

# Breakout Rev[F] SCH to PCB Differences

## Abstract:

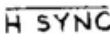
The schematic on p35 thru p42 of the Breakout Operation, Maintenance, Service Manual (TM-058, 4<sup>th</sup> printing) shows Rev[F]. This schematic does not perfectly match Rev[F] circuit boards. This document details the differences. Naturally we modify the schematics to match the boards because the boards ... work.

## Nomenclature:

We use the following nomenclature in this document:

**Schematic Sheet and Location references** in this document are shown as [S#<x>-<yz>] where x is the sheet number, and yz is the location, e.g. [S#1-D1]. If the reference spans more than one location then additional locations are appended with a forward-slash separator, e.g. [S#1-D1/C1].

**PCB IC Sites** are shown as [<c><r>] where c is the column A-N and r is the row 1-9, e.g. [M6]. Other components are labeled as per the schematic and the service manual board layout page. Components not on the original schematic are labeled in a similar flow.

**Signal Names** are negated with the '!' preface instead of the overhead bar, e.g. !H\_SYNC and  are equivalent.

## Ancillary Documents:

The original ½ page Rev [F] schematics were extracted from the manual, merged, and modified. The following documents are associated with this process.

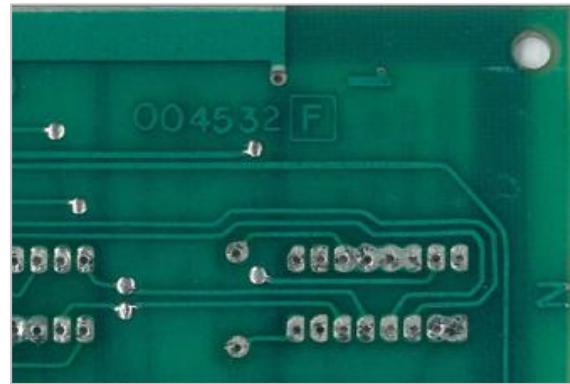
File	Description
Breakout-RevF-S#1.jpg	Original Sheet 1 reconstituted from p35/36
Breakout-RevF-S#2.jpg	Original Sheet 2 reconstituted from p37/38
Breakout-RevF-S#3.jpg	Original Sheet 3 reconstituted from p39/40
Breakout-RevF-S#4.jpg	Original Sheet 4 reconstituted from p41/42
Breakout-RevF-Layout.jpg	Original Parts layout from p45
Breakout-RevFx-S#1.jpg	Modified Sheet 1
Breakout-RevFx-S#2.jpg	Modified Sheet 2
Breakout-RevFx-S#3.jpg	Modified Sheet 3
Breakout-RevFx-S#4.jpg	Modified Sheet 4
Breakout-RevFx-Layout.jpg	New Layout

# Breakout Rev[F] SCH to PCB Differences

## Revisions and Engineering Changes

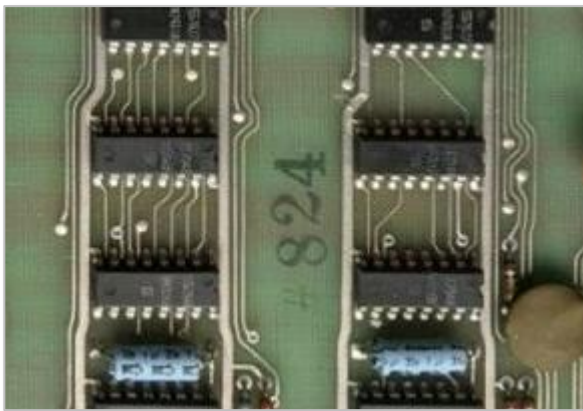
A revisions list is shown on Sheet#1-D1/D2 while the physical PCB revision is shown on the solder side near site N1.

2		1	
REVISIONS			
SYM	DESCRIPTION	INITIALS and DATE	
		DRFTG	CHECK ENGRC
A	PRODUCTION RELEASE	2/13/76	
B	REV PER ECN 2275, 2276, 2277	3-16-76 208	
C	REV PER ECN 2289, 2349, 2387	4-8-76	
D	REV PER ECN 2471	4/29/76	
E	REV PER ECN 2525	5/14/76	
MF	F REV PER ECN 2547, 2569	6/2/76	



Unfortunately, many of the on-line images are of the component side only. While we can see various modifications, we don't know the exact revision. Fortunately, we have great hi-res images of a rev-F board, and I purchased duff rev-D and rev-E boards off the inter-web to compare modifications and narrow the ECN changes.

Boards often (but not always) have a number stamp between rows 6 & 7 near columns B & C. It would be interesting to see the ranges of numbers to revisions. You can clearly see that the modifications decrease as the stamped numbers increase. Seems like the stamp disappears at one point. Perhaps they lost it, it got worn out, or it ran out of numbers.



# Breakout Rev[F] SCH to PCB Differences

## Differences, Modifications, Notes

Here is a list of the modifications I've seen and the differences between the rev-F schematics and PCB. Looks like they didn't keep the schematics completely up to date with the PCB. We discuss these in detail in the next section. Note: '\*' denotes parts found on Rev-F boards but not on the schematic.

Ref	Title/Description	Sheet-Zone
<b>Diff-1</b>	Suppress LH/RH duing HSYNC (adds CR9*, CR10*, R59*)	[S#1-C6]
<b>Diff-2</b>	Different wiring of the Set Bricks FF [D3b]	[S#1-A6]
<b>Diff-3</b>	Video Chain Resistor Differences	[S#1-D3/D4]
<b>Diff-4</b>	Play FF [F5a] Cleared by HSYNC instead of 128H	[S#1-C2]
<b>Diff-5</b>	Different wiring in Ball Motion Logic	[S#1-B4]
<b>Diff-6</b>	Serve Wait Logic Differences & Add 330pF cap C39*	[S#1-B1/B2]
<b>Diff-7</b>	Another Serve Wait Logic Difference (adds a 7408 @ [C1*])	[S#1-B1/B2]
<b>Diff-8</b>	Paddle Wiring Differences	[S#2-B2]
<b>Diff-9</b>	Paddle Timer Changes to 555 @ [C9] (adds C40*)	[S#2-B3]
<b>Diff-10</b>	Add 0.001uF Capacitor in Score Logic (adds C38*)	[S#2-A4]
<b>Diff-11</b>	1-Credit Start FF Wrong Signal Marking	[S#3-C7]
<b>Diff-12</b>	Free-Game Wiring Different	[S#3-A5/A6]
<b>Mod-1</b>	4.7K pull-up on Brick Storage RAM Data-Out [L3-6] (optional mod)	[S#1-B7]
<b>Note-1</b>	R51 & R52 are swapped on the schematic (or PLAYFIELD and SCORE)	[S#1-D4]
<b>Note-2</b>	[N4].8 has an extraneous dot indicator	[S#1-C6]
<b>Note-3</b>	[A7].11 is missing the dot indicator	[S#2-C3/C4]
<b>Note-4</b>	[N5].11,12,13 labeled differently than on other instances	[S#2-C7]
<b>Note-5</b>	[N5,M5,L5,K5] Z outputs not labeled (and the !Z output is missing)	[S#2-C7/B7/A7]
<b>Note-6</b>	[H5,J4] the Z output is missing	[S#2-B6]
<b>Note-7</b>	The "1 CR START" label coming off [E8].6 s.b. "1 CR START"	[S#3-C6]
<b>Note-8</b>	L8 pins 11 and 12 are connected	[S#3-B4]
<b>Misc-1</b>	Unused inputs not shown	
<b>Misc-2</b>	Specific pull-up nets are not identified in Rev-F but are shown in Rev-Fx	
<b>Misc-3</b>	Unused outputs almost always shown except ...	
<b>Misc-4</b>	Unused input [B8].15 (-C) not shown on schematic ...	[S#2-B5]
<b>Misc-5</b>	[N2] (7483) shows power pins while [M2] does not	[S#4-C8]
<b>Misc-6</b>	Resistors R22 and R23 are swapped	[S#2-D4]
<b>Misc-7</b>	Resistors R47 and R48 are swapped	[S#2-D2/3]
<b>Misc-8</b>	K9b Reset Line s.b. pin 10, not pin 11	[S#3-B5]
<b>Misc-9</b>	CR1 and CR2 are swapped	[S#4-C8]
<b>Misc-10</b>	L8 pins 11 & 12 are connected together	[S#3-B4]

