

PAL-1 Serial Interface Adapter

Plastic Objects Limited

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Introduction

The PAL-1 Serial Interface Adapter is an expansion module for the PAL-1 system¹ based on the Motorola MC6850 Asynchronous Communications Interface Adapter (ACIA)². The design borrows from a homebrew project in CPC Schneider International magazine³.

The MC6850 ACIA manages data formatting and asynchronous data communications control. Data from the PAL-1 is serially transmitted and received by the ACIA's asynchronous data interface, with appropriate formatting and error checking. The functional configuration of the ACIA may be programmed during system initialisation. It includes variable word lengths, clock division ratios, and interrupt conditions giving full control over serial communications⁴.

Unlike the on-board PAL-1 serial interface, the PAL-1 Serial Interface Adapter provides hardware flow control at rates from 150 to 38400 baud. Serial connections may be made at either TTL or RS-232 levels, allowing users to connect to other devices with either a TTL-to-USB adaptor or using a 9 pin D-sub serial cable.

¹Liu Ganning, 'PAL-1 Microcomputer User Manual' (November 2020), (http://pal.aibs.ws/assets/PAL_en.pdf) accessed 2022-07-21.

²Motorola Semiconductors, 'MC6850, Asynchronous Communications Interface Adapter (ACIA)' (1994).

³Joachim Schweda, 'Schnittstelle RS-232 im Selbstbau', *CPC Schneider International*, 7:3 (1986), pp. 88-92.

⁴Motorola Semiconductor Products, 'Motorola Microcomputer Components' (1978), p.11.

1. *Getting Started*

Board assembly

Before assembling your PAL-1 Serial Interface Adapter board check the package contents against the Bill of Materials on page 23, and contact your distributor as soon as possible if any items are missing.

No specialist tools are required for assembling the board, though care must be taken when handling ESD sensitive components, especially the ICs. Before inserting the ICs into their sockets, check the board for dry joints and solder bridges. Also be sure to pay special attention to the orientation of the ICs, ensuring pin 1 of each IC is correctly aligned.



To prevent damage to your system, *always* power off your PAL-1 before installing or removing the PAL-1 Serial Interface Adapter board. Ensure that the pins are correctly aligned when inserting the board into the PAL-1 motherboard or when directly connecting it to the PAL-1 expansion port using a 40-pin IDC cable.

Builds options

The PAL-1 Serial Interface Adapter can be assembled with or without a MAX232 dual transmitter / dual receiver, depending on whether RS-232 or TTL level signals are preferred (see also Figure 1.1). If only TTL level signals are required, the components listed in Table 1.1 can be omitted. In this case pin-header J3 and resistors R7 to R10 should be installed to provide access to the TTL level signals (see also ‘*TTL Pin Header*’ on page 18).

Parts	Description
C9 - C12	1.0uF capacitors
J2	DB-9 serial connector
JP5	Jumper, 2-pole, open
U6	MAX232 dual transmitter / dual receiver

