Sheet: CPU

File: cpu.sch

Sheet: TED

File: ted.sch

Sheet: RAM

File: ram.sch

Sheet: ROMs

File: rom.sch

Sheet: Keyboard

File: keyboard.sch

Sheet: Datassette & Serial Bus

File: datasette.sch

Sheet: Expansion Port

File: exp_port.sch

Sheet: Power & Misc

File: misc.sch

Sheet: Joysticks

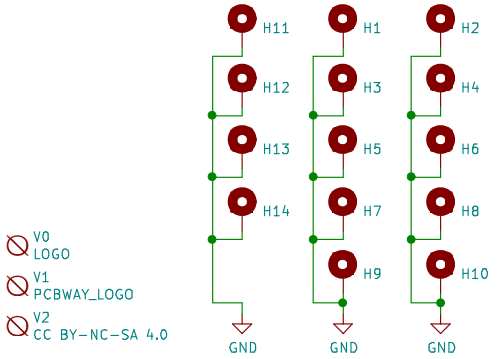
File: joysticks.sch

Sheet: PLA & Chip Selection

File: pla.sch

Sheet: Audio/Video Output

File: avout.sch

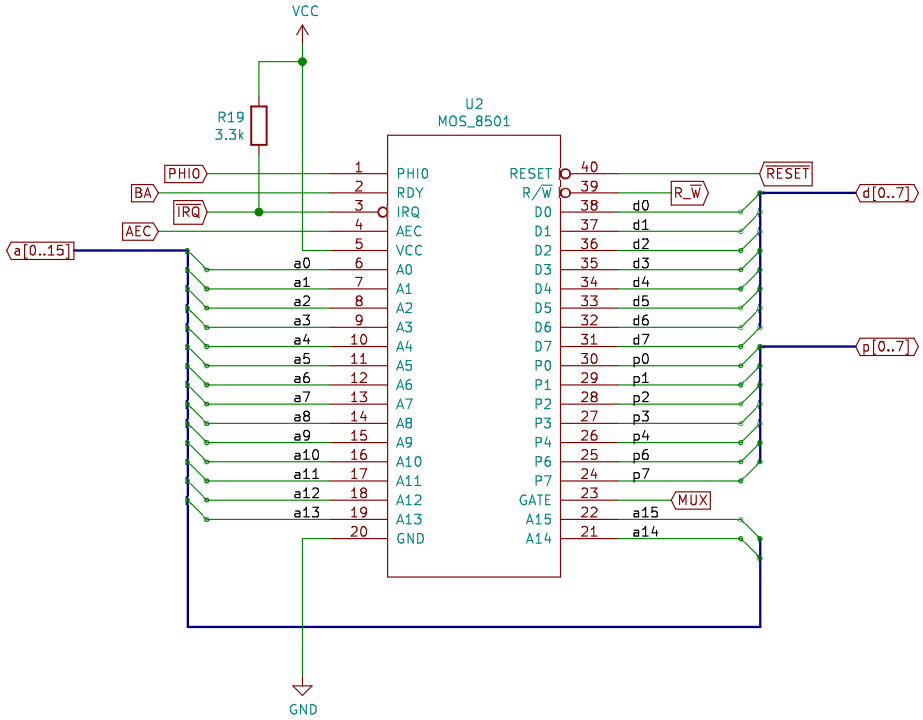


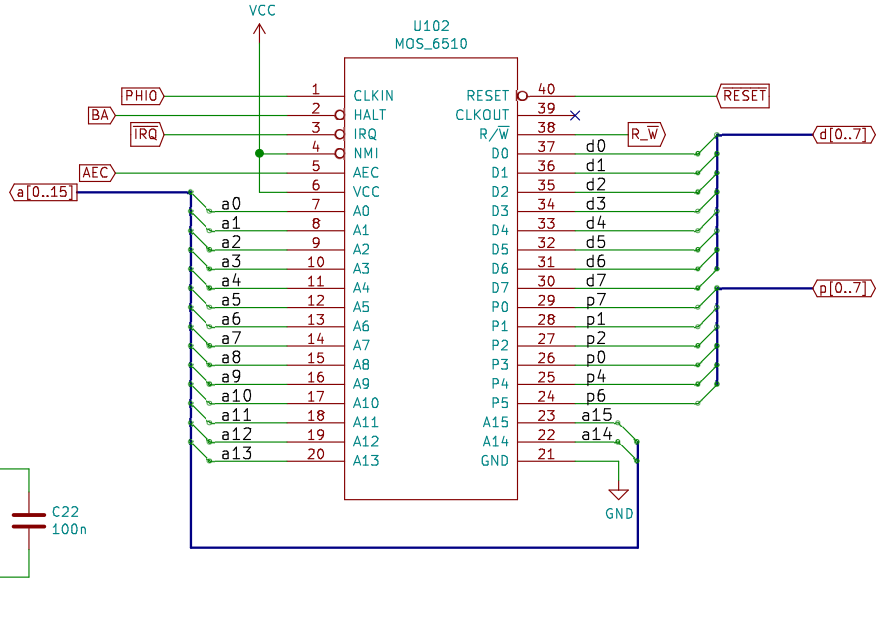
SukkoPera

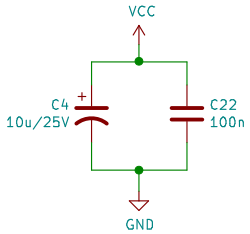
Sheet: /
File: LittleSixteen.sch

Title: LittleSixteen

Size: A4	Date: 2021-11-17	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 1/12







The 7501/8501 CPU used in the x264 series is not much different from the 6510 that was used in the C64. Mapping of most pins is straightforward. Some signals change names but they are obviously the same.

6510s were working at 1MHz in the C64, while the x264 design is able to push them to nearly 2 MHz during video blanking. Since most 6510s seem to be pretty forgiving in this regard, we are left with two issues:

- GATE_IN: There is a lot of myth and inaccuracy about the purpose of this pin that is not available on the 6510. Here's a quote from the TED System Hardware Manual that should clarify things:

  "GATE IN: TTL level input, used to gate the R/W line to prevent the R/W line from going low during a read cycle, before RAS and CAS go high (resulting in a Read/Write cycle). Normally connected to the MUX line in a system configuration to synchronize the DRAM memory cycle to the processor clock cycle.

  If AEC is low when Gate In makes a low to high transition, the R/W line will go to a high impedence until the next transition of the Gate In line and AEC is high prior to the transition."

  This is confirmed by some guys who recently decapped an 8501 and analyzed its die, please see http://forum.6502.org/viewtopic.php?f=4&t=6617.

  A forum thread (http://www.softwolves.com/arkiv/cbm-hackers/16/16855.html) seems to suggest that when using DRAMs the signal is pretty useless, but it would be needed if SRAMs were used. I'm not sure this is correct and I really can't judge by myself, but since experience shows that leaving GATE_IN unconnected doesn't *seem* to hurt, we'll go with that for the moment, but for the future we might do something along the lines of this quote from Bil Herd himself:

  "[During the development of the x264 family, where we were using 6510 CPUs] I think I did the Gated Read/Write with a 74LS73 only I drove the R/W line high, not HiZ."

- I/O Port: The 8501 has a 7-bit I/O port while the 6510 only has a 6-bit, plus the exposed bits are numbered differently, so some remapping is needed, which implies that some modding to the KERNAL is required as well. I decided to follow what Andrew Challis did at http://hackjunk.com/2017/06/23/commodore-16-plus-4-8501-to-6510-cpu-conversion/. So, the 6510 socket is basically Andy's adapter built into the mainboard. If you go with a 6510 you will need to use his modified KERNAL and to solder the diode and resistor at D/R93. This comes at a compromise though:
  - Disk fastloaders will not work (unless they are modified themselves to match our pin shuffling).
  - The Datassette motor will spin whenever one of its keys is pressed, the computer will no longer be able to control it.

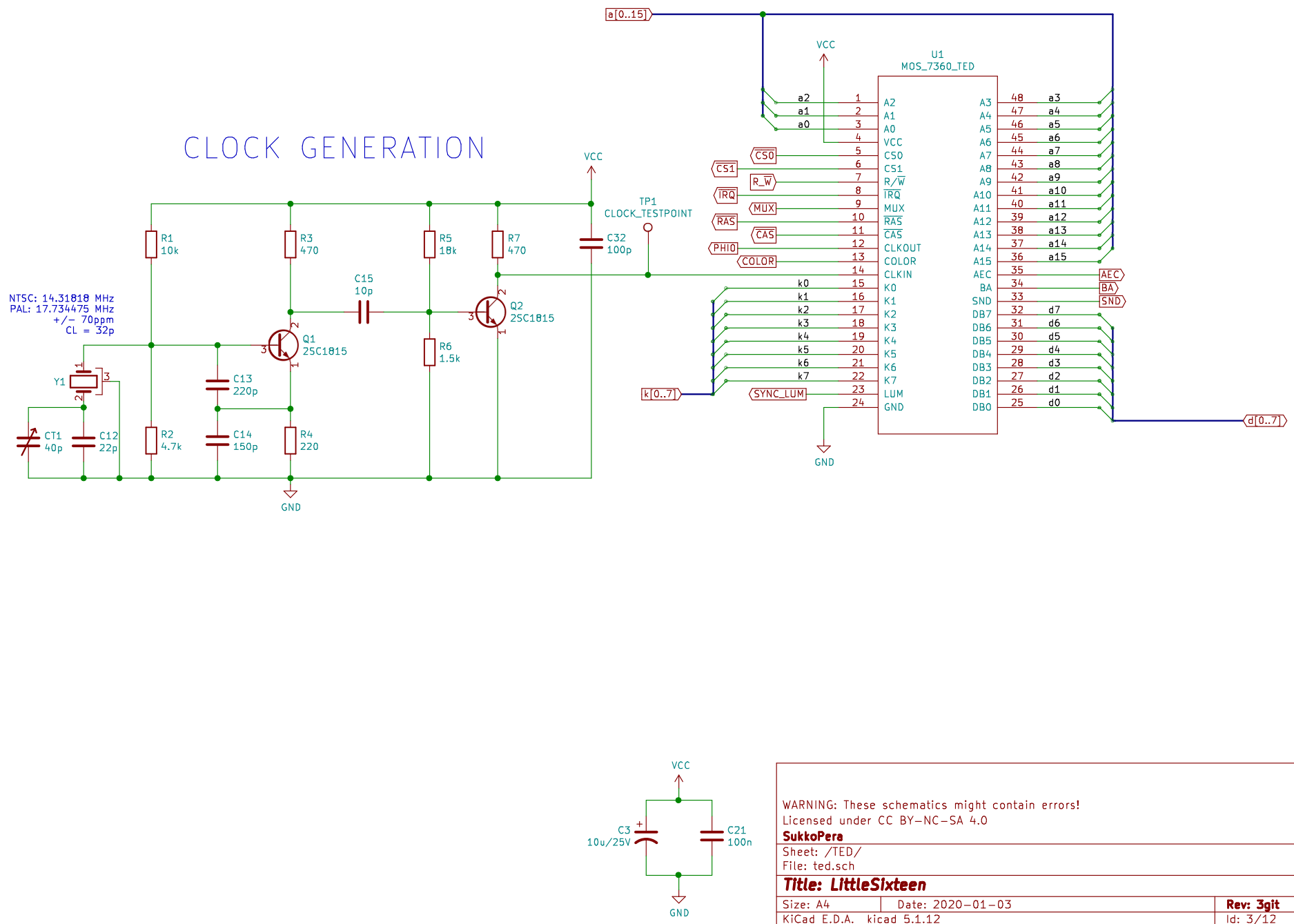
  I think these drawbacks are acceptable, as most fastloaders won't work anyway when using an SD2IEC, which is what most people do these days, I guess, while the loss of tape control isn't much of an issue in itself. Make sure to send a small donation to Andy if you go this way.

SukkoPera

Sheet: /CPU/
File: cpu.sch

Title: LittleSixteen

Size: A4	Date: 2021-11-17	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 2/12



