

Color Computer Expansion Interface Designed to Emulate the Tandy Multi-Pak Interface

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INTRODUCTION

This 4-slot Expansion Interface provides the Tandy Color Computer with 4 fully buffered slots for system expansion. The interface allows up to four I/O, ROM or RAM paks to be available to the Color Computer. This greatly expands the capability of the original computer with its single cartridge connector.

The Color Computer's cartridge connector was designed for game cartridges and other expansion such as a floppy disk controller. Select signals for memory and I/O devices are made available at the connector. These decoded select signals are:

1. CTS - Cartridge Select Address space \$C000 - \$FEFF selected
2. SCS - Spare Chip Select Address space \$FF40 - \$FF5F selected

A third signal called CART is used to indirectly send (through a 6821 PIA chip) a Fast Interrupt Request to the microprocessor. This is normally done on ROM cartridges by shorting the quadrature clock (Q) to CART on the cartridge's circuit board. The fast interrupt then automatically starts the ROM cartridge software.

A primary requirement of this interface is to buffer the address, data, and control busses. This design emulates the original Tandy Multi-Pak Interface as follows:

1. Buffering of all signals except SND (sound source from cartridge)
2. Hardware switch selection of any slot with a manual rotary switch (instead of slide switch)
3. Software selection of any slot at address \$FF7F with the following features:
 - High order nibble of control byte controls routing of CTS
 - Low order nibble of control byte controls routing of SCS
 - Ability to independently route CTS or SCS to any slot
 - Manual slot selection is disabled after software select
4. Ability to read the status of the interface at \$FF7F with initial control byte values of:
 - \$CC for slot 1
 - \$DD for slot 2
 - \$EE for slot 3
 - \$FF for slot 4

(as determined by hardware switch setting)
5. Routing of CART from the slot that CTS is active in
6. Resetting the computer should reset the interface to the manual slot selector switch

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ADDITIONAL FEATURES

This Expansion Interface design includes the following additional features:

1. Compatible with all Color Computers -- the original Tandy MPI does not work with the Color Computer 3.
2. LED's indicate the routing of SCS and CTS signals
3. An Auto Start switch can prevent auto-starting of cartridge ROM software
4. A 3 position Reset switch is included with the following functions:
 - Reset the interface to the slot selected by the manual selector switch
 - Disconnect the interface from the Color Computer
 - Prevent the resetting of the interface when the computer's reset is pressed

Each of the four slots accepts 40-pin edge card connector devices -- the same that normally plug into the Color Computer's single cartridge connector.

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USING THE EXPANSION INTERFACE

The Expansion Interface is mapped to address \$FF7F. By writing a 'control byte' to that address, one can change the setup of active slots. The control byte is setup as follows:

Bits 0 and 1 - Determines the routing of SCS

Bits 2,3,6,7 - don't care

Bits 4 and 5 - Determines the routing of CTS

On power-up of the computer and Expansion Interface, if you peek at \$FF7F you will see the following:

If manual selector switch is in:

Slot Position 1 - \$CC

Slot Position 2 - \$DD

Slot Position 3 - \$EE

Slot Position 4 - \$FF

Note that the Expansion Interface's manual selection simply sets the unused bits 2,3,6 and 7 high.

The best way to software select a slot is to poke \$FF7F with one of the following control bytes (even though others could be used because of the unused bits):

\$00 - Sends CTS and SCS to slot 1

\$11 - Sends CTS and SCS to slot 2

\$22 - Sends CTS and SCS to slot 3

\$33 - Sends CTS and SCS to slot 4

Note that the high order nibble routes CTS and the low order nibble routes SCS. It is possible to route either signal individually to any slot. For example, suppose you want CTS routed to slot 1 and SCS routed to slot 4. The following control could be used :

\$03 - CTS to slot 1, SCS to slot 4

If you have a Disk Controller it should go in slot 4 as recommended by Tandy. Some other hardware I/O devices may need to be in a special slot. Consult your I/O device documentation as required. This Expansion Interface should be compatible with any software written for the Color Computer, including OS-9.

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DESIGN DETAILS

The Expansion Interface has its own power supply (see schematic sheet 2 of 2) which is controlled by +5 VDC from the CoCo (pin 9 of the edge connector).

When the CoCo is powered up, the +5 VDC from the computer turns on a solid state AC output relay, thus allowing the expansion interface's power supply to start (a surplus TI 99/4 computer power supply). This power supply provides +5 VDC at 1.1 A and +12 VDC at 400 mA. The -12 VDC is supplied to the Expansion Interface slots from the computer's supply (max 100 mA).

You may substitute any other power supply in place of the surplus TI 99/4 power supply as required. I used it because it was available at the time and the price was right. If another model is used, it would be ideal if it also supplied the -12 VDC to the expansion interface instead of using the CoCo's -12 VDC supply.

Referring to the schematic, the **P1** connector is the Color Computer's cartridge connector.

U1 and U2, 74LS244 Octal Tri-State Bus Drivers buffer the address bus. These devices are always active by holding their select pins low.

U3, a 74LS645 Octal Tri-state Bus Transceiver buffers the data bus. The data direction is controlled by the R/W* line.

U4 and U5, 74LS367 Hex Tri-State Bus Drivers buffer the control bus.

U6, a 74S373 Octal D-Type Transparent Latch latches the data bus (control byte) when address \$FF7F is written to.

U7, a 74LS244 Octal Tri-State Bus Driver allows reading the control byte when address \$FF7F is read.

U8, a 74S139 Dual 2-Line to 4-Line Decoder, is used to decode the data bits latched from writing to \$FF7F or as hardwired from the manual slot select circuit. The bits are decoded as follows:

Bits 0 and 1 - Determines the routing of SCS

Bits 4 and 5 - Determines the routing of CTS

U9, a 74LS125 Quadruple Bus Buffer with 3-State Outputs, is used to pass the SCS signal to the appropriate slot. The result of decoding bits 0 and 1 by U8 are routed to this chip's G enable pins. SCS1 is routed to Slot 1, SCS2 is routed to Slot 2, SCS3 is routed to Slot 3, SCS4 is routed to Slot 4.

U10, a 74LS125 Quadruple Bus Buffer with 3-State Outputs, is used to pass the CTS signal to the appropriate slot. The result of decoding bits 4 and 5 by U8 are routed to this chip's G enable pins. CTS1 is routed to Slot 1, CTS2 is routed to Slot 2, CTS3 is routed to Slot 3, CTS4 is routed to Slot 4.

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U11, a 74LS244 Octal Tri-State Bus Driver is used to buffer the manual slot select circuit's bits 0, 1, 4, 5 to the control byte if selected, and keeps bits 2, 3, 6, 7 of the control byte high.

U12 and U13, 74LS257 Quadruple 2-Line to 1-Line Data Selectors are used to provide the required control bits (0, 1, 4, 5) for each of the four manual slot select positions. The required "manual" control bytes are constructed by these 4 bits and 4 bits from U11 (2, 3, 6, 7) which are set high.

U14, a 74LS74 Dual D-Type Flip-Flop is used to select either manual or software control of the Expansion Interface. When RESET is pressed on the computer U14 is preset to deselect the software output latch U6, and select the manual buffer U11. When \$FF7F is written to, U14 is clocked to set the Q output low, thereby selecting the software output latch U6 and deselecting the manual buffer U11.

U15, a 74LS00 Quadruple 2-Input NAND Gate is used for address decoding and selection of the manual slot select decoders U12 and U13.

U16, a 74LS10 Triple 3-Input NAND Gate, is used for address decoding.

U17 and U18, 74LS30 8-Input NAND Gates are used for address decoding.

U19, a 74LS04 Hex Inverter is used as required in the design.

U20, a 74LS125 Quadruple Bus Buffer with 3-State Outputs controls routing of the CART signal from the slot that has the CTS signal. On the schematic, CART1 is from Slot 1, CART2 is from Slot 2, etc. Only one slot can have the CTS active.

The AUTO START switch controls the passing of the CART signal from the active slot to the Color Computer. When the switch is closed to ground, the CART signal can pass to the Color Computer. If it is open it prevents the CART from passing to the computer.

The ON-DISC-OFF switch controls the RESET signal from the Color Computer as follows :

1. ON Position - Reset on computer resets the interface to the slot selected by the manual selector switch.
2. DISC Position - Disconnects the interface from the Color Computer entirely
3. OFF Position - Prevents resetting of the interface when the computer's reset is pressed.

Normal emulation of the Tandy MPI would have the AUTO START switch closed to ground, and the ON-DISC-OFF switch set to ON. The other options are enhancements included in this design.

The MANUAL SELECT switch controls which hardwired bits from U12 and U13 are routed to the Manual Buffer U11.

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BUILDING THE INTERFACE

The Expansion Interface can be built a perf board using the wire wrapping technique. I obtained most of the parts from Digi-Key. The expansion slot edge card connectors are from Texas Instruments (I am not sure these are available anymore – substitute as required). The resistor packs are mounted in wire wrapping sockets.

The attached drawing shows the arrangement of parts on the board.

The list on the following page shows the wire connections as they are routed from the edge card connector to the 40-pin header. All connections on the Expansion Interface board are made from the 40-pin DIP header to the IC's and expansion slots.

Wire all of the buffered address bus, data bus, and control signals to each of the 4 slots as shown on sheet 2 of the schematic, creating the equivalent of a backplane. (The only unbuffered exception is the SND signal which should be routed to each slot's pin 35 and then to pin 23 of the 40-pin header).

Wire the SCS and CTS signals from the pass gates U9 and U10 to pins 36 and 32 of the appropriate slots. Wire the CART signals 1 – 4 from U20 to pin 8 of slots 1 - 4.

Not shown on the schematic are 0.1 uF bypass capacitors which should be mounted across the +5 VDC power supply close to each integrated circuit.

There are many possibilities for the enclosure. I used 1/16" aluminum, which I had bent into a "C" form. I mounted the power supply inside and the perf board on top using standoffs. The LED's and switches were then mounted on the front.

For connection from the computer to the expansion interface, use a 40 conductor ribbon cable. One end of the cable comes with an attached 40-pin DIP header for plugging into the interface's 40-pin DIP socket (from Digi-Key – see Bill of Materials). On the other end of the cable attach a 40-pin edge card connector. From this connector to the computer's connector use a "extender" board cut from an old game cartridge. The extender board is simply a 1/2 inch long board with 0.062" fingers on 0.1 inch centers.

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Edge Connector to 40-pin Header Connections and Function

Edge Connector	40 Pin Header	Function
1	40	-12 VDC
2	1	+12 VDC
3	39	HALT*
4	2	NMI*
5	38	RESET*
6	3	E
7	37	Q
8	4	CART*
9	36	+5 VDC
10	5	D0
11	35	D1
12	6	D2
13	34	D3
14	7	D4
15	33	D5
16	8	D6
17	32	D7
18	9	R/W*
19	31	A0
20	10	A1
21	30	A2
22	11	A3
23	29	A4
24	12	A5
25	28	A6
26	13	A7
27	27	A8
28	14	A9
29	26	A10
30	15	A11
31	25	A12
32	16	CTS*
33	24	GND
34	17	GND
35	23	SND
36	18	SCS*
37	22	A13
38	19	A14
39	21	A15
40	20	SLENB*

Note: The asterisk indicates an active low signal.

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BILL OF MATERIALS

INTEGRATED CIRCUITS

REF	PART NO.	NO. PINS	USE
U1	74LS244	20 PIN	A0-A7 BUFFER
U2	74LS244	20 PIN	A8-A15 BUFFER
U3	74LS645	20 PIN	DATA BUS BUFFER
U4	74LS367	16 PIN	CONTROL BUS BUFFER
U5	74LS367	16 PIN	CONTROL BUS BUFFER
U6	74S373	20 PIN	DATA LATCH
U7	74LS244	20 PIN	DATA INPUT BUFFER
U8	74S139	16 PIN	CONTROL BYTE DECODE
U9	74LS125	14 PIN	SCS PASS GATE
U10	74LS125	14 PIN	CTS PASS GATE
U11	74LS244	20 PIN	MANUAL CONTROL BUFFER
U12	74LS257	16 PIN	SLOTS 1&3 MANUAL SELECTOR
U13	74LS257	16 PIN	SLOTS 2&4 MANUAL SELECTOR
U14	74LS74	14 PIN	SET/RESET LATCH
U15	74LS00	14 PIN	NAND GATE
U16	74LS10	14 PIN	WRITE/READ CONTROL
U17	74LS30	14 PIN	ADDRESS DECODE
U18	74LS30	14 PIN	ADDRESS DECODE
U19	74LS04	14 PIN	INVERTER
U20	74LS125	14 PIN	INTERRUPT CONTROL

RESISTOR PACKS

REF.	TYPE	RATING
RP1	10 PIN SIP	330 OHM x 9 RESISTOR
RP2	10 PIN SIP	4.7KOHM x 9 RESISTOR
RP3	14 PIN DIP	4.7KOHM x 13 RESISTOR

SWITCHES

REF.	TYPE
SW1	2 POLE 4 POSITION ROTARY SWITCH FOR MANUAL CONTROL
SW2	SPST SWITCH FOR INTERRUPT ENABLE
SW3	SPDT CENTER OFF SWITCH FOR RESET CONTROL

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WIRE WRAP SOCKETS

<u>QTY</u>	<u>TYPE</u>
1	40 PIN WW SOCKET
7	20 PIN WW SOCKET
5	16 PIN WW SOCKET
10	14 PIN WW SOCKET

MISCELLANEOUS

<u>QTY</u>	<u>PART DESCRIPTION</u>
1	TI 99/4 SWITCHING POWER SUPPLY
8	T-1 3/4 LED HOLDERS
8	T-1 3/4 RED LED'S
1	POTTER & BRUMFIELD AC OUTPUT MODULE, 5 VDC CONTROL
4	20 / 40 PIN EDGE CARD CONNECTORS FOR SLOTS (0.1 inch centers)
8	PCB STANDOFFS WITH SCREWS
1	40 CONDUCTOR RIBBON CABLE (4 INCHES LONG)
1	40 PIN DIP HEADER FOR RIBBON CABLE (Consider using Digi-Key Part No. C4PXG-4006M-ND for 2 items above)
1	40 PIN EDGE CARD CONNECTOR FOR RIBBON CABLE CONNECT (Consider using Digi-Key Part No. CCE40G-ND)
1	PANEL MOUNT FUSE HOLDER
20	0.1 uF BYPASS CAPACITORS

6 x 8 INCH PERF BOARD

WIRE WRAPPING WIRE

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CONCLUSION

This Expansion Interface should prove to be a valuable addition to your Color Computer setup. I have had mine in operation since 1987 and it still performs as designed and built. Please send me your comments about this design.

If anyone has the time, it would be nice if a printed circuit board was designed for this interface. If time permits and there is a demand for it I may design one in the future.

As a final note, the following program can be used to "cycle" the interface from BASIC, and provides a nice walking display of the SCS and CTS LED's on the Expansion Interface's front panel. Before running this program, make sure the AUTO START switch is in the OFF position.

CYCLE.BAS

```
10 C=1
20 POKE &HFF7F,&H00
30 GOSUB 200
35 POKE &HFF7F, &H11
40 GOSUB 200
45 POKE &HFF7F, &H22
50 GOSUB 200
55 POKE &HFF7F, &H33
60 GOSUB 200
65 C=C+1:IF C<5 THEN 20
70 FOR X=1 TO 255 STEP 7
75 POKE &HFF7F,X
80 GOSUB 200
85 NEXT X
90 GOTO 10
200 FOR D=1 TO 50:NEXT D
210 RETURN
```

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RS-232 PAK SLOT ASSIGNMENT IN OS-9

Here's how to patch the RS-232 Pak's OS-9 driver ACIAPAK to work in any slot of the expansion interface.

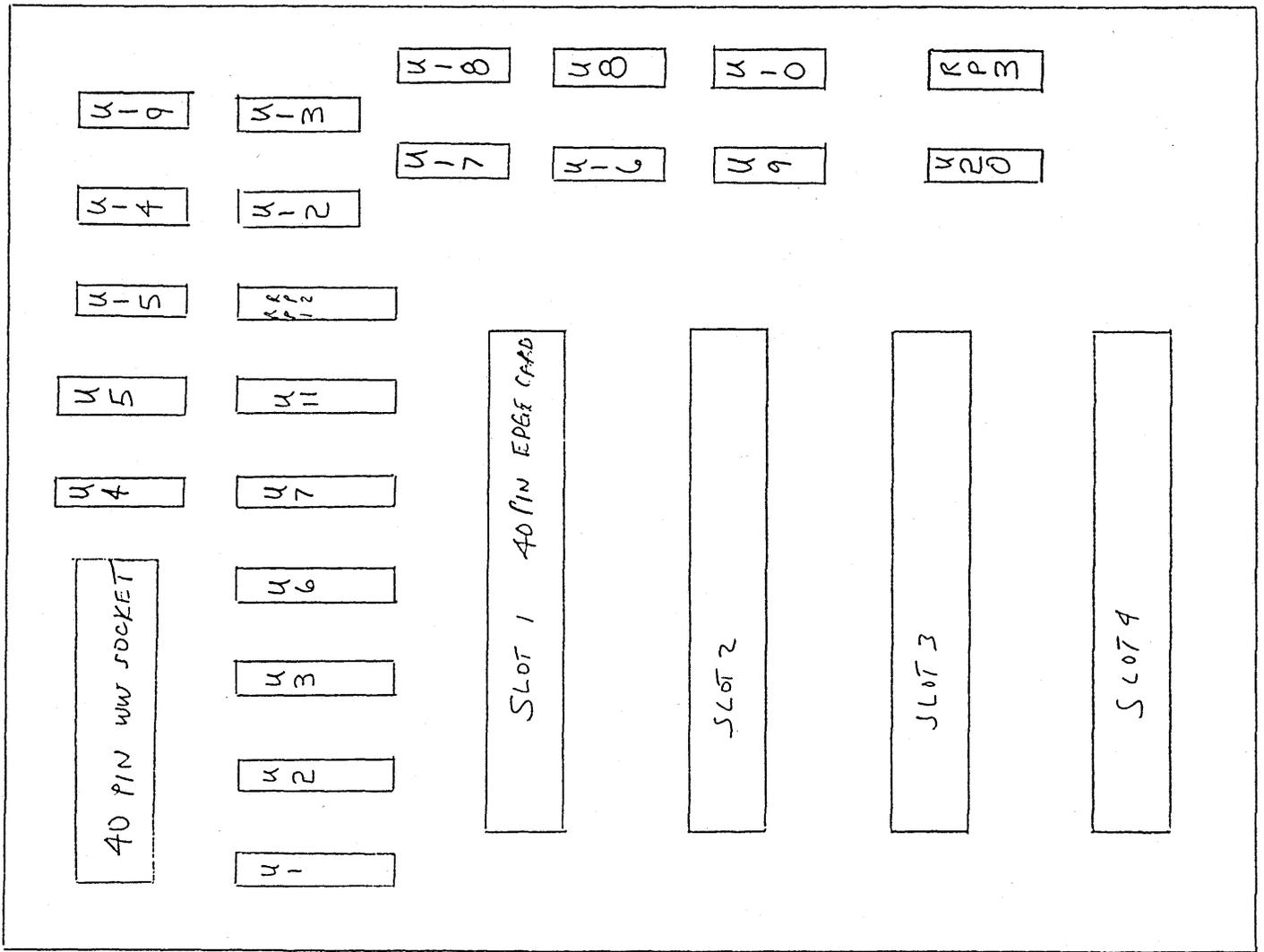
ACIAPAK uses an \$03 control byte when it sets up the expansion interface for using the RS-232 Pak. This byte routes CTS to slot 1 and SCS to slot 4 -- it assumes you have the RS-232 Pak in slot 1 and your disk controller in slot 4.

To put the RS-232 Pak in another slot, we need to patch ACIAPAK's control byte to route the CTS signal to the correct slot. (The SCS signal must remain routed to slot 4 for the disk controller)

The patch location is \$68 in ACIAPAK. I patched my ACIAPAK so I could put my RS-232 Pak in slot 3. The following change did the trick:

Location	Old Value	New Value
\$68	\$03	\$23

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COLOR COMPUTER EXPANSION INTERFACE
BOARD LAYOUT

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