Table 1.1: Components to be omitted for TTL level signals

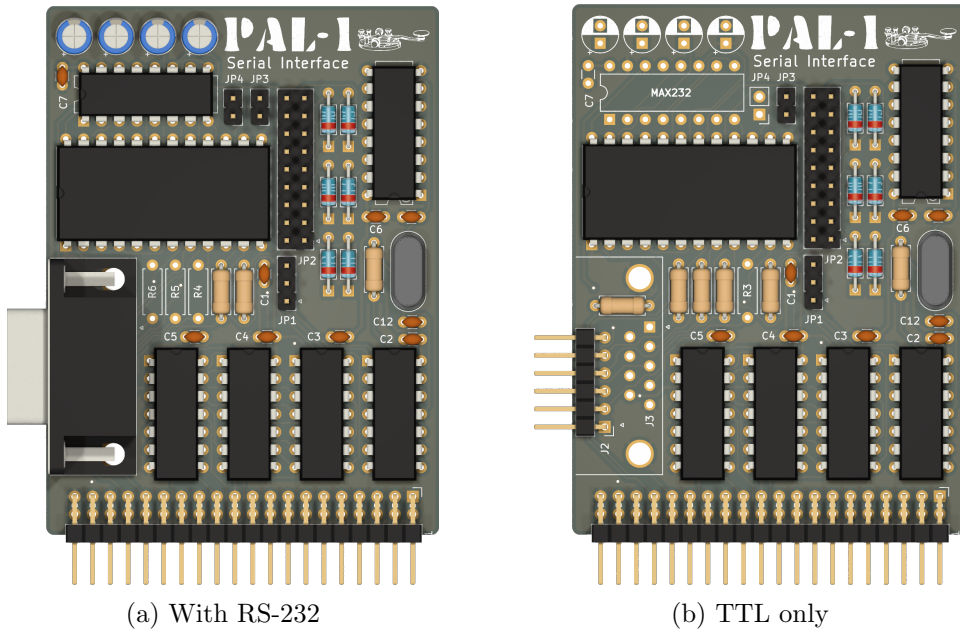


Figure 1.1: PAL-1 Serial Interface Adapter build options.

Configuration

Base I/O address

The MC6850 ACIA has an 8-bit data bus, which is memory mapped on the PAL-1 system. The base address at which it is mapped can be configured using jumper JP1, as shown in Table 1.2.

The default base address (and the address used in all examples in this manual) is \$16E8. In situations where multiple serial interface adapters are installed in the same PAL-1 system, each board must have a unique base address.

JP1 pins	Address
1-2	\$16E8 (5864 ₁₀)
2-3	\$16EA (5866 ₁₀)

Table 1.2: I/O address configuration

Clock frequency

The MC6850 ACIA uses an external clock from which data transmission rates are derived. The frequency of this clock is configured using jumpers JP2 as shown in table 1.3. For example, to select a clock frequency of

19.2kHz, shunt pins 2, 4, 5, and 8 as shown in figure 1.2. **Note that only the combinations shown in this table are valid — other settings may result in unpredictable behaviour.**

Clock	JP2 pins									Baud rates	
	1	2	3	4	5	6	7	8	9	Min	Max
9600Hz	-	-	□	-	□	□	-	-	□	150	9600
19.2 kHz	-	□	-	□	□	-	-	□	-	300	19,200
38.4 kHz	□	-	□	□	-	-	□	-	-	600	38,400

Table 1.3: Clock frequency configuration

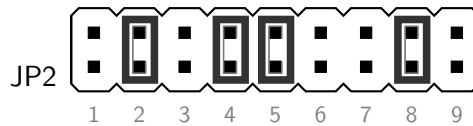


Figure 1.2: Clock configuration example

Interrupts

Interrupts result from conditions in both the transmitter and receiver sections of the MC6850 ACIA. To enable interrupt handling on the PAL-1, pins JP3 must be shunted. For details about ACIA interrupt processing, refer to the section on interrupts on page 7.

Data Terminal Ready

The MC6850 ACIA does not provide a Data Terminal Ready (DTR) signal. While normally disconnected, the DTR signal can be set to active using JP4 if required by the data communications equipment (DCE). Note that the DTR signal is only available on the RS-232 connector (see also page 17).

2. *Using the Serial Interface Adapter*

The MC6850 ACIA appears on the PAL-1 as two addressable memory locations (see table 2.1). Internally, the ACIA has four registers. Of these, two are read-only, the Status and Receive Data registers. The remaining two registers are write-only, the Control and Transmit Data registers.

Address ¹	Access	ACIA Register
\$16E8 (5864 ₁₀)	Read	Status Register
	Write	Control Register
\$16E9 (5865 ₁₀)	Read	Receive Data
	Write	Transmit Data

¹ The PAL-1 Serial Interface Adapter base address is configured using jumper JP1. See page 2 for details.

Table 2.1: MC6850 registers

Much of the information in this chapter is taken from the MC6850 datasheet¹. Refer to this datasheet for further details

Master Reset

The *master reset bits* (CR0 and CR1) must be set immediately after power up to ensure the reset condition and to prepare for programming the ACIA functional configuration. After a master reset, the Control Register can be set to configure options, including clock divider ratios, word lengths, the number of stop and parity bits.

Basic Usage

The minimal steps required to send and receive data using the serial interface are:

¹Motorola Semiconductors.

1. Master reset the ACIA

```
write &16E8, 3
```

2. Set communications parameters (e.g. no interrupts, 8 bits, 1 stop bit, 1200 baud)

```
write &16E8, 21
```

3. Send data when the Transmit Data Register Empty bit in the Status Register is set

```
do
    status := read &16E8
until (status & 2) == 1
write &16E9, 'A'
```

4. Read data when the Receive Data Register Full bit in the Status Register is set

```
do
    status := read &16E8
until (status & 1) == 1
data := read &16E9
```

ACIA Control Register

The MC6850 ACIA Control Register is used to configure serial communication parameters, including baud rates, word lengths, and transmission control parameters. The format of the 8-bit write only register is shown in figure 2.2.

CR7	CR6	CR5	CR4	CR3	CR2	CR1	CR0
IQR Enable	Transmit Ctrl		Word Select			Counter Divide	

Figure 2.2: ACIA Control Register

Counter Divide and Reset

The *counter divide bits* (CR0 and CR1) determine the divide ratios used in both the transmitter and receiver sections of the ACIA. Additionally, these bits are used to force a master reset of the ACIA, which clears the Status Register and initialises both the receiver and transmitter. Note that after power-on or a restart these bits must be set high to reset the ACIA. After resetting the clock divide ratio may be selected. The counter select bits provide for the following clock divide ratios and corresponding baud rates:

CR1	CR0	Function	Baud rate ¹		
			9600Hz	19.2kHz	38.4kHz
0	0	÷1	9600	19200	38400
0	1	÷16	600	1200	2400
1	0	÷64	150	300	600
1	1	master reset			

¹ Baud rates are shown for all clock frequencies.

Table 2.2: Counter Divide / Reset bits

Word Select

The *word select bits* (CR4, CR3 and CR2) are used to select word length, parity, and the number of stop bits as shown in table 2.3. Note that word length, parity select, and stop bit changes are not buffered and therefore become effective immediately.

CR4	CR3	CR2	Word Length	Parity	Stop bits
0	0	0	7	even	2
0	0	1	7	odd	2
0	1	0	7	even	1
0	1	1	7	odd	1
1	0	0	8	none	2
1	0	1	8	none	1
1	1	0	8	even	1
1	1	1	8	odd	1

Table 2.3: Word Select bits

Interrupts

The *transmitter control bits* (CR5 and CR6) and the *receive interrupt enable bit* (CR7) define the circumstances under which interrupts are raised. Note

that in addition to setting the relevant control register bits, pin JP3 on the PAL-1 Serial Interface Adapter board must be shunted (see also page 3).

Transmitter Control

The *transmitter control bits* (CR5 and CR6) are used to configure the interrupt from the Transmit Data Register Empty condition, the Request to Send (\overline{RTS}) output, and the transmission of a Break level (space), as shown in table 2.4.

CR5	CR6	\overline{RTS}	Transmitter IRQ
0	0	low	disabled
0	1	low	enabled
1	0	high	disabled
1	1	low	disabled and break

Table 2.4: Transmitter Control bits

Receiver Interrupt Enable

Setting the *receiver interrupt enable bit* (CR7) will enable interrupts for the following conditions: Receive Data Register fill, Overrun, or a low-to-high transition on the Data Carrier Detect (\overline{DCD}) signal line.

ACIA Status Register

The status of the MC7850 ACIA may be read from the ACIA Status Register. The information stored in this register indicates the status of the Transmit Data Register, the Receive Data Register and error logic, and the peripheral status inputs of the ACIA.

SR7	SR6	SR5	SR4	SR3	SR2	SR1	SR0
\overline{IRQ}	PE	OV RN	FE	\overline{CTS}	\overline{DCD}	TDRE	RDRF

Figure 2.3: ACIA Control Register

Receive Data Register Full (RDRF)

The *receive data register full bit* (SR0) indicates that received data has been transferred to the receive data register. The *receive data register full bit* is

cleared when the Receive Data Register is read or by a master reset. When the *receive data register full bit* is not set the data in the Receive Data Register is not current.

Transmit Data Register Empty (TDRE)

The *transmit data register empty bit* (SR1) is set when the contents of the Transmit Data Register have been transferred, indicating that new data may be entered. When the *transmit data register empty* is not set, the transmission of the character currently in the Transmit Data Register has not yet begun.

