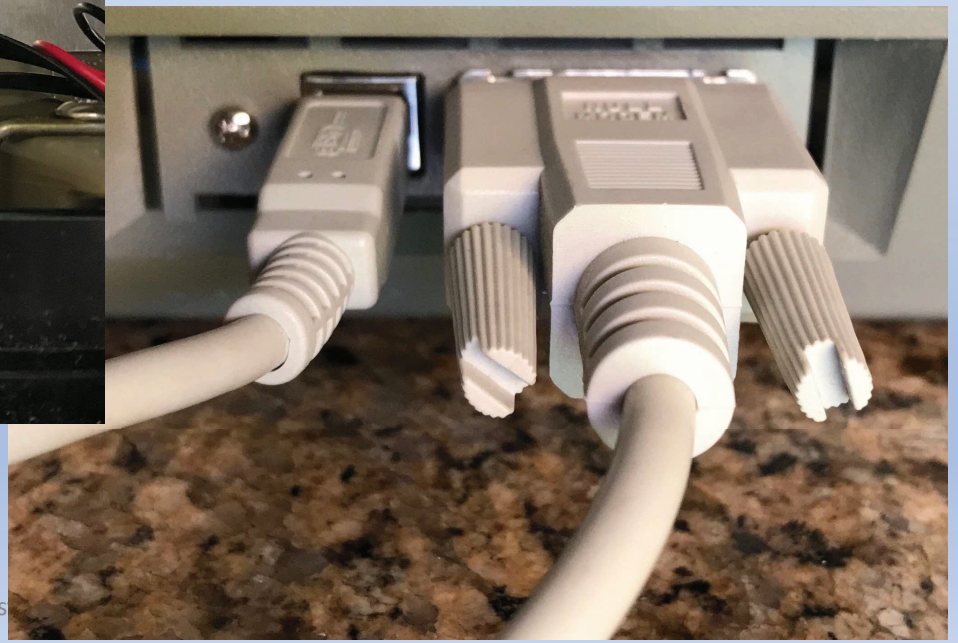

Or 6-520314-5/6-520315-5
Rev.
2.0
Or 6-520314-5/6-520315-5
J3
6-103635-4
J4
6-103635-4
IBM 1620 Jr. Project
CHM 2019 · Wheelwriter
USB & RS232 Interface
C6-C9
0.1
IC2
C5
0.1
4114R LF
2-103
C1518
IC1
C2
0.1
83AHKLKE4
SN74LS540N
C1
0.1
R1 4.2K
LED1
J5
GND +5
C12
10
C3
0.1
J6
C4
0.1
UART
RS232
T1
2N4403
MAXIM
MAX3232ECPE
+1527
R4 10K
R3 220
R2 75
LED3
TxD
LED
RxD
MK64FX512VMD12
1N83J
CTCTAB1751B
J9
J1
6-520315-5
J2
6-520315-5



Cadetwriter

Cadetwriter





Cadetwriter

Serial Interface Boards

	Rev 1.6	Rev 1.7	Rev 2.0
USB Interface	USB-B Connector	USB-B Connector	USB-B Connector
RS-232	Solder pads TTL level	Solder pads TTL level	DE-9 Connector RS-232 level
Keyboard connectors	Locking	LIF	LIF
Additional modifications	Piggyback 2 resistor packs	None	None
Motherboard changes	Add power connector Replace keyboard connectors	Add power connector	Add power connector
I2C Expansion	Supported	Supported	Supported if no RS232
Size	4.42” x 2.37”	4.42” x 2.37”	4.42” x 2.37”
Status	Retired	Retired	Current