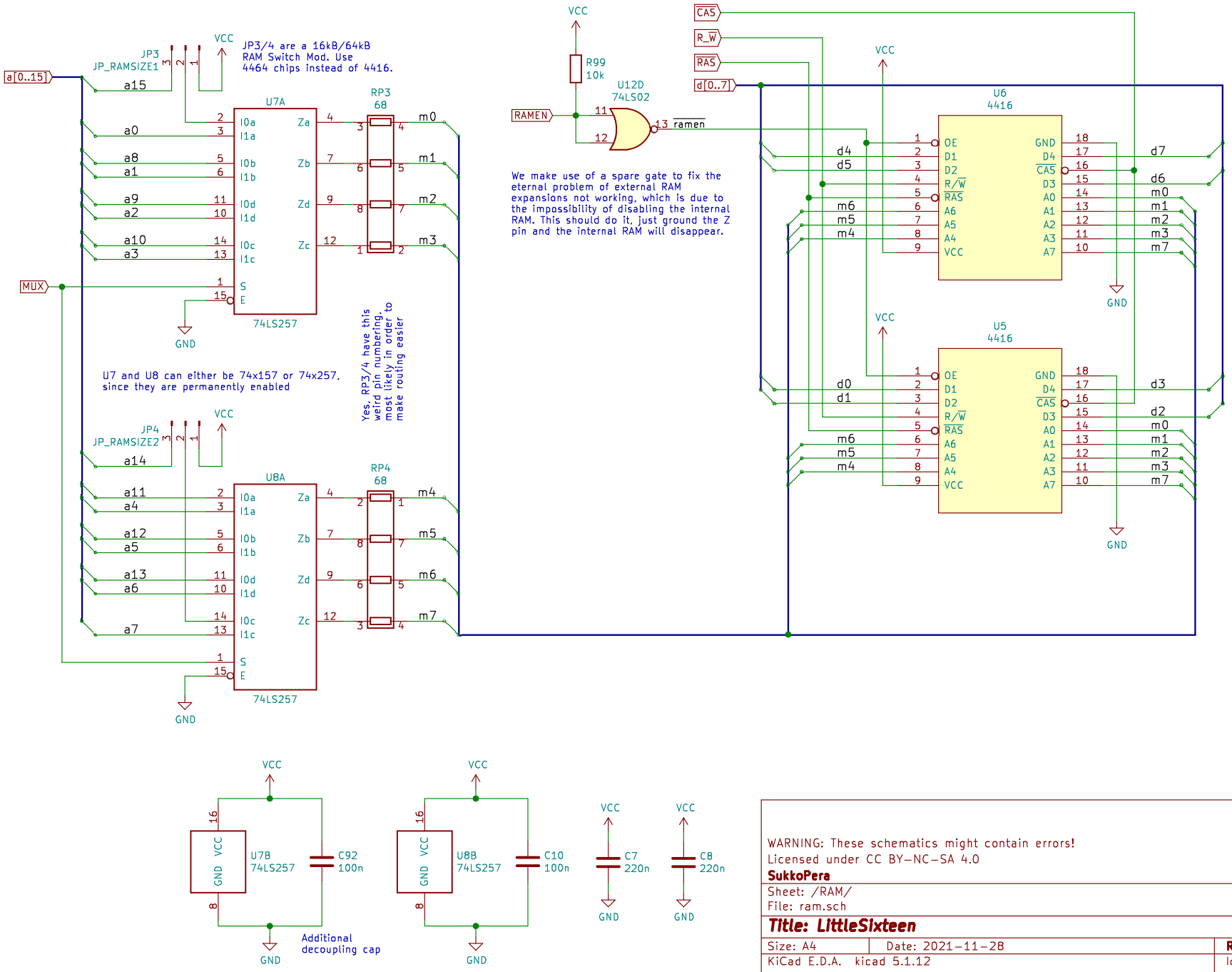
WARNING: These schematics might contain errors!

SukkoPera

Sheet: /TED/
File: ted.sch

Title: LittleSixteen

Size: A4	Date: 2020-01-03	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 3/12



WARNING: These schematics might contain errors!

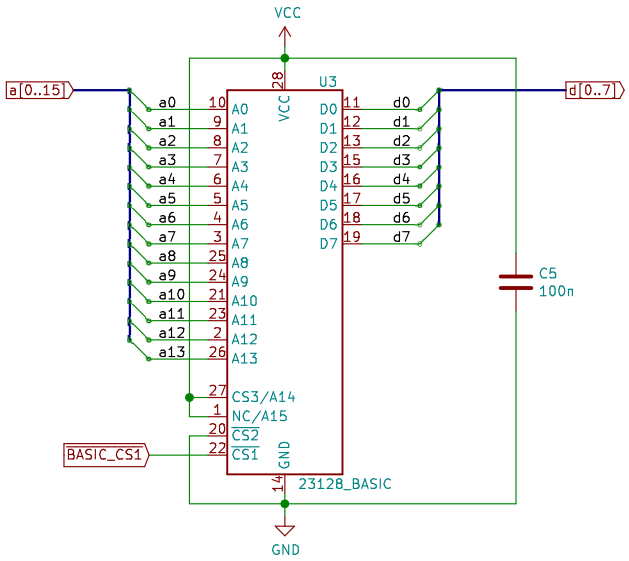
SukkoPera

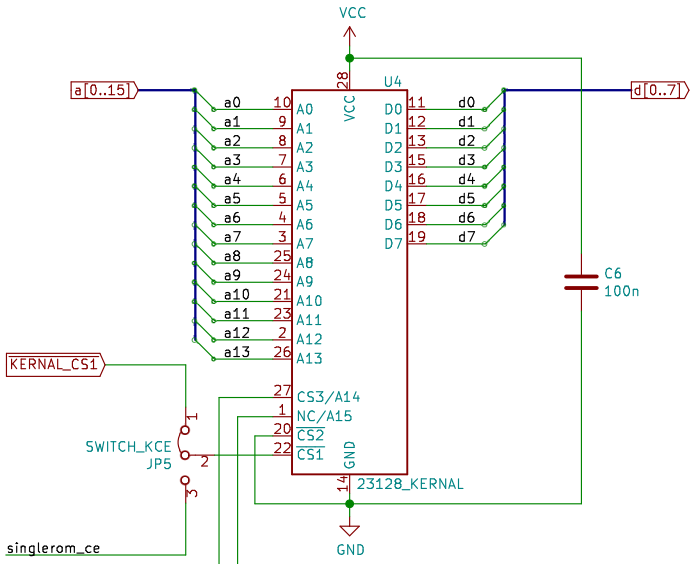
Sheet: /RAM/

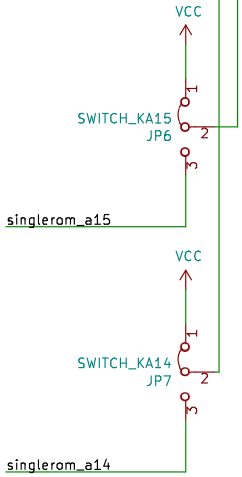
File: ram.sch

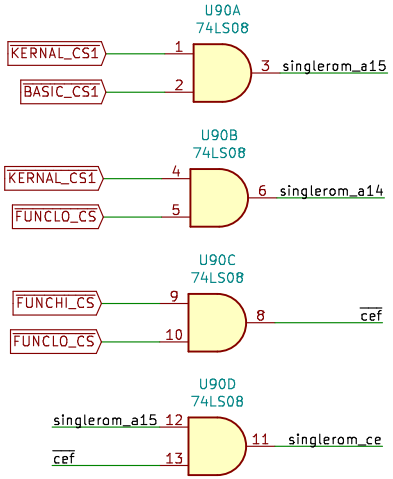
Title: LittleSixteen

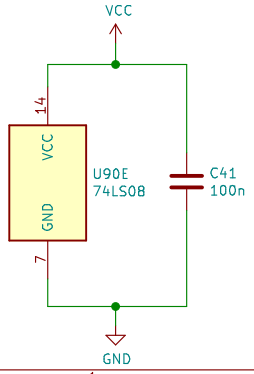
Size: A4	Date: 2021-11-28	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 4/12