Data Carrier Detect (\overline{DCD})

The *data carrier detect bit* (SR2) would normally indicate the modem carrier status. However, as the \overline{DCD} pin of the MC6850 is permanently connected to ground on the PAL-1 Serial Interface Adapter, the *data carrier detect bit* will never be set.

Clear-to-Send (\overline{CTS})

The *clear to send bit* (SR3) indicates the Clear-to-Send input from the modem. A low \overline{CTS} indicates that there is a Clear-to-Send from the modem. In the high state, the Transmit Data Register Empty bit is inhibited and the Clear-to-Send status bit will be high. Master reset does not affect the Clear-to-Send status bit.

Framing Error (FE)

The *framing error bit* (SR4) indicates that the received character is improperly framed by a start and stop bit. Framing errors are detected by the absence of the first stop bit. This error indicates a synchronisation error, a faulty transmission, or a break condition. The framing error bit is set or reset during the receive data transfer time. Therefore, this error indicator is present throughout the time that the associated character is available.

Receive Overrun (OVRN)

A receive overrun error indicates that one or more characters in the data stream were lost. This happens when a character or number of characters were received, but not read from the Receive Data Register prior to subsequent characters being received. The *receive overrun bit* (SR5) is reset after reading data from the Receive Data Register, or by a master reset.

Parity Error (PE)

The *parity error bit* (SR6) is set when the number of highs (ones) in the character does not agree with the preset odd or even parity. If no parity is selected then both the transmitter parity generator output and receiver parity check results are inhibited.

Interrupt Request (\overline{IQR})

The *interrupt request bit* (SR47) indicates that an interrupt has occurred. This status bit may be set by any enabled interrupt condition. It is cleared when the Receive Data Register is read, or when a character is written to the Transmit Data Register.