# Breakout Rev[F] SCH to PCB Differences

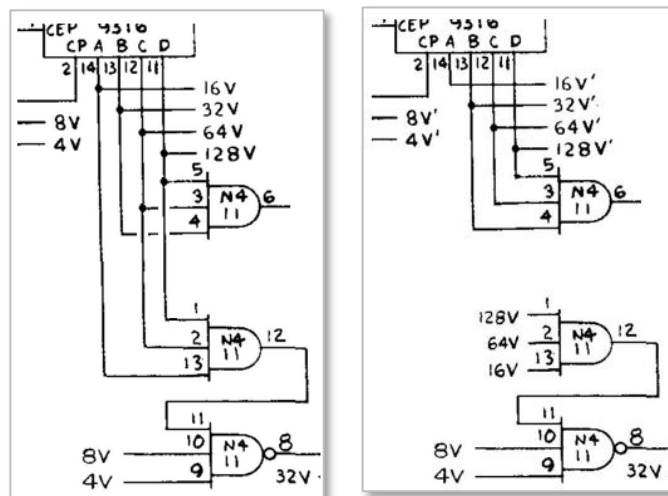
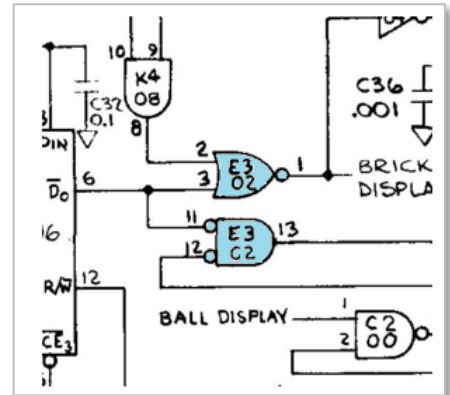
## Revision F Schematic and PCB Differences

There are several differences between the revision F schematic and PCB as detailed below. I traced each net in the hi-res rev F images and compared them to the schematic using MS Paint. Took a few days.



### General Schematic Notes

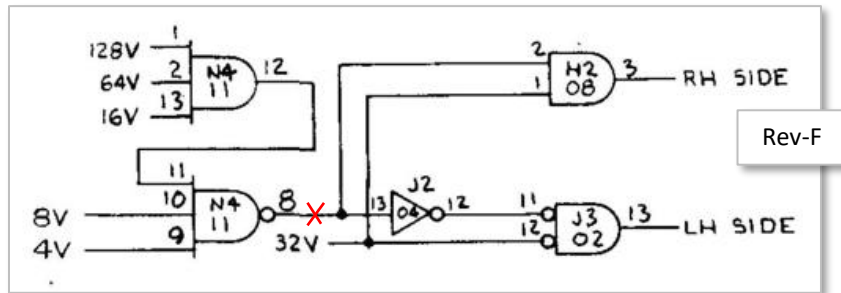
- Most gates in the original schematic are drawn in their logical setting. For example, the two gates highlighted here are both from the same 7402 (quad 2-input NOR) but represented differently. The upper gate is a positive-logic NOR while the bottom is a negated-input AND. While contextually accurate, using different logic representations on the same device in Autodesk Eagle (at least) is not supported without creating custom part symbols for each use case. The retro schematic uses all positive logic gates, but all pinouts remain the same except where ICs are replaced with non-pin-compatible parts.
- Since the original schematics were drawn by hand and were not completely redrawn for revisions, you can feel some of the work that was done to use empty white space to squeeze in new logic or to make other modifications. On the left I imagine what the schematic looked like [S#1-C6] before adding the cocktail table reverse logic on the right. A little white-out, add tick marks to the original H/V chain outputs, add sheet#4, etc. Lots of work to make changes compared to today!



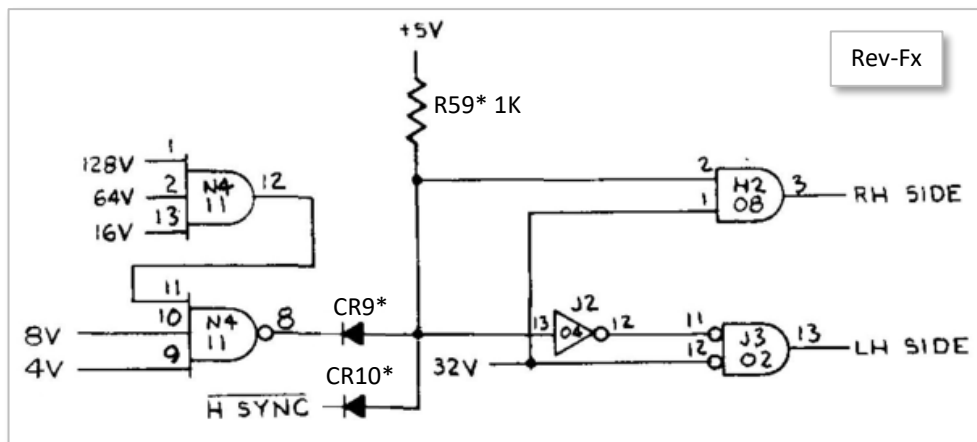
# Breakout Rev[F] SCH to PCB Differences

Diff-1 @ [S#1-C6]: Suppress LH/RH during HSYNC (adds CR9\*, CR10\*, R59\*)

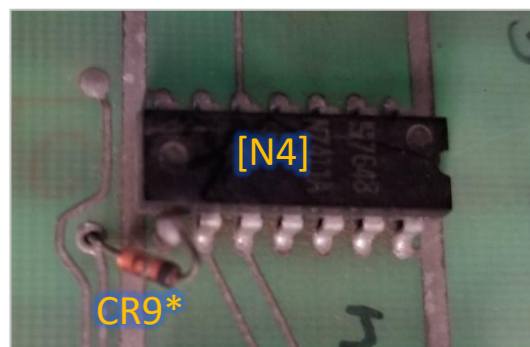
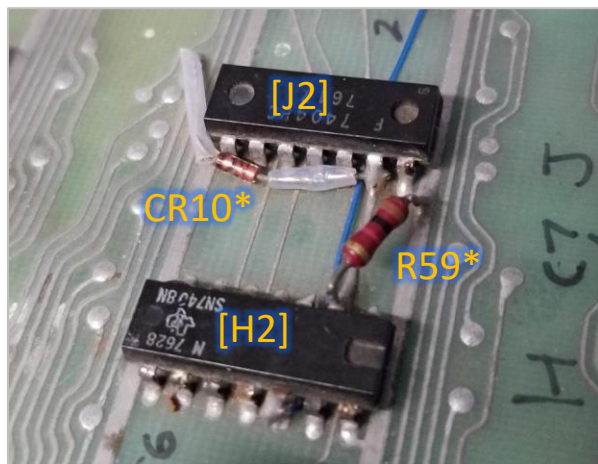
Here is the original LH/RH generator:



Net was cut and two diodes and a 1K resistor were added, effectively creating an AND gate (or negative-input NOR) to suppress LH/RH sides during !H\_SYNC.



You can see part of this mod on the rev-D board as shown below. This is built into rev-E boards. ECN therefore should be 2525. Diodes are 1N914 and the resistor is 1K.

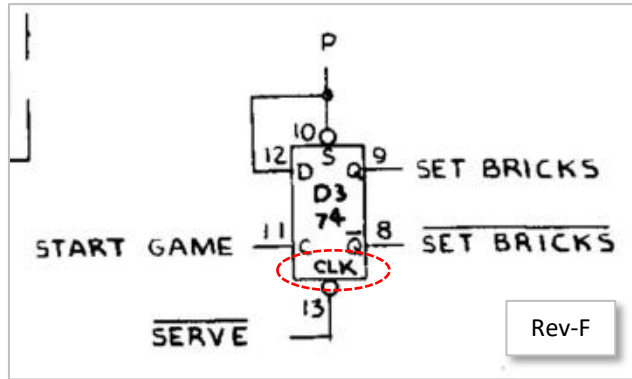




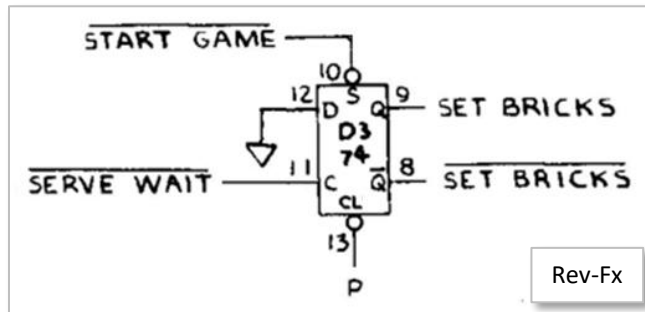
# Breakout Rev[F] SCH to PCB Differences

Diff-2 @ [S#1-A6]: Different wiring of the Set Bricks FF [D3b]

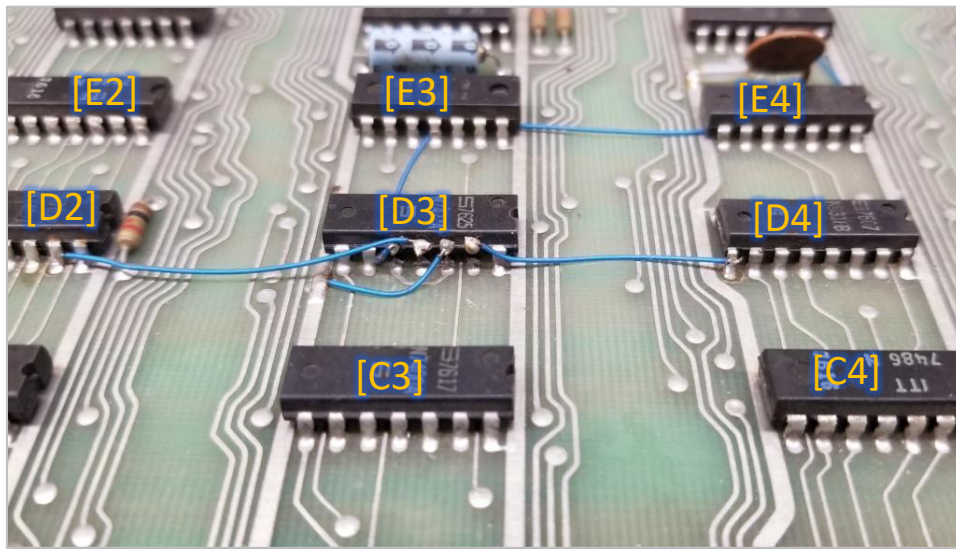
The set bricks driver FF is wired like this on the schematic:



But is wired like this on the PCB. Note that pin 13 is labeled CLK but is clearly CL[R].



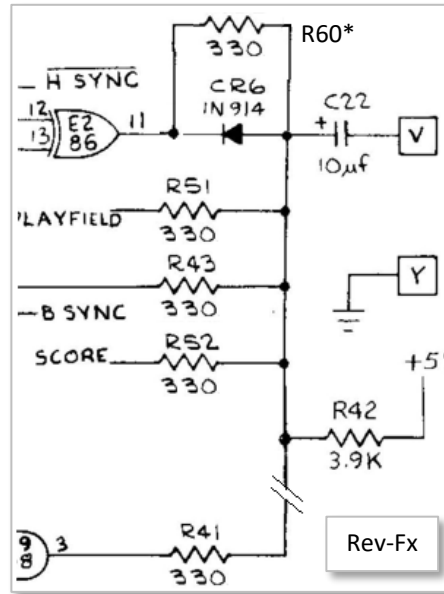
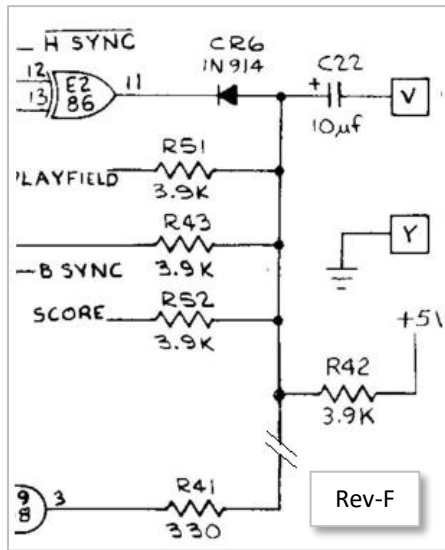
You can see change this was a mod to a Rev-C board, but is present in boards >= Rev-D:



# Breakout Rev[F] SCH to PCB Differences

Diff-3 @ [S#1-D3/D4] - Video Chain Resistor Differences

R41, R43, R51, and R52 on my ref-D board and in subsequent images are 330 ohms (R42 remains @ 3.9K). This increases the white level of the video signal. Another 330 ohm resistor was also added over CR6 (effectively removing CR6 function).



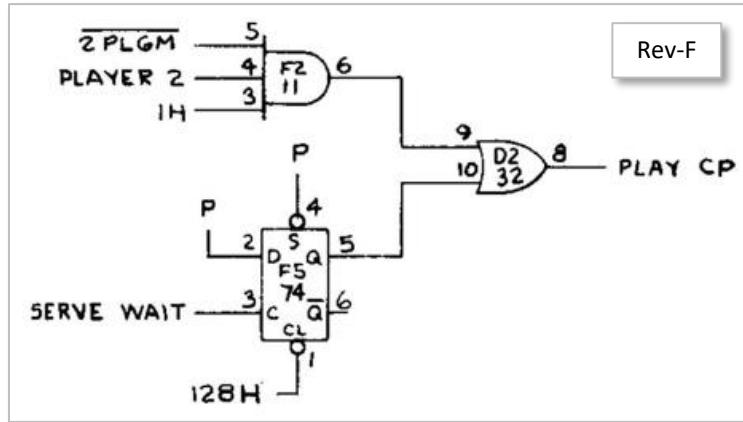
You can see the new resistor soldered over CR6 on my ref-D board (left) and a new place for this resistor on a rev-E board. Again, the ECN should be 2525.



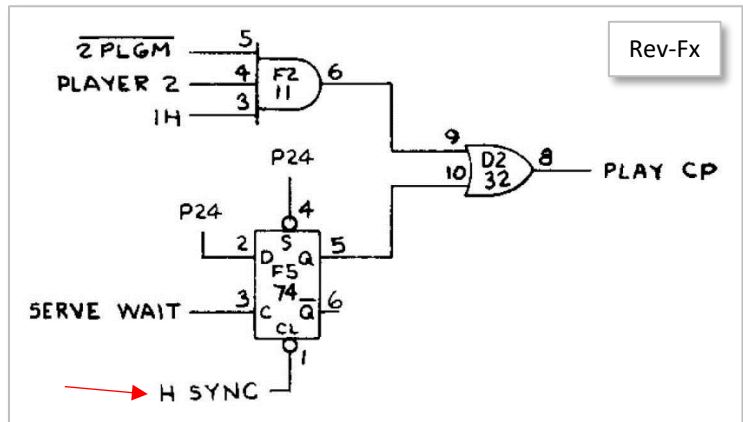
# Breakout Rev[F] SCH to PCB Differences

Diff-4 @ [S#1-C2]: Play FF [F5a] Cleared by HSYNC instead of 128H

FF Clear is driven by 128H on the schematic.