Range	Size	A15	A14	Content
$0000–$3FFF	16K	0	0	Kernal
$4000–$7FFF	16K	0	1	Basic
$8000–$BFFF	16K	1	0	FnLO
$C000–$FFFF	16K	1	1	FnHI

A15 = /CEK & /CEB
A14 = /CEK & /CEFL
/CEF = /CEFL & /CEFH
/CE = /CEK & /CEB & /CEF = A15 & /CEF

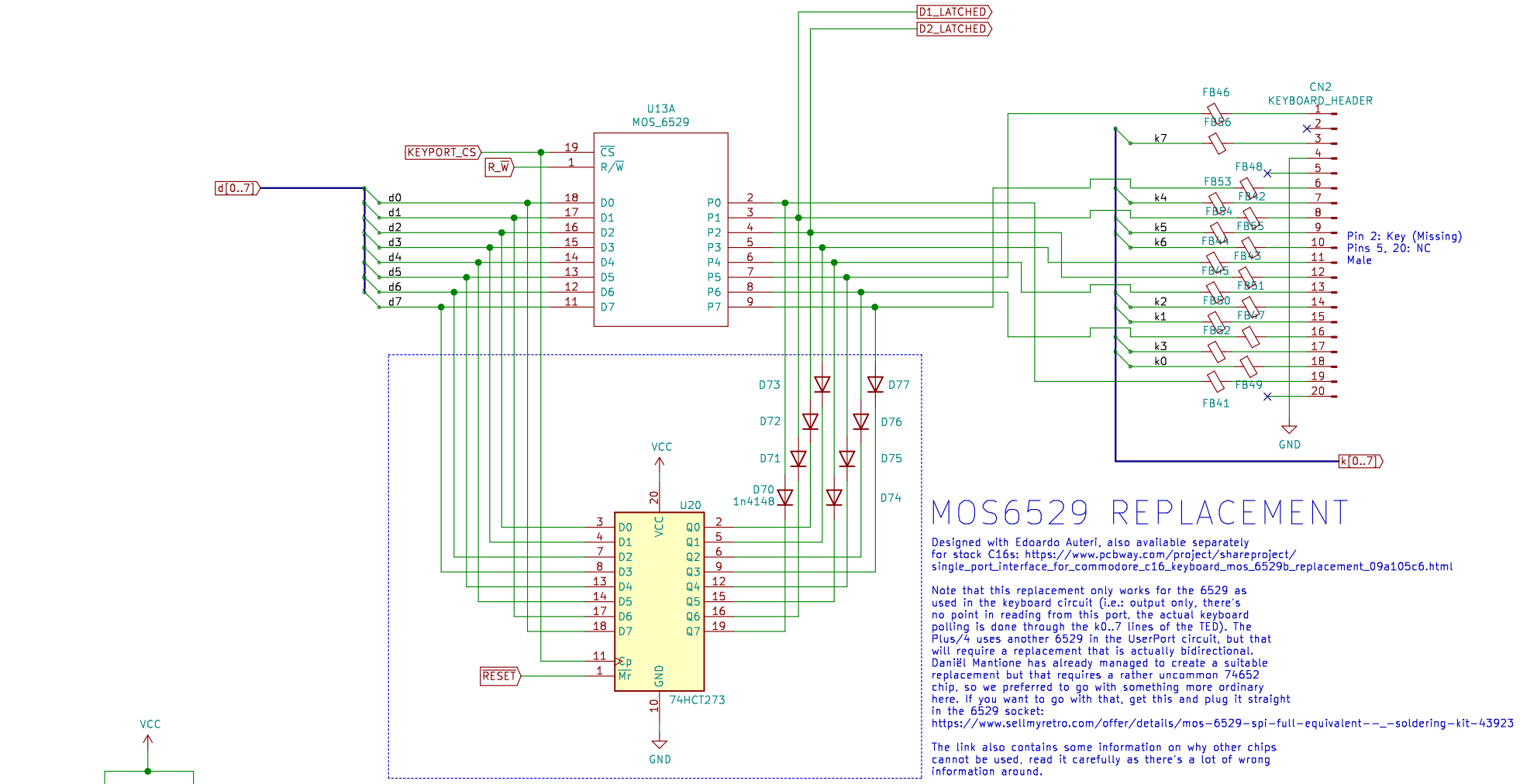
/CEK	/CEB	/CEFL	/CEFH	A15	A14	/CEF	/CE
0	1	1	1	0	0	1	0
1	0	1	1	0	1	1	0
1	1	0	1	1	0	0	0
1	1	1	0	1	1	0	0
1	1	1	1	1	1	1	1

SukkoPera

Sheet: /ROMs/
File: rom.sch

Title: LittleSixteen

Size: A4	Date: 2021–11–14	Rev: 3git
KiCad E.D.A. kicad 5.1.12		Id: 5/12



SukkoPera

Sheet: /Keyboard/
File: keyboard.sch

Title: LittleSixteen

Size: A4	Date: 2022-08-17	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 6/12

DATASSETTE INTERFACE

These are protection diodes retrofitted after production on *some* C16s I've seen. These seem different from the 1n4148 that are retrofitted on p6/p7 on the same board, since those clearly say 1n4148 on their bodies, while these have a color coding of yellow (thick/cathode), brown, yellow, grey (or light blue?), which... erm, would make them 1n4148 ^___^. Multimeter says their Voltage drops are 0.555V and 0.561V, while it says 0.323 for the others (all measures in-circuit).

ADDITIONAL CURRENT-LIMITING RESISTOR

WARNING: The drawing of this connector does not match the real connector exactly!

CST_SENSE: LOW if one of the keys PLAY, RECORD, F.FWD or REW is pressed, HIGH otherwise

This diode is the one Andrew Challis recommends in order to let the Datassette motor run only when one of its keys is pressed. We add a pull-up resistor just in case. Install both only when using a 6510 CPU. (He says FB15 on his page but it's a clear mistake.)

CST_MTR: LOW = Motor on HIGH = Motor off

tape_sense 6
tape_wr 5
tape_read 4
tape_mtr 3
tape_+5v 2
tape_gnd 1
CN93 C64_STYLE_CASSETTE

SERIAL BUS (OR 1541 DISK DRIVE)

These (and the ones below) are more retrofitted protection diodes, these are present on most C16s I've seen. Note that these protection diodes have been added on all pins going straight to the CPU from the outside world.

These protection diodes are usually installed in place of ferrites FB3 and FB4.