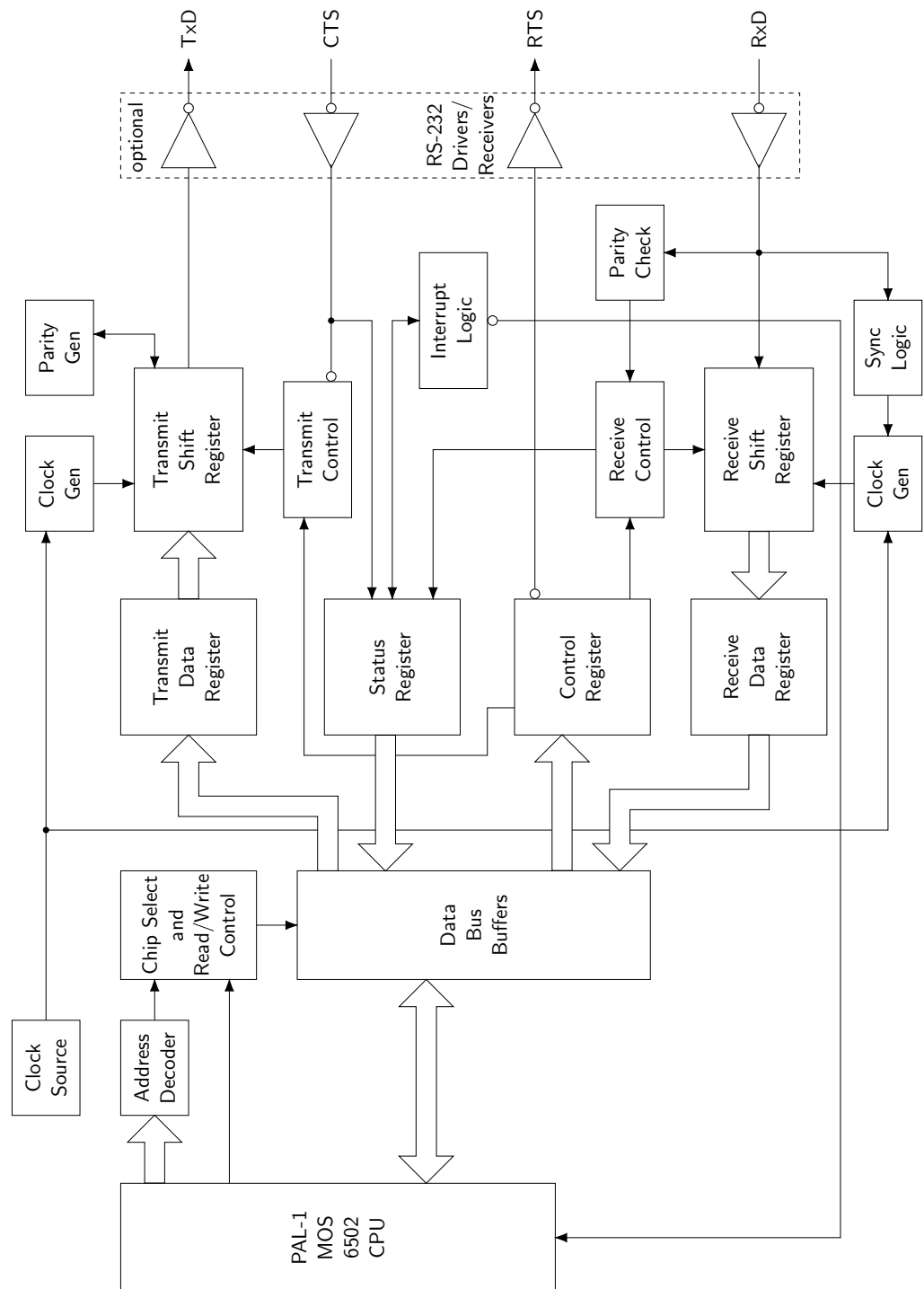


Figure 2.1: PAL-1 Serial Interface Adapter block diagram.

3. *Sample Code*

Programming the PAL-1 Serial Interface Adapter simply requires the ability to write to and read from the mapped I/O address. Many programming languages provide statements to achieve this, including the POKE and PEEK statements in BASIC, and C! and C@ in Forth.

Note that all examples included below use the default base address (ie. \$16E8, 5864₁₀). Further examples may be found on Github at <https://github.com/dimitrit/pal1serial>.

BASIC

The following example was taken from the ‘*Do-It-Yourself RS-232 Interface*’ article in the 1986 Special Edition, Issue 3 of CPC Schneider International magazine¹. Because the MC6850 ACIA is memory mapped on the PAL-1 all OUT statements have been replaced with POKE statements, and IN with PEEK. Note that this example requires loopback connections from TXD to RXD, and from RTS to CTS.

```
10 REM *****
20 REM *   RS-232-TEST   *
30 REM *****
40 BA=5864:REM PAL-1 SERIAL I/F ADAPTER BASE ADDRESS
50 PRINT "          RS-232 "
60 PRINT "-----"
70 PRINT:PRINT:PRINT
80 PRINT "BAUDRATE: A) 300 Bd [ 600 Bd] "
90 PRINT "          B) 1200 Bd [2400 Bd] "
100 PRINT:PRINT:INPUT "SELECT BAUDRATE ";B$
110 IF B$="A" THEN BD=2:GOTO 130
120 IF B$="B" THEN BD=1 ELSE GOTO 100
130 PRINT:PRINT:PRINT"ENSURE THE FOLLOWING PINS ARE CONNECTED: "
140 PRINT"      TXD<--->RXD "
150 PRINT"      RTS<--->CTS "
160 PRINT:PRINT
170 INPUT"<ENTER> ";E$
180 PRINT:PRINT
190 POKE BA,3:REM MASTER RESET
```

¹Schweda, pp. 88-92.

```

200 POKE BA,16+BD:REM SET WORD LENGTH & BAUD RATE
210 PRINT "    ***RS-232TEST***"
220 IF PEEK(BA) AND 8 THEN PRINT"CTS AND RTS NOT SHORTED":END
230 FOR A=32 TO 127
240 IF PEEK(BA) AND 2 THEN POKE BA+1,A ELSE 240
250 IF PEEK(BA) AND 1 THEN GOTO 260 ELSE 250
260 B=PEEK(BA+1)
270 PRINT " ";CHR(A);"-";CHR(B);" ";
280 IF A<>B THEN PRINT"FAILURE: ";PEEK(BA):END
290 NEXT
300 END

```

Listing 3.1: RS-232 Test Program

6502 assembly language

The assembly language example below repeatedly writes a short message to the serial port. It checks that the Transmit Data Register Empty bit is set before sending a character.

```

serio          = $16e8          ; MC6850 base i/o address
outch          = $1ea0          ; print ASCII char in A on tty

                * = $60

textptr        .word message    ; pointer to text to be sent

                * = $200

                cld              ; binary mode
                lda #%011        ; reset MC6850 ACIA
                sta serio
                lda #%010100      ; set to 38400,8,N,1
                sta serio
initptr        ldy #0           ; initialise pointer

waitsnd        lda serio        ; get status
                and #%010        ; is transmit buffer empty?
                beq waitsnd       ; no, wait longer

                lda (textptr),y  ; get next character
                beq initptr       ; null, so start again
                sta serio+1       ; write character to buffer
                iny              ; increase pointer
                jmp waitsnd       ; and go round

                .align $100      ; align to next page boundary

                .enc "screen"    ; use ascii encoding

```

```
message          .text "HELLO FROM PAL-1 ",0  
                .end
```

Listing 3.2: Hello World!

A. *Connector Pin Outs*

RS-232 D-Sub Connector

The pin-out of the RS-232 D-Sub 9-pin male connector (J2) follows the standard convention for Data Terminal Equipment (DTE), as shown in Figure A.1.

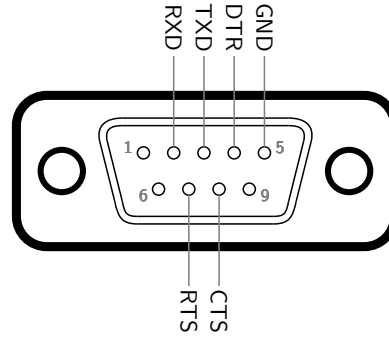


Figure A.1: D-Sub 9-Pin Male Connector

Pin	Signal	Description
1	NC	Not Connected
2	RXD	Receive Data
3	TXD	Transmit Data
4	DTR	Data Terminal Ready ¹
5	GND	Ground
6	NC	Not Connected
7	RTS	Request to Send
8	CTS#	Clear to Send
9	NC	Not Connected

¹ DTR is set using JP5 (see page 3).

Table A.1: D-Sub 9-Pin Male Connector

TTL Pin Header

The PAL-1 Serial Adapter TTL pin header (J3) allows 6-way FTDI based USB to TTL converters to be directly connected¹. **Be sure to check the USB to TTL converter voltage levels and signals before connecting as incorrect voltage and/or incompatible signals may result in damage to the PAL-1 Serial Adapter.**