Parts List

Count	Description	Source	Source PN	Cost
1	USB & RS232 Interface PCB	OSHPark	TlkAO4NE	$17.42
1	Teensy 3.5 without pins	PJRC	TEENSY35	$24.25
2	32 SIL header pins for Teensy	DigiKey	952-2521-ND	$10.46
1	48-pin socket for Teensy	DigiKey	ED3648-ND	$3.84
1	74LS540 PDIP IC	DigiKey	296-3715-5-ND	$1.64
1	RS232 transceiver PDIP IC	DigiKey	MAX3232ECPE+-ND	$5.37
1	Transistor PNP 40V 0.6A TO-92	DigiKey	2N4403-ND	$0.30
1	10K x 13 resistor network	DigiKey	4114R-2-103LF-ND	$1.12
9	0.1 µF capacitor	DigiKey	399-4264-ND	$1.50
1	10 µF capacitor	DigiKey	490-14508-ND	$1.21
1	3mm LED (blue)	DigiKey	VAOL-3LSBY2-ND	$0.65
1	3mm LED (green)	DigiKey	VAOL-3LDE2-ND	$0.44
1	3mm LED (red)	DigiKey	732-5006-ND	$0.17
1	75 Ω 1/8W resistor	DigiKey	CF18JT75R0CT-ND	$0.10
1	220 Ω 1/8W resistor	DigiKey	CF18JT220RCT-ND	$0.10
1	4.7K Ω 1/8W resistor	DigiKey	CF18JT4K70CT-ND	$0.10
1	10K Ω 1/8W resistor	DigiKey	CF18JT10K0CT-ND	$0.10
2	TE/AMP 6-520314-5 FFC connector	Heilind	6-520314-5	$1.48
2	TE/AMP 6-520315-5 FFC connector	Heilind	6-520315-5	$1.48
1	6” Flat flex cable, same side contacts	Wavelink	254-015-0155-AA	$10.00
1	6” Flat flex cable, opposite side contacts	Wavelink	255-015-0155-AB	$10.00
1	Molex 22-27-2021 2-pin connector M	DigiKey	WM4111-ND	$0.27
1	Molex 22-01-3027 2-pin housing F	DigiKey	WM2000-ND	$0.12
1	Molex 22-27-2031 3-pin connector M	DigiKey	WM4112-ND	$0.35
1	Molex 22-01-3027 3-pin housing F	DigiKey	WM2001-ND	$0.18
4	Molex 08-50-0114 female pins tin	DigiKey	WM1114-ND	$0.78
3	1x2 header for J6,J7,J8 jumper	DigiKey	732-5315-ND	$0.39
3	Shorting jumper for J6,J7,J8	DigiKey	S9337-ND	$0.30
4	3/16 x 3/8 female-male standoff	DigiKey	1772-2032-ND	$4.20
4	0.28” diameter flat washer for #4-40	DigiKey	36-4692-ND	$0.33
4	Hex nut 3/16” #4-40	DigiKey	36-4694-ND	$0.30
4	#4-40 3/8” flat-head screw, phillips	Bolt Depot	3717	$0.20
3	Self-tapping screws to hold bracket	Bolt Depot	7754	$0.15
1	Bracket to depress keyboard cables	coat hanger		
1	USB cable B panel to micro male, 24”	DataPro	1581-02C	$10.95
1	Cable clamp for USB cable	DigiKey	RP325-ND	$0.10
1	Cable tie	DigiKey	298-1017-ND	$0.05
1	2x5 header, 4-wall, keyed	DigiKey	3M155831-ND	$2.01
1	2x5 IDC ribbon cable socket	DigiKey	3M156030-ND	$0.74
1	2x5 IDC strain relief	DigiKey	MESR10-ND	$0.46
1	10-wire ribbon cable, 1 meter	DigiKey	732-11801-ND	$2.25
1	DE9-M panel mount IDC	DigiKey	MMR09K-ND	$6.34
2	Jackscrew Socket with hardware	DigiKey	160-17FA-ND	$1.68
1	Solder lug for DE9 shield ground	DigiKey	36-7328-ND	$0.17
2	Hookup wire, red & black 24AWG, 8”	DigiKey	A2924R-100-ND	$0.70
1	Set of ASCII keycaps	Unicomp	PSET 104+ (see note)	$26.60
				$151.35

Cadetwriter

Firmware Highlights

Firmware Structure

setup()

Initialize data, GPIO pins, and serial ports

loop()

- Process all keyboard input
- Read & process all serial input
- Send all serial output
- Decompose & buffer all print output into carefully timed "fake" key presses

ISR_common()

- Service all column scan interrupts by reading & buffering any keyboard key presses
- Assert "fake" key presses to motherboard

Firmware Highlights

- Firmware is 9,000 lines of C code
- No locking operations needed between loop() and ISR_common()
- 4 circular buffers pass data between loop() and ISR_common()
- Very large data tables encapsulate most of the logic decisions
- 85% common code for all terminal emulations

Firmware Highlights (cont'd)

- All board revisions support all terminal emulations
- Manages all settings saved in EEPROM
- Can set margins and tab stops
- Detects, counts, and reports errors and warnings
- Principles of Operation documented in 700+ line comment block

Firmware Setup Function

```
Command [settings/errors/character set/QUIT]:                    settings

  record errors [TRUE/false]:                                    true
  record warnings [true/FALSE]:                                  false
  batteries installed [TRUE/false]:                              true
  serial [usb/RS232]:                                            rs232
  duplex [half/FULL]:                                            full
  baud rate [50-921600, 9600]:                                   9600
  dps [7o1/7e1/8N1/8o1/8e1/8n2/8o2/8e2]:                         8n1
  sw flow control [none/XON_XOFF]:                               xon_xoff
  hw flow control [NONE/rts_cts/rtr_cts]:                        none
  auto return [TRUE/false]:                                      true
  transmit end-of-line [CR/crlf/lf/lfcr]:                        cr
  receive end-of-line [cr/CRLF/lf/lfcr]:                         crlf
  ignore escape sequences [TRUE/false]:                          true
  line width [80-165, 80]:                                       80
  column offset [TRUE/false]:                                    true

  Save settings [yes/NO]?                          no
```

Firmware Customization

- One emulation slot available for customization – EBCDIC, APL, etc.
- Three data tables need to be defined: key press action, received character action, print information
- Minimal unique code needs to be written
- Custom keycaps can be ordered at low cost
- Special print characters can be synthesized with overprinting and/or period graphics

Other Wheelwriters

We have not tested the Serial Interface Board or firmware with other model Wheelwriter typewriters.

However, we believe that the rev 2.0 Serial Interface Board should work with other Wheelwriters and only minor changes to the firmware might be needed.

We are interested in working with anyone who would like to try using a different Wheelwriter.

For More Information

- Visit our booth
  - Experience the Cadetwriter
  - Try out Cadetwriter with your computer
- Contact us at: Cadetwriter@IBM1620.org
- All project material available at:

  https://github.com/IBM-1620/Cadetwriter
- Serial Interface Board available from:

  https://oshpark.com/shared_projects/TIkAO4NE

Questions?