These offer better ESD protection than the retrofitted diodes, but use an SMT component. Mount only one or the other, at your preference.

NOTES:
- Fastloaders might use these signals differently!
- All signals are active-low
- All signals are open collector, since this is a *bus*

J90 CONN_TAPE_DRIVE

	1	2	
tape_sense	3	4	iec_srq
tape_wr	5	6	iec_atn
tape_read	7	8	iec_clk
tape_mtr	9	10	iec_dat
	11	12	iec_rst
	13	14	

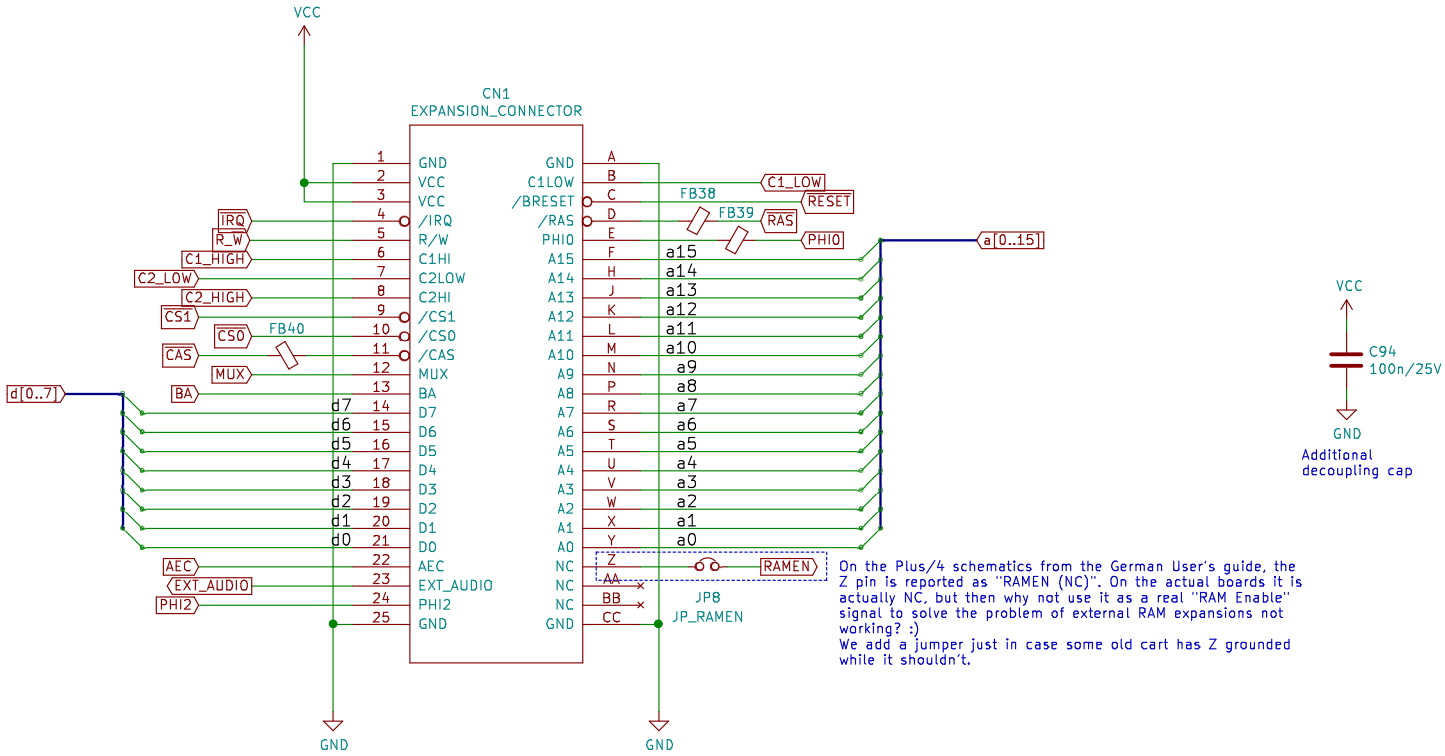
This connector has all the Tape and IEC signals and can be used to implement an internal SD2IEC or Tapuino.

SukkoPera

Sheet: /Datassette & Serial Bus/
File: datasette.sch

Title: LittleSixteen

Size: A4	Date: 2021-12-05	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 7/12

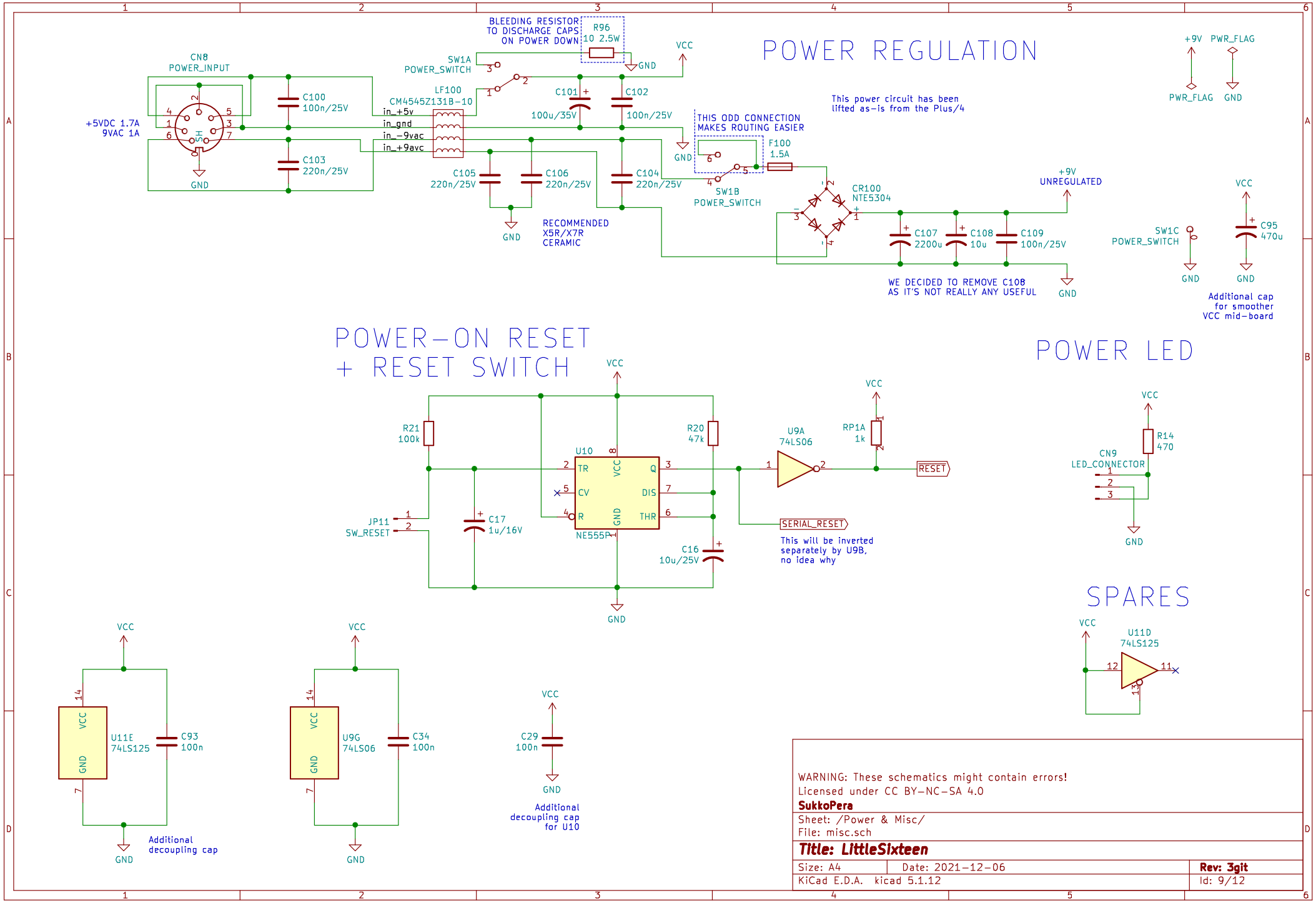


SukkoPera

Sheet: /Expansion Port/
File: exp_port.sch

Title: LittleSixteen

Size: A4	Date: 2021-12-05	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 8/12



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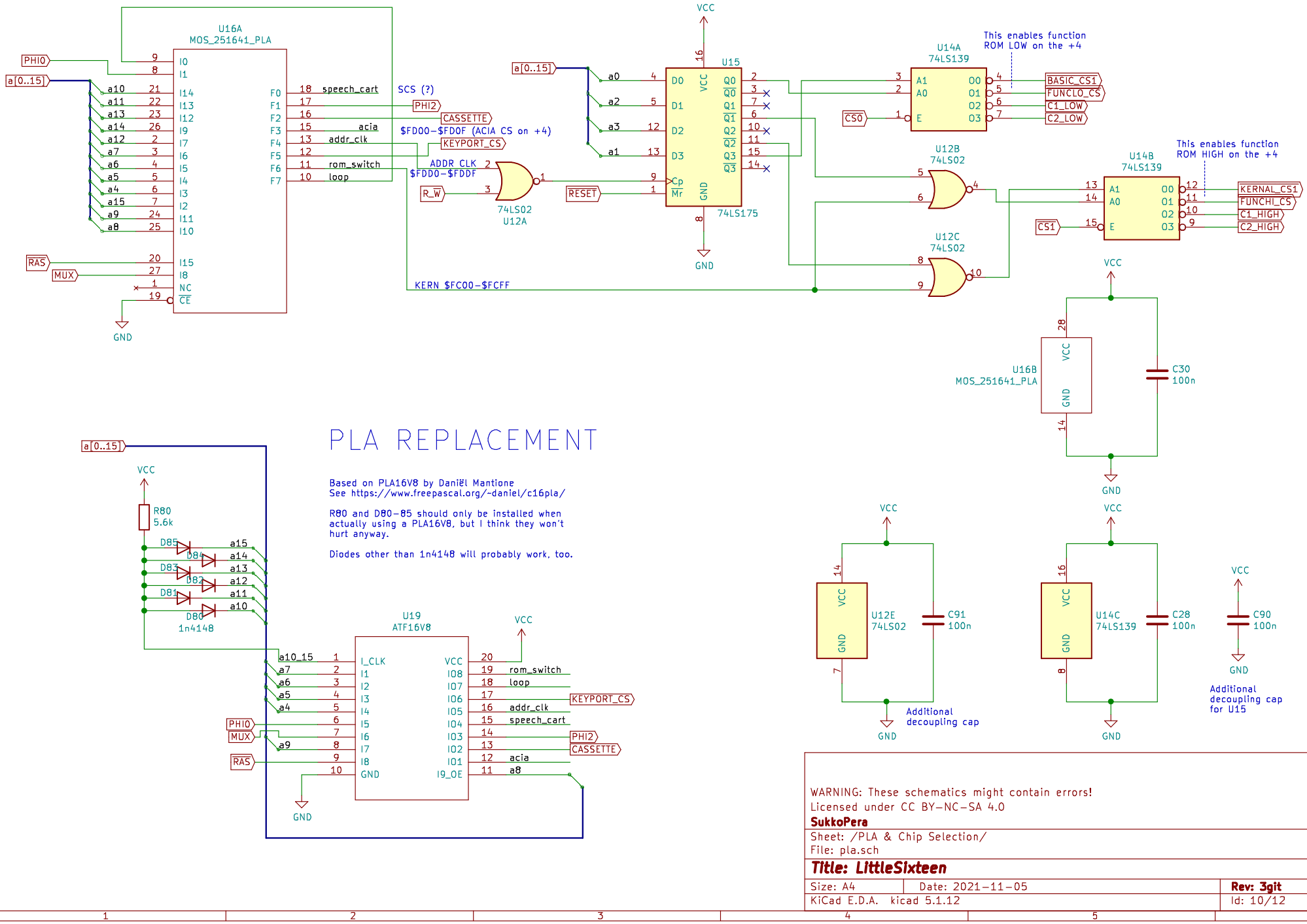
SukkoPera

Sheet: /Power & Misc/
File: misc.sch

Title: LittleSixteen

Size: A4	Date: 2021-12-06	**Rev: 3git**
KiCad E.D.A. kicad 5.1.12		Id: 9/12


U16A
MOS_251641_PLA
PHI0
a[0..15]
RAS
MUX
GND
speech_cart
SCS (?)
PHI2
CASSETTE
acia
addr_clk
KEYPORT_CS
rom_switch
loop
$FDD0–$FDDF (ACIA CS on +4)
ADDR CLK
$FDD0–$FDDF
R_W
74LS02
U12A
VCC
U15
74LS175
RESET
KERN $FC00–$FCFF
U14A
74LS139
This enables function
ROM LOW on the +4
CS0
BASIC_CS1
FUNCLO_CS
C1_LOW
C2_LOW
U12B
74LS02
U14B
74LS139
This enables function
ROM HIGH on the +4
CS1
KERNAL_CS1
FUNCHI_CS
C1_HIGH
C2_HIGH
U12C
74LS02
U16B
MOS_251641_PLA
C30
100n
PLA REPLACEMENT
Based on PLA16V8 by Daniël Mantione
See https://www.freepascal.org/~daniel/c16pla/
R80 and D80–85 should only be installed when
actually using a PLA16V8, but I think they won't
hurt anyway.
Diodes other than 1n4148 will probably work, too.
R80
5.6k
D85
D84
D83
D82
D81
D80
1n4148
U19
ATF16V8
a10_15
rom_switch
loop
KEYPORT_CS
addr_clk
speech_cart
PHI2
CASSETTE
acia
a8
U12E
74LS02
C91
100n
Additional
decoupling cap
U14C
74LS139
C28
100n
C90
100n
Additional
decoupling cap
for U15
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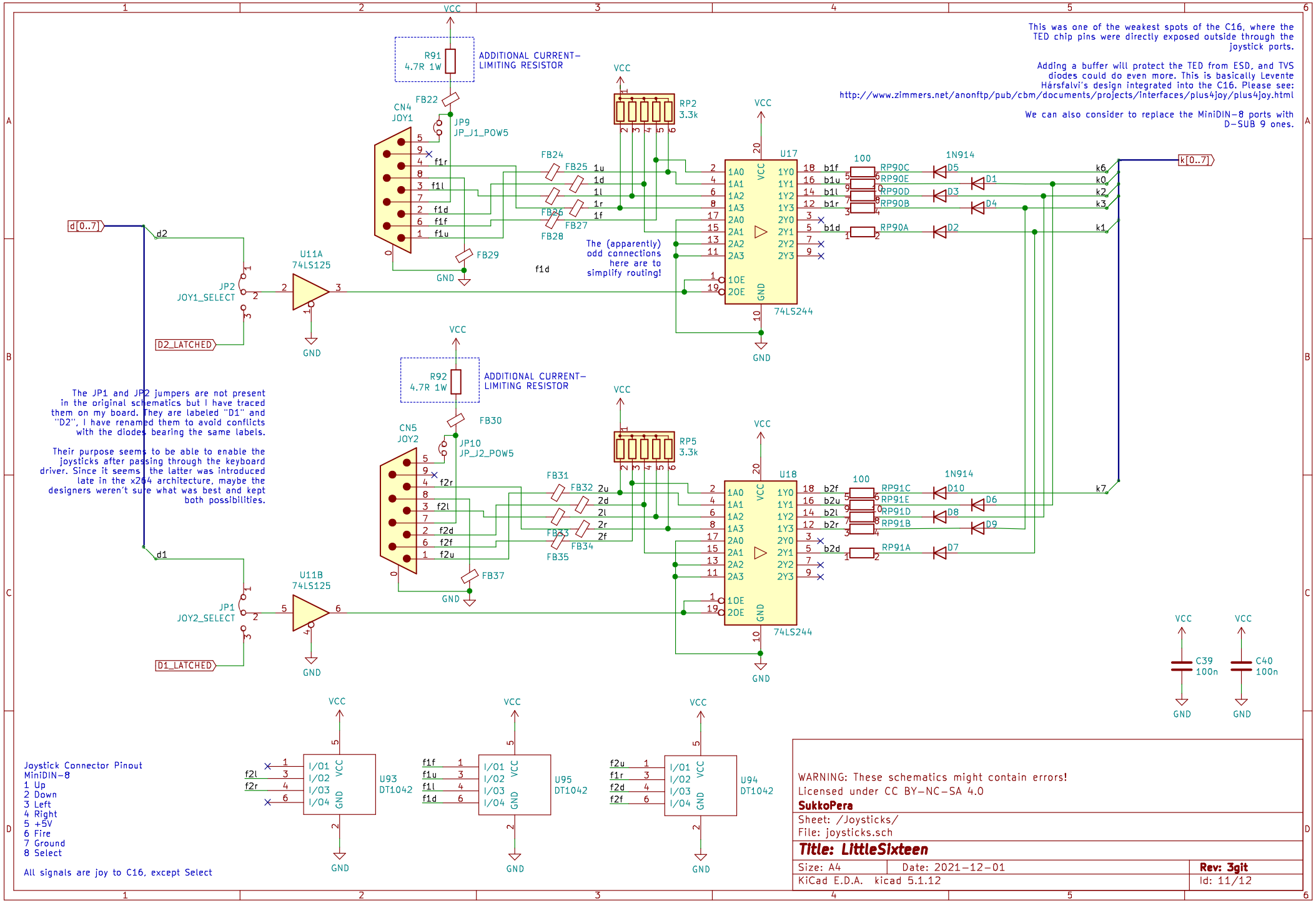
Sheet: /PLA & Chip Selection/
File: pla.sch
Title: LittleSixteen
Size: A4
Date: 2021–11–05
Rev: 3git
KiCad E.D.A. kicad 5.1.12
Id: 10/12