But is wired to H\_SYNC on the PCB

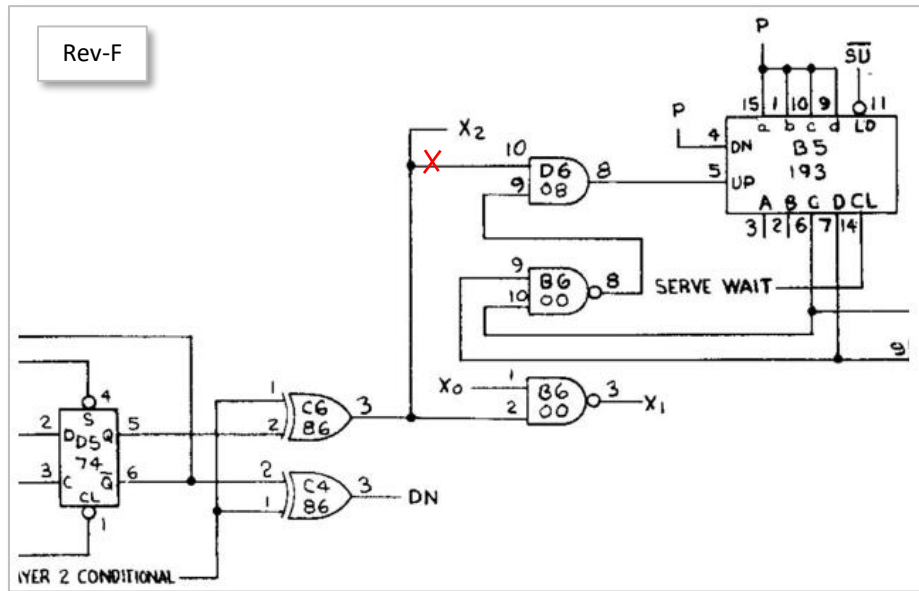




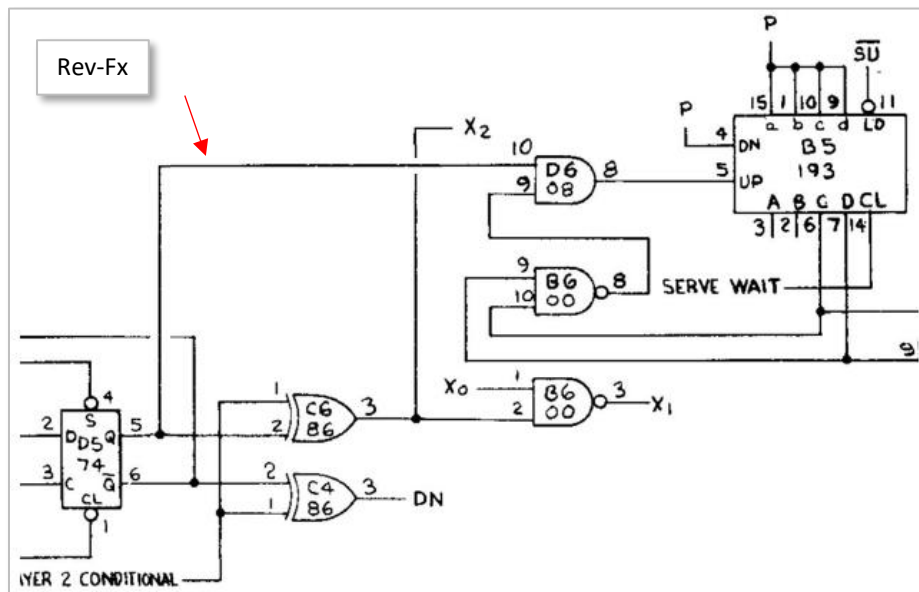
# Breakout Rev[F] SCH to PCB Differences

Diff-5 @ [S#1-B4]: Different Wiring in Ball Motion Logic

X2 into D6.10 comes off C6.3 on the schematic.



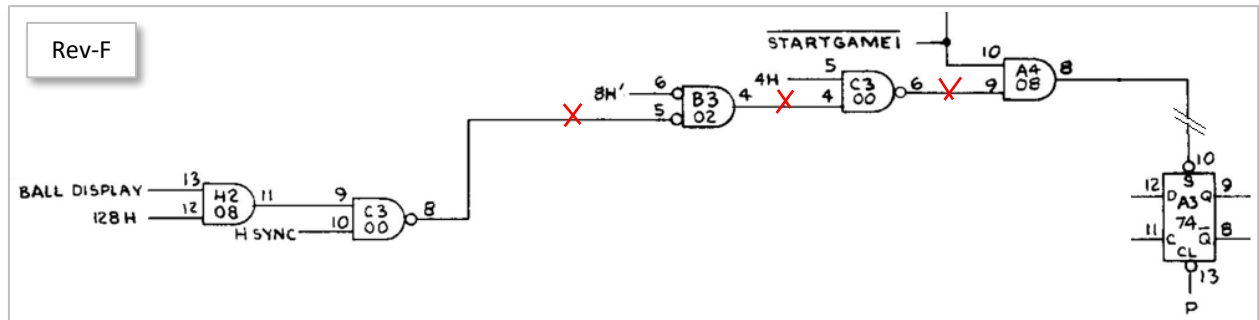
But D6.10 is driven by D5.5 on the PCB. This only takes effect when player 2 is up on a cocktail machine. Using the rev-F schematic, the ball is shot quickly towards player 2. We don't see this behavior in FPGA derivatives because 2-player cocktail models are never implemented (that I've seen).



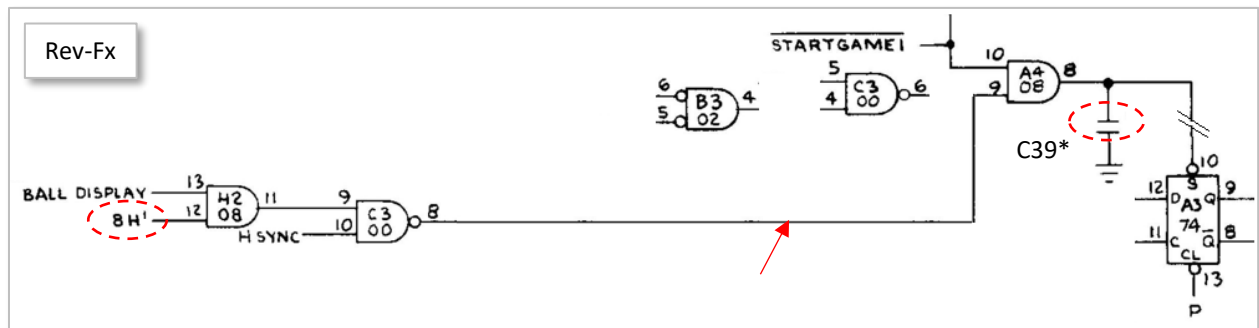
# Breakout Rev[F] SCH to PCB Differences

Diff-6 @ [S#1-B1/2]: Serve Wait Logic Differences & Add 330pF Cap C39\*

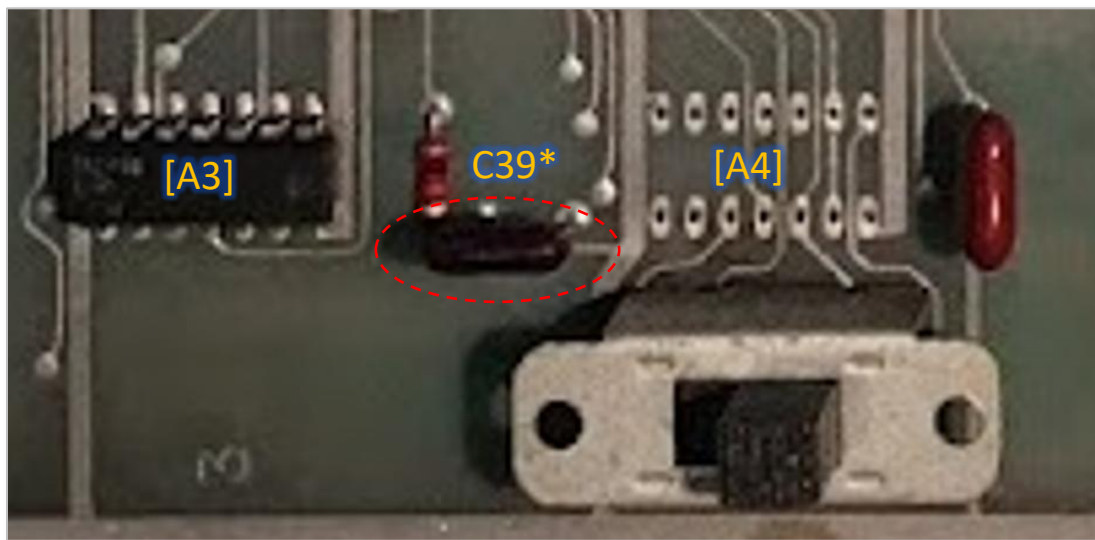
The serve wait FF [F3b] set logic looks like this in the schematic.



But looks like this on the PCB. Gates B3b(4,5,6) and C3b(4,5,6) are unused on the PCB (inputs should be tied down or pulled up). Gate H2 pin 12 is tied to 8H' on the PCB, not 128H as shown in the schematic.



There is also a cap present at site A3/A4 on ref-F board shown below, connected to A4.8 as shown in the revised schematic above. This is not present on my Rev-D (mod or otherwise), but is present as a mod on #3877 (assume rev-E). No clue what the value is. Looks the same as the other 0.001uF caps, e.g. C37.

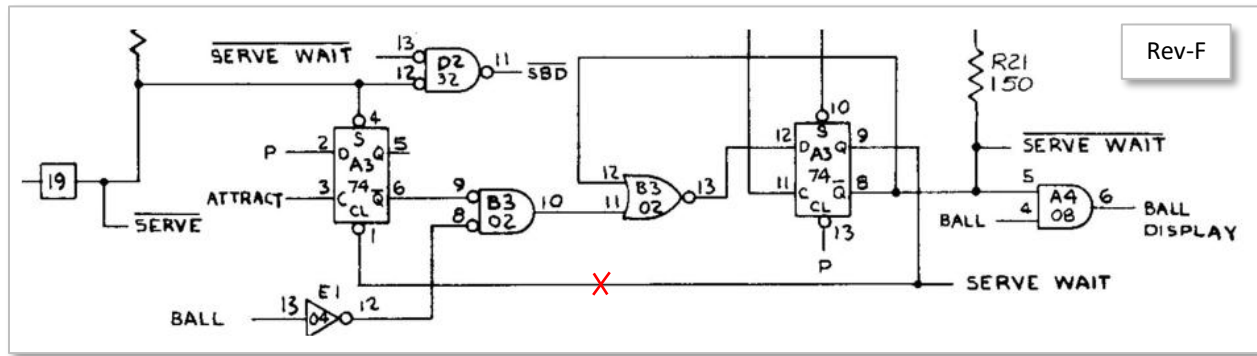


## Breakout Rev[F] SCH to PCB Differences

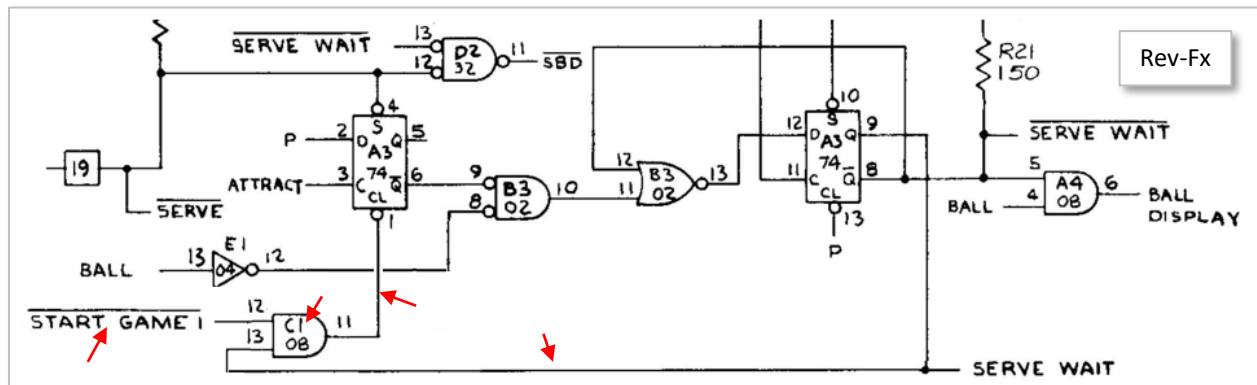
Diff-7 @ [S#1-B1/B2]: Another Serve Wait Logic Difference (adds a 7408 @ [C1\*])

Site C1 is clearly populated on most PCBs but there are no C1 gates on the schematic. Only one gate is used. This mod allows the !START\_GAME signal to reset FF A3a (blocks ball from attract mode). This modification is present in many early boards.

Logic as present in the schematic. A3a's CLR is wired to the SERVE\_WAIT signal driven by A3b-Q.



Logic as present on the PCB. Both SERVE\_WAIT and !START\_GAME\_1 drive A3a's reset pin.



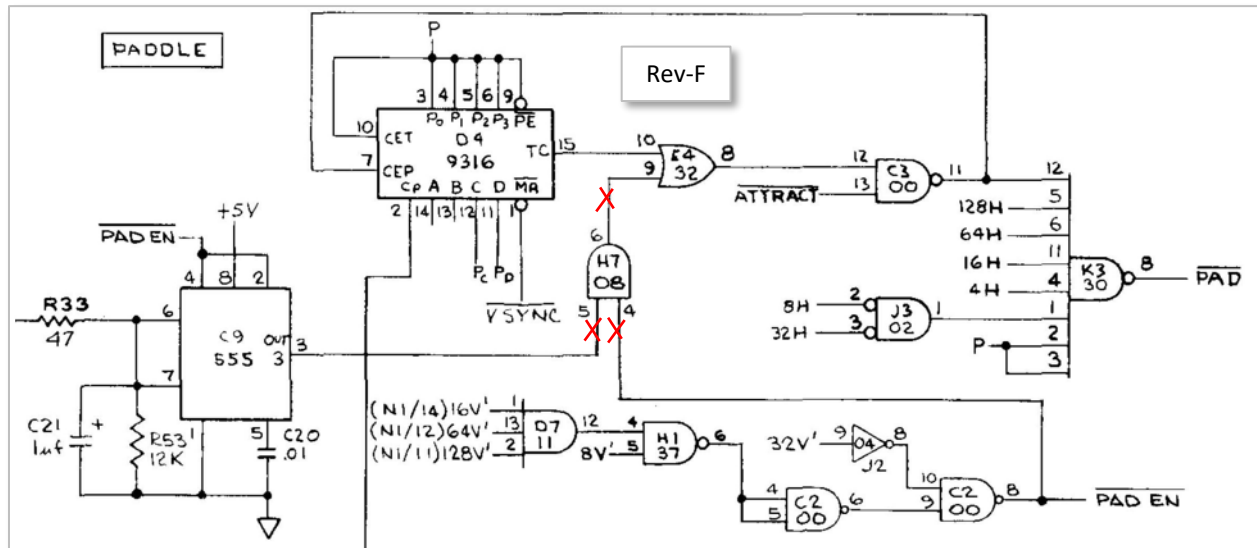
Left: Site C1 added and modified on Rev-C. Right: Site C1 built-in PCB on  $\geq$  Rev-D.



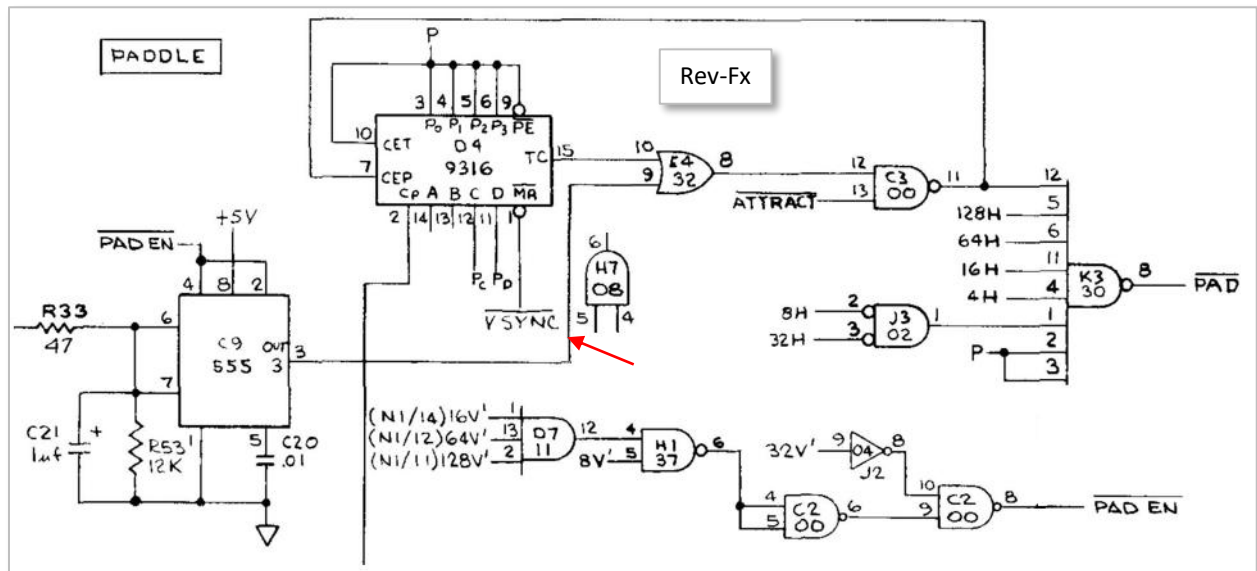
## Breakout Rev[F] SCH to PCB Differences

## Diff-8 @ [S#2-B2] - Paddle Wiring Differences

Schematic shows the output of C9 wired to H7.5



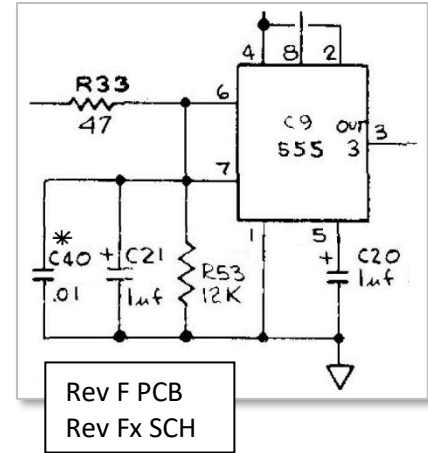
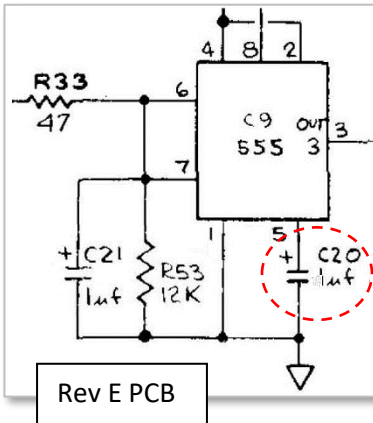
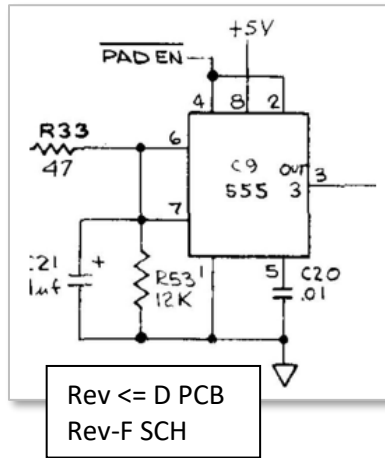
On the PCB, C9.3 is wired to E4.9 as shown below and gate H7b (4,5,6) is unused.