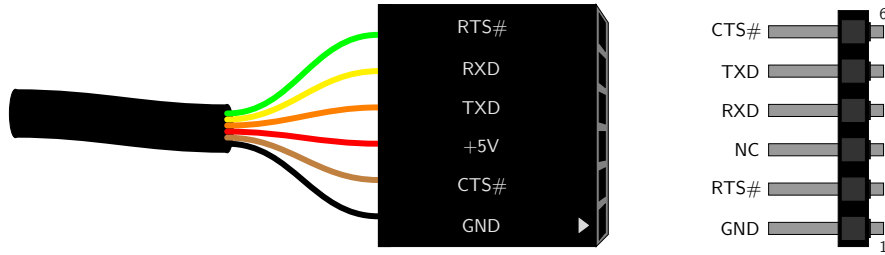


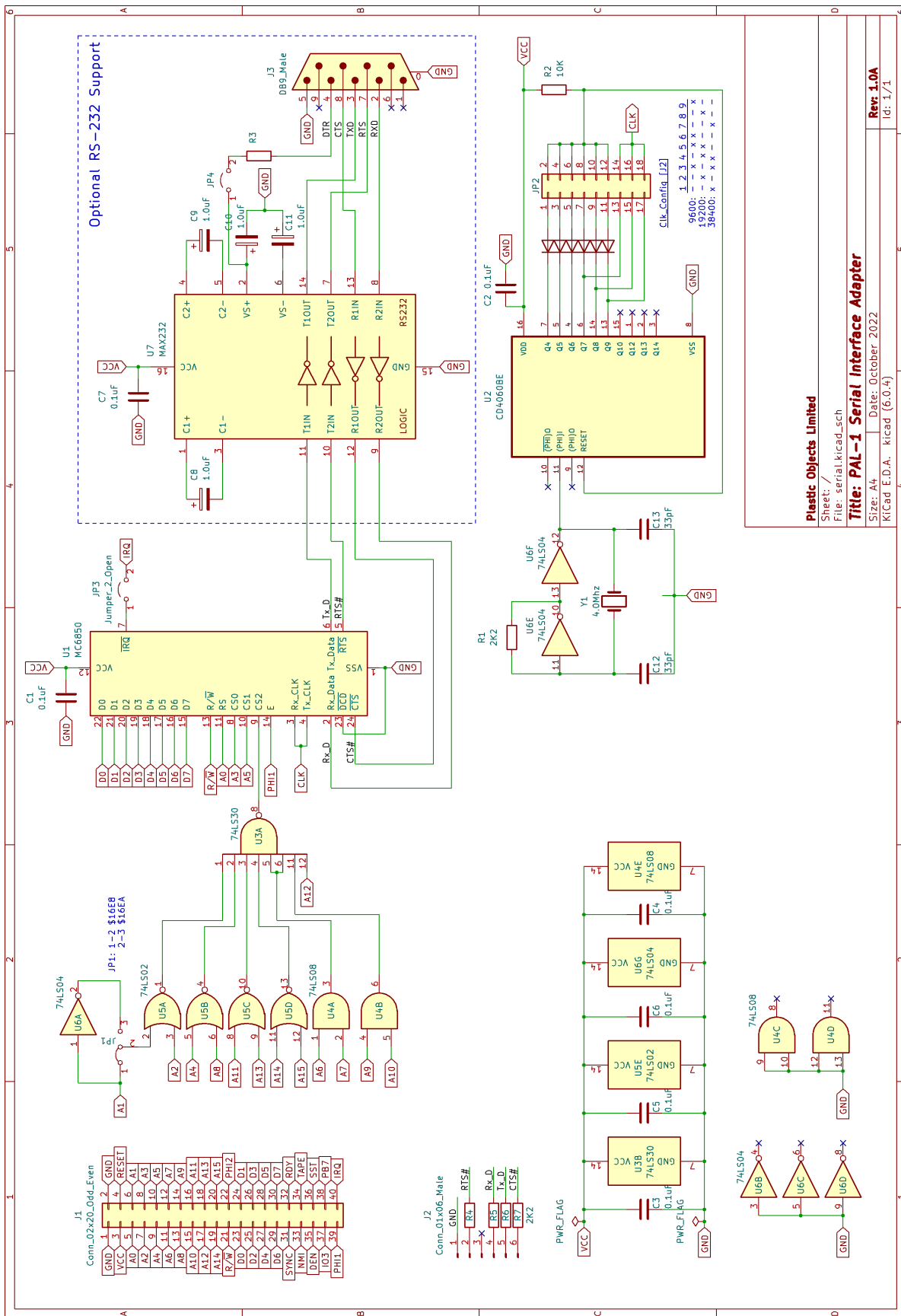
Figure A.2: TTL Pin Header

Pin	Signal	Description	TTL-232R-5V	Signal
1	GND	Ground	Black	GND
2	RTS#	Request to Send	Brown	CTS#
3	NC	Not Connected	Red	5V
4	RXD	Receive Data	Orange	TXD
5	TXD	Transmit Data	Yellow	RXD
6	CTS#	Clear to Send	Green	RTS#