This was one of the weakest spots of the C16, where the TED chip pins were directly exposed outside through the joystick ports.
Adding a buffer will protect the TED from ESD, and TVS diodes could do even more. This is basically Levente Hársfalvi's design integrated into the C16. Please see: http://www.zimmers.net/anonftp/pub/cbm/documents/projects/interfaces/plus4joy/plus4joy.html
We can also consider to replace the MiniDIN-8 ports with D-SUB 9 ones.
R91 4.7R 1W
ADDITIONAL CURRENT-LIMITING RESISTOR
R92 4.7R 1W
ADDITIONAL CURRENT-LIMITING RESISTOR
CN4 JOY1
CN5 JOY2
JP9 JP_J1_POW5
JP10 JP_J2_POW5
JP1 JOY2_SELECT
JP2 JOY1_SELECT
D1_LATCHED
D2_LATCHED
d[0..7]
k[0..7]
U11A 74LS125
U11B 74LS125
U17
U18
74LS244
RP2 3.3k
RP5 3.3k
RP90A
RP90B
RP90C
RP90D
RP90E
RP91A
RP91B
RP91C
RP91D
RP91E
100
1N914
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
C39 100n
C40 100n
U93 DT1042
U95 DT1042
U94 DT1042
The (apparently) odd connections here are to simplify routing!
The JP1 and JP2 jumpers are not present in the original schematics but I have traced them on my board. They are labeled "D1" and "D2", I have renamed them to avoid conflicts with the diodes bearing the same labels.
Their purpose seems to be able to enable the joysticks after passing through the keyboard driver. Since it seems the latter was introduced late in the x264 architecture, maybe the designers weren't sure what was best and kept both possibilities.
Joystick Connector Pinout
MiniDIN-8
1 Up
2 Down
3 Left
4 Right
5 +5V
6 Fire
7 Ground
8 Select
All signals are joy to C16, except Select
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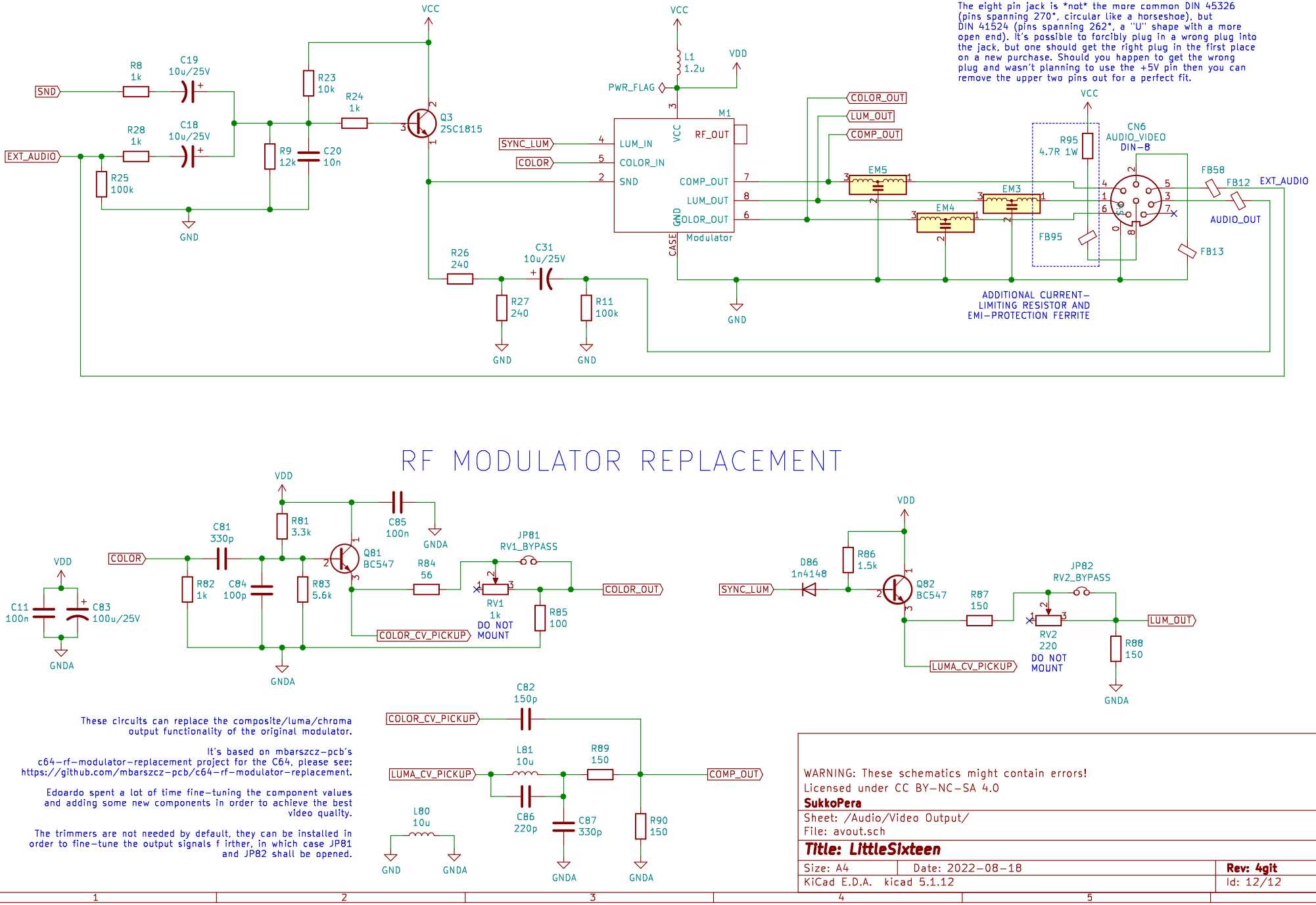
SukkoPera
Sheet: /Joysticks/
File: joysticks.sch
Title: LittleSixteen
Size: A4
Date: 2021-12-01
Rev: 3git
KiCad E.D.A. kicad 5.1.12
Id: 11/12


From C64-Wiki (C64 uses the same connector):
The eight pin jack is *not* the more common DIN 45326 (pins spanning 270°, circular like a horseshoe), but DIN 41524 (pins spanning 262°, a "U" shape with a more open end). It's possible to forcibly plug in a wrong plug into the jack, but one should get the right plug in the first place on a new purchase. Should you happen to get the wrong plug and wasn't planning to use the +5V pin then you can remove the upper two pins out for a perfect fit.
SND
EXT_AUDIO
R8 1k
C19 10u/25V
R28 1k
C18 10u/25V
R25 100k
R23 10k
R24 1k
R9 12k
C20 10n
Q3 2SC1815
VCC
GND
L1 1.2u
VDD
PWR_FLAG
M1
SYNC_LUM
COLOR
LUM_IN
COLOR_IN
SND
VCC
RF_OUT
COMP_OUT
LUM_OUT
COLOR_OUT
GND
CASE
Modulator
COLOR_OUT
LUM_OUT
COMP_OUT
EM5
EM4
EM3
R95 4.7R 1W
CN6 AUDIO_VIDEO DIN-8
FB58
FB12
EXT_AUDIO
AUDIO_OUT
FB13
FB95
R26 240
C31 10u/25V
R27 240
R11 100k
ADDITIONAL CURRENT-LIMITING RESISTOR AND EMI-PROTECTION FERRITE
RF MODULATOR REPLACEMENT
VDD
COLOR
C81 330p
R81 3.3k
C85 100n
GNDA
Q81 BC547
JP81 RV1_BYPASS
R84 56
RV1 1k DO NOT MOUNT
R85 100
COLOR_OUT
COLOR_CV_PICKUP
R82 1k
C84 100p
R83 5.6k
C11 100n
C83 100u/25V
SYNC_LUM
D86 1n4148
R86 1.5k
Q82 BC547
R87 150
JP82 RV2_BYPASS
RV2 220 DO NOT MOUNT
LUM_OUT
R88 150
LUMA_CV_PICKUP
C82 150p
L81 10u
R89 150
C86 220p
C87 330p
R90 150
L80 10u
These circuits can replace the composite/luma/chroma output functionality of the original modulator.
It's based on mbarszcz-pcb's c64-rf-modulator-replacement project for the C64, please see: https://github.com/mbarszcz-pcb/c64-rf-modulator-replacement.
Edoardo spent a lot of time fine-tuning the component values and adding some new components in order to achieve the best video quality.
The trimmers are not needed by default, they can be installed in order to fine-tune the output signals f irther, in which case JP81 and JP82 shall be opened.
WARNING: These schematics might contain errors!
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SukkoPera
Sheet: /Audio/Video Output/
File: avout.sch
Title: LittleSixteen
Size: A4
Date: 2022-08-18
Rev: 4git
KiCad E.D.A. kicad 5.1.12
Id: 12/12