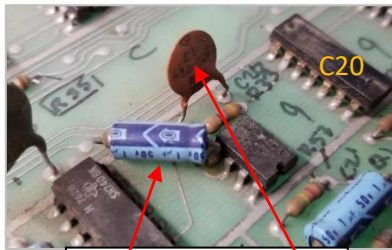
# Breakout Rev[F] SCH to PCB Differences

Diff-9 @ [S#2-B3] Paddle Timer Changes to 555 @ [C9] (adds C40\*)

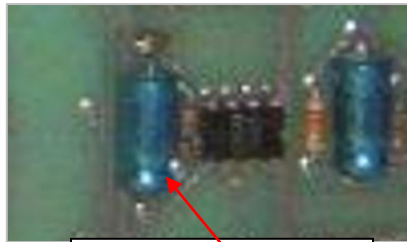
Schematic shows only one cap on L9.5 but the PCB and mods have 2. From the board images it looks like they first changed C20 to 1uF in Rev-E (but still 0.01 in Ref-F SCH), then added C40\* in Rev-F.



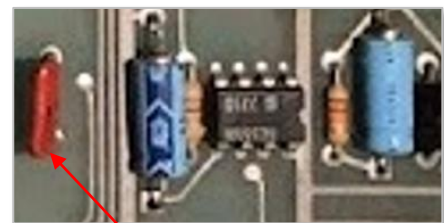
Here are board images showing a Rev-D with 1uF mod (over) C20, a Rev-D board with C20 changed to 1uF on the PCB, and a Ref-F board with an additional 0.01uF cap (C40\*) on the input line.



Rev D Board (with  
1uF mod over C20)



Rev-E Board with C20  
changed to 1uF



Rev-F Board with new  
0.01uF cap (C40\*)

## Notes:

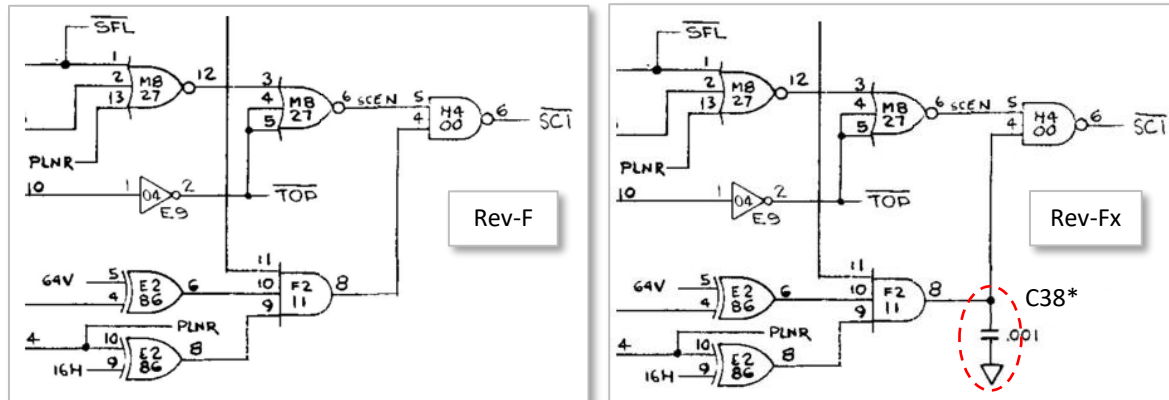
- In <= Rev-C the timing component values were different: R33 was 100ohm, C21 was 2.2uF, and R53 was 47K ohm.
- In <= Rev-C [C9] pin 2 (!RESET) was driven by !V\_SYNC , not !PAD\_EN.



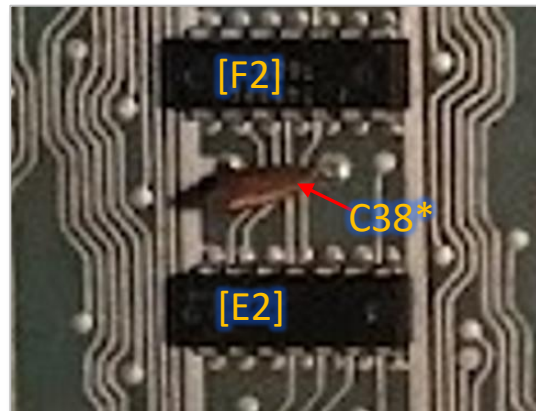
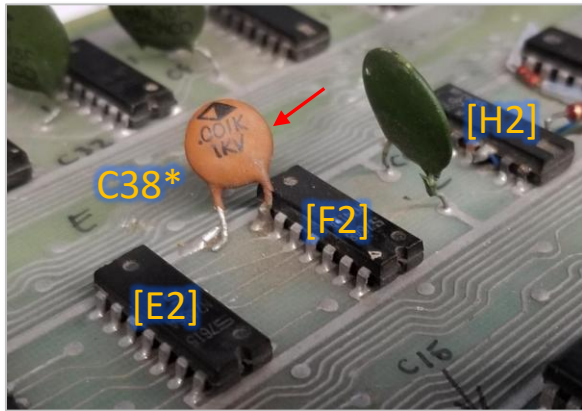
# Breakout Rev[F] SCH to PCB Differences

Diff-10 @ [S#2-A4]: Add 0.001uF Capacitor in Score Logic (adds C38\*)

The PCB has a 0.001uF capacitor on K2.8 that is not shown in the schematic.



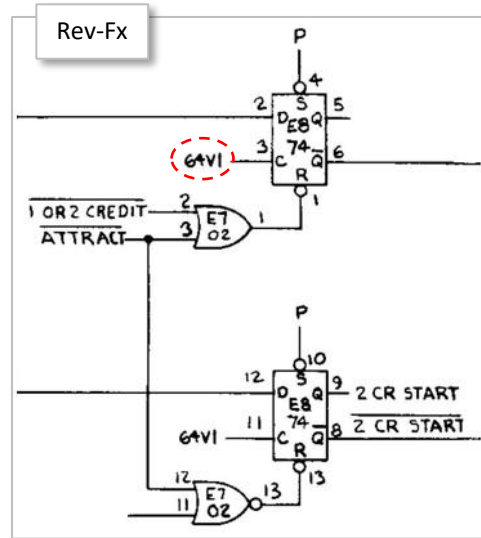
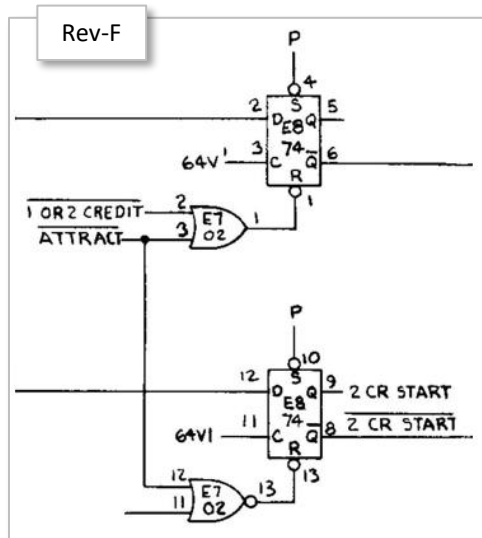
This is a modification on the rev-D board but is built-in on the ref-F board between [E2] and [F2]



# Breakout Rev[F] SCH to PCB Differences

Diff-11 @ [S#3-C7]: 1-Credit Start FF Wrong Signal Marking

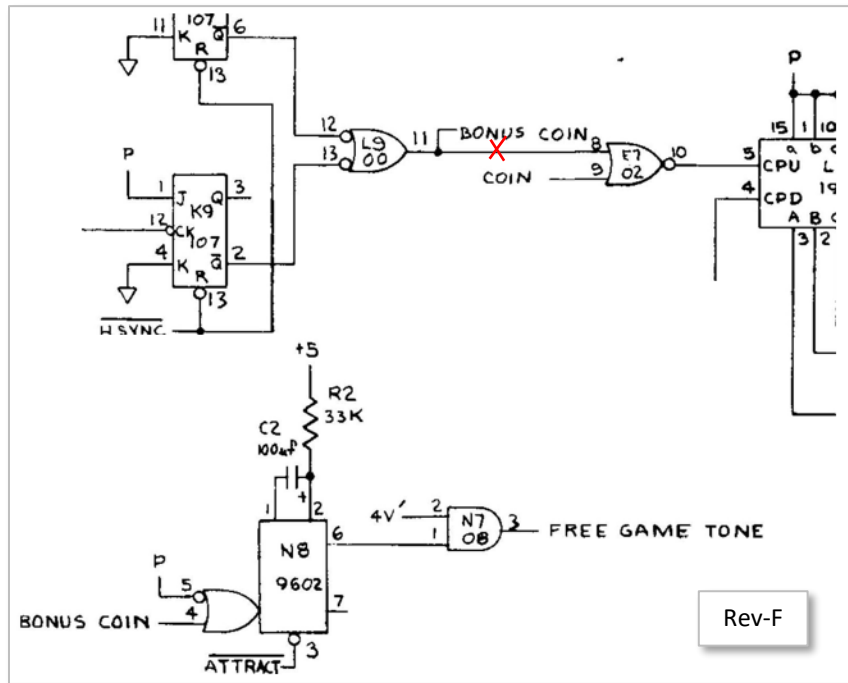
Schematic shows 64V' going into E8a.3 (FF clock) but this is 64V1 on the PCB. This is the same signal going into E8b.11 (FF clock). My guess is that they intended to use 64V' on both of these clocks because there is absolutely no reason you would want to change this coin logic signal when player 2 is up on a cocktail table.



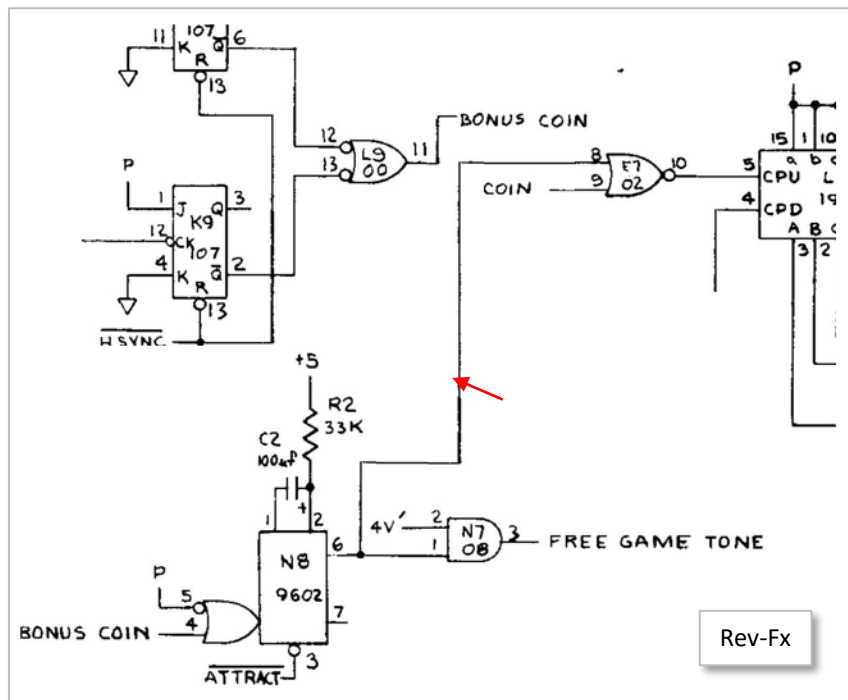
# Breakout Rev[F] SCH to PCB Differences

## Diff-12: @ [S#3-A5/A6] - Free Game Wiring Different

Schematic shows these elements (cropped for relevance), where L9.11 drives E7.8.



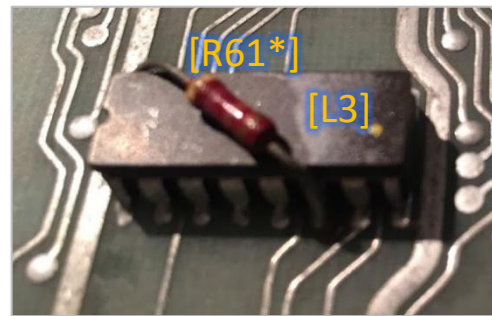
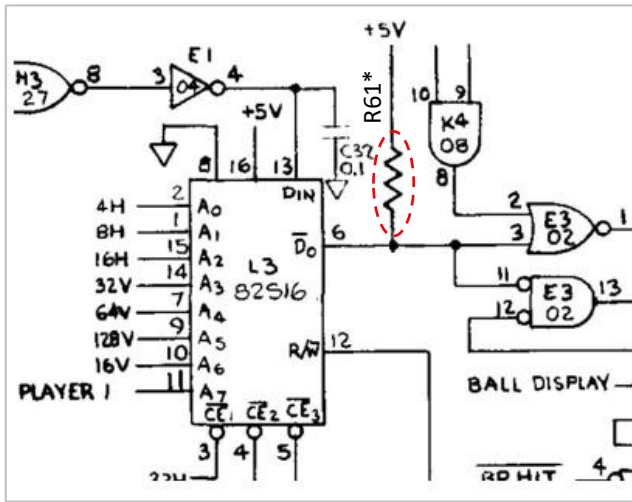
On the PCB, N8.6 drives E7.8.



# Breakout Rev[F] SCH to PCB Differences

Mod-1: @ [S#1-B7] 4.7K pull-up on brick storage RAM (optional modification)

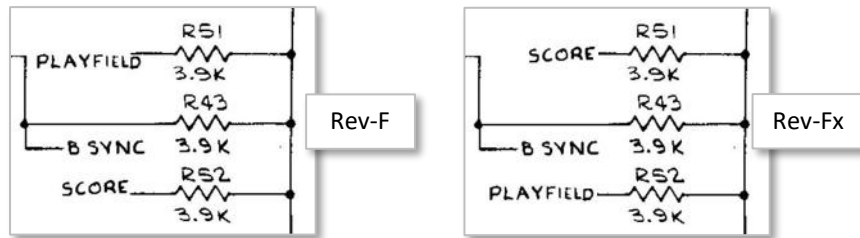
This is not a Rev-F SCH to PCB difference but on some boards, you can clearly see a 4.7Kohm pull-up resistor soldered between L3.6 and VCC. Most likely present when open-collector output versions of the BiPolar RAM (e.g. 82S17) are used. Will be added as an optional part in the retro PCB as R61\*.



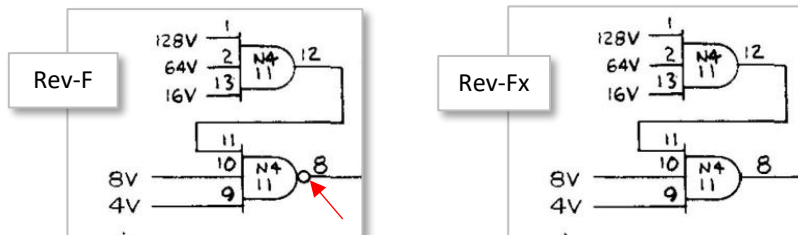
# Breakout Rev[F] SCH to PCB Differences

Note-1 @ [S#1-D4] R51 & R52 are swapped on the schematic (or PLAYFIELD and SCORE)

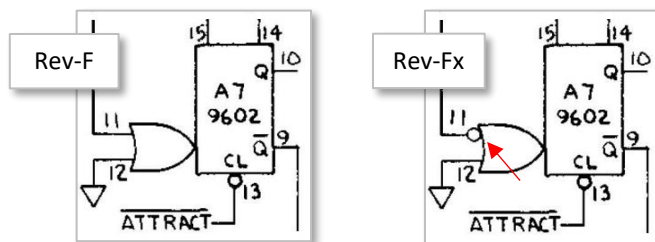
- R51 is driven by PAYFIELD in the schematic but by SCORE (D3a.5) on the PCB.
- R52 is driven by SCORE in the schematic but by PLAYFIELD (H4a.3) on the PCB.



Note-2: [S#1-C6] N4.8 has an extraneous dot indicator.

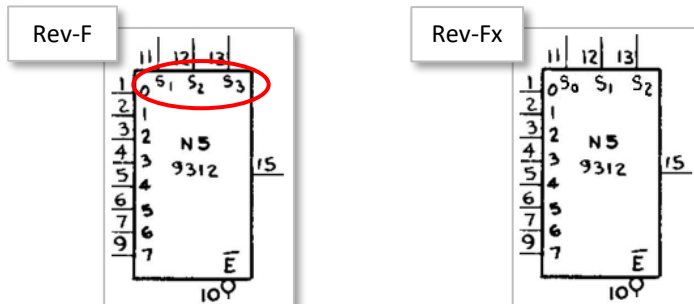


Note-3: [S#2-C3/C4] A7.11 is missing the dot indicator.



Note-4: [S#2-C7] N5 labeling

[N5] pins 11, 12, 13 are labeled S1, S2, S3 while all other 9312s are labeled S0, S1, S2

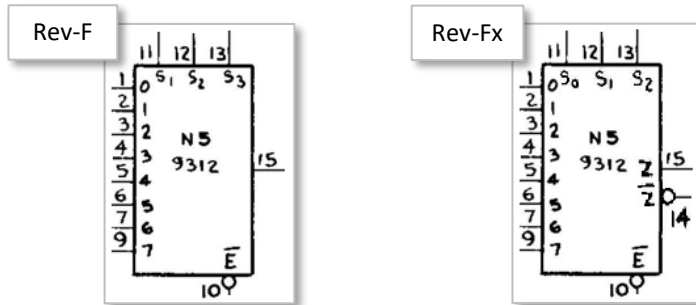




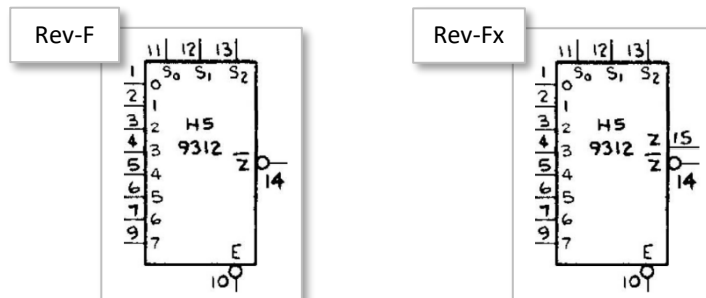
# Breakout Rev[F] SCH to PCB Differences

Note-5: [S#2-C7/B7/A7] Output Labeling

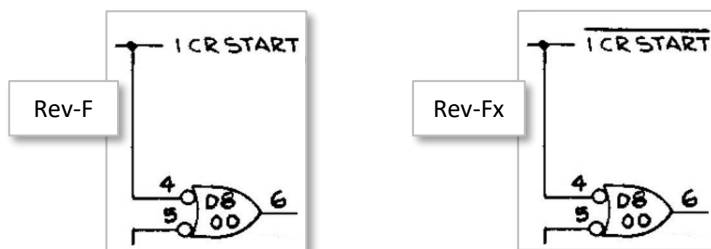
[N5, M5, L5, K5] the Z output is not labeled. Also added the unused !Z output for clarity.



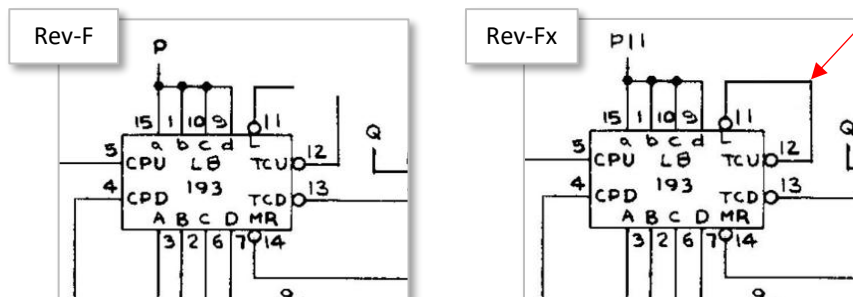
Note-6: [S#2-B6] Added the unused Z output to [H5, J4] for clarity



Note-7: [S#3-C6] The “1 CR START” label coming off E8.6 s.b. “!1 CR START”



Note-8: [S#3-B4] L8 pins 11 and 12 are connected



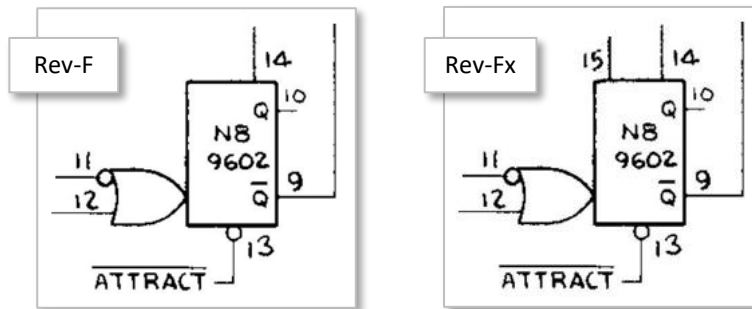
# Breakout Rev[F] SCH to PCB Differences

## Miscellaneous

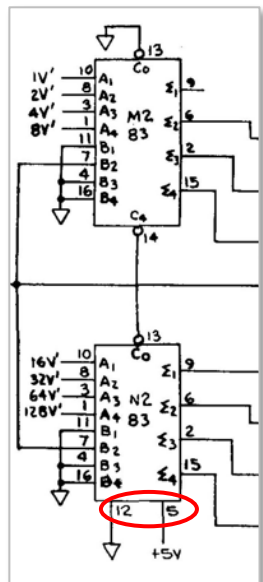
- Misc-1: Unused inputs are not shown on the schematic and are open on the PCB. We show all unused input pins in Rev-Fx for clarity. In the retro version we tie up all unused inputs to one of the existing pull-up nets.
- Misc-2: All pull-up inputs are specifically attached to a specific pull-up net. In Rev-Fx we label each use of a pull-up with it's net. Nets are named after the pull-up resistor, e.g. P1, P5, P6, etc.
- Misc-3: Unused outputs are almost always shown on the schematic except for the following:
  - o 74193s B5.12(!CO), B5.13(!BO), F6.12(!CO)
  - o 9312s K5, L5, M5, N5 pin 14 (!Z)
  - o 9312s H5, J4 pin 15 (Z)
  - o 7483 N2 pin 14 (C4)

We show all unused output pins in Rev-Fx for clarity.

- Misc-4 @ [S#2-B5]: Unused input [N8]-15 (-C) not shown on the schematic and is unused on the PCB. This pin is internally tied to GND inside the 9602 so we include it in Rev-Fx.

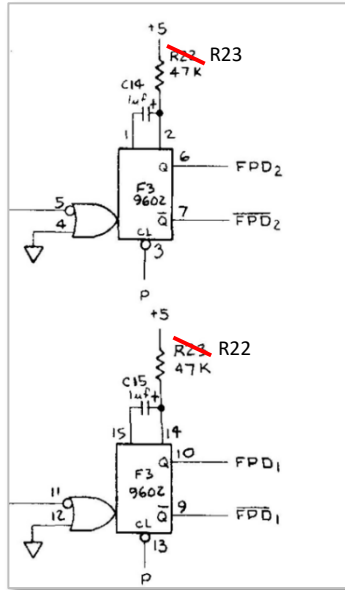


- Misc-5 @ [S#4-C8]: N2 (7483) on the schematic S#4-C8 shows the power pins because of their unusual location (VCC=5, GND=12). This is not shown on M2. Retro versions will use 74LS286 devices with "normal" power pinouts.

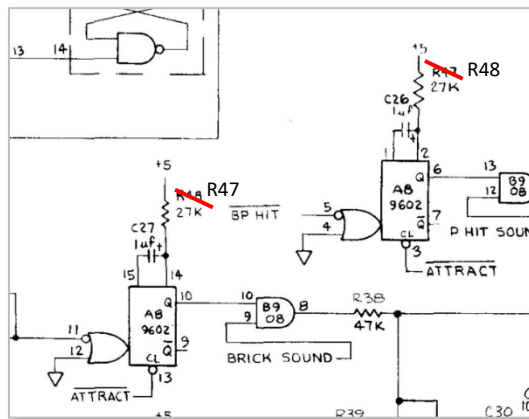


# Breakout Rev[F] SCH to PCB Differences

- Misc-6 @ [S#2-D4]: Resistors R22 and R23 are swapped on the schematic. R23 goes to [F3a].2 while R22 goes to [F3b].14 on the board.

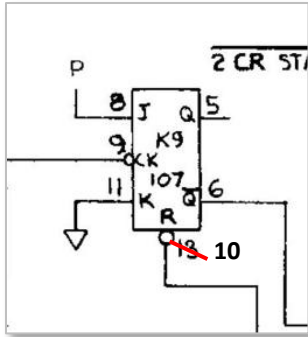


- Misc-7 @ [S#2-D2/3]: Resistors R47 and R48 are reversed on the schematic. R48 goes to [A8a].2 while R47 goes to A8b].14 on the board.



# Breakout Rev[F] SCH to PCB Differences

- Misc-8 @ [S#3-B5]: K9b reset line s.b. labeled pin 10, not pin 13.



- Misc-9 @ [S#4-C8]: CR1 and CR2 are swapped on the schematic. CR1 goes to connector pins 4 and D while CR2 goes to connector pins 5 and C on the PCB.