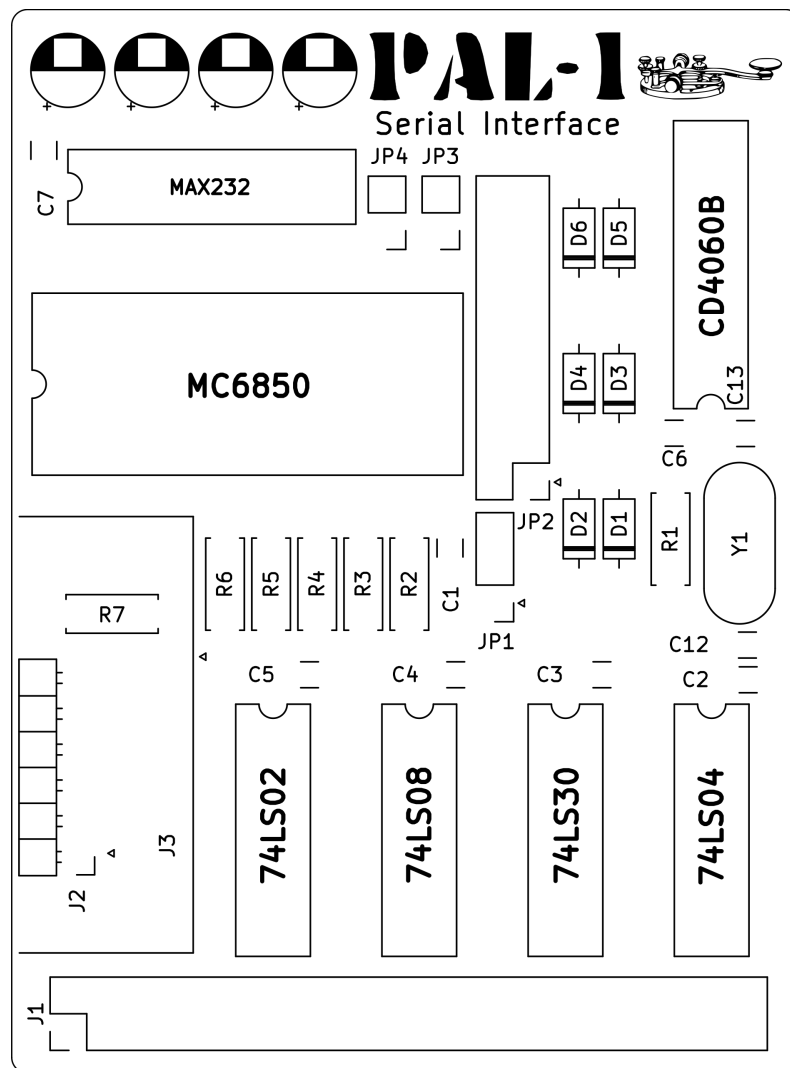
Table A.2: TTL Pin Header & FTDI USB Adapter Connections

¹FTDI Chip, 'TTL-232R TTL to USB Serial Converter Range of Cables Datasheet' (2019), (https://ftdichip.com/wp-content/uploads/2021/02/DS_TTL-232R_CABLES.pdf) accessed 2022-10-27, pp. 11-12.

B. *Schematic Diagram*



C. Board layout



D. *Bill of Materials*

Part	Qty	Value	Description
C1 - C7	7	0.1uF	Unpolarized capacitor
C8 - C11	4	1.0uF	Polarized capacitor
C12, C13	2	33pF	Unpolarized capacitor
D1 - D6	6	1N4148	Standard switching diode, DO-35
J1	1		Connector, double row, 2x20
J2	1		Connector, single row, 1x6
J3	1		Connector, 9-pin male D-SUB
JP1	1		Jumper, 3-pole, pins 1+2 closed/bridged
JP2	1		Connector, double row, 2x9
JP3, JP4	2		Jumper, 2-pole, open
R1, R4-R7	5	2K2	Resistor
R2	1	10K	Resistor
R3	1	2K7	Resistor
U1	1	MC6850	Asynchronous Communications Interface Adapter 1MHz
U2	1	CD4060BE	14-stage binary counter/divider
U3	1	74LS30	8-input NAND gate
U4	1	74LS08	Quad 2-input AND gate
U5	1	74LS02	Quad 2-input NOR gate
U6	1	74LS04	Hex Inverter
U7	1	MAX232	Dual RS232 driver/receiver
Y1	1	4.0Mhz	Two pin crystal

Table D.1: PAL-1 Serial Interface Adapter v1.0A components

References

- FTDI Chip, ‘TTL-232R TTL to USB Serial Converter Range of Cables Datasheet’ (2019), https://ftdichip.com/wp-content/uploads/2021/02/DS_TTL-232R_CABLES.pdf accessed 2022-10-27.
- Ganning, Liu, ‘PAL-1 Microcomputer User Manual’ (November 2020), http://pal.aibs.ws/assets/PAL_en.pdf accessed 2022-07-21.
- Motorola Semiconductor Products, ‘Motorola Microcomputer Components’ (1978).
- Motorola Semiconductors, ‘MC6850, Asynchronous Communications Interface Adapter (ACIA)’ (1994).
- Schweda, Joachim, ‘Schnittstelle RS-232 im Selbstbau’, *CPC Schneider International*, 7:3 (1986), 88–92.