OpenCem 3340 rev. 3 and Thru Zero Sync Expander

Datasette

Abstract
This is now the third revision of the Open Hardware Oscillator based on the famous CEM3340 chip. The main goal was not only to provide a free working PCB for everyone with low budget, further it was designed to provide an experimentation platform to discover the potential of this chip. Especially the various sync options, which make the CEM3340 unique but are unfortunately not very well documented in the original datasheet (7), should empower various waveshaping possibilities and invite to experiment. Furthermore the various in and outputs should make it easy to couple devices and establish hardwired crossmodulation. In the second part of the document a at this state very experimental expander is presented, which should unlock Thru.Zero FM capabilities.

To credit where credit is due I am of course not the inventor of most of the implemented ideas and I try to reference the origins as good as possible. Additionally you may find one or too useful links regarding other designs or professional products (10) (12) (5), which are also worth a look, in the references. Further if you are not fixed on the not very cheap CEM3340 chip and just looking to build a very good cheap VCO, I can recommend Fonitronik's stuff. Very well described, easy to build, very cheap and great sounding (9).

As I am no professional electronic designer and more a hobbyist, as most of you, there might be errors in the design. Ill try to test it as good as I can, but claim that you might use all of this at your own risk. I am not responsible for any caused damage! Overall I would define the difficulty of this project as intermediate. If you have already assembled a few modules you should be comfortable, otherwise i would recommend to start with something more simple.

In case someone find issues or has recommendations to make i would be glad to receive them either via Git or Muffwiggler and try to come up with a solution. As it is Open Hardware one is of course allowed to copy parts of the design. If you find my work actually usefull and you have been satisfied with OpenCem3340 I would be happy if you donate me a small amount.

Keywords
CEM 3340 — Voltage Controlled Oscillator — Open Hardware

Special notion to Muffwiggler member Mrand for correspondance and help

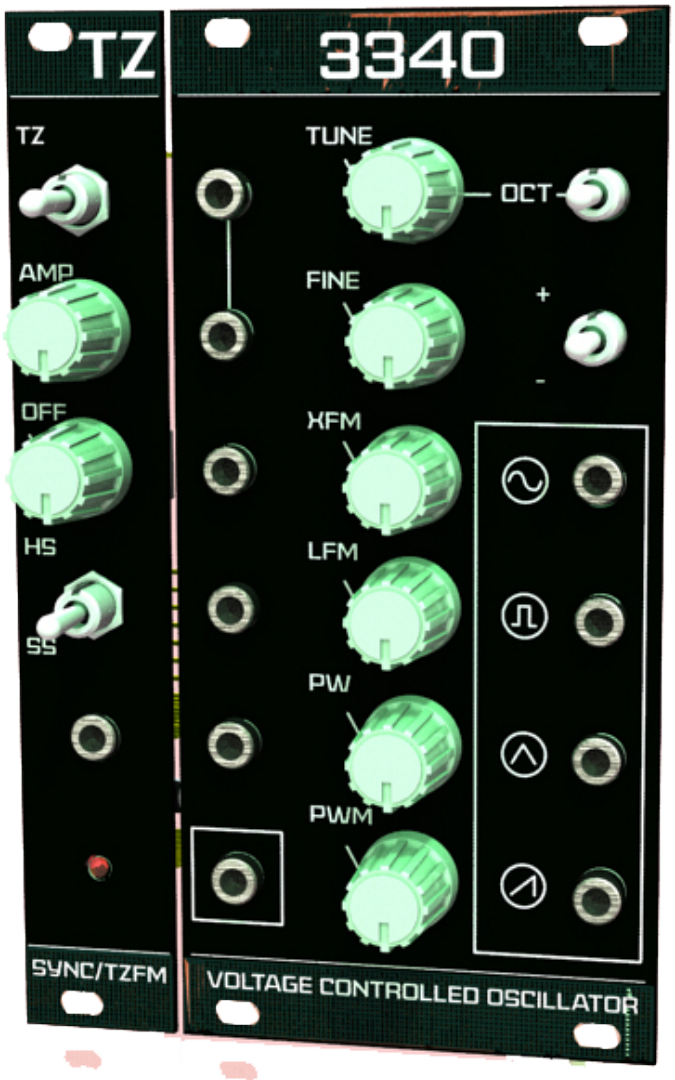


Figure 1. OpenCem3340 VCO with Thru Zero Sync Expander

Contents

1. OpenCem 3340 rev3

1.1 Mainboard Layout

The format of the mainboard is 63x100 mm. Hence it can be ordered at very low cost, if you restrict yourself to basic prototyping quality. A quick guide on how to order is given in the following section. All Potentiometers can be mounted on board if one uses standard Alpha 9mm types. Jacks and switches have to be handwired. If there is enough depth available I would recommend to mount it to a front panel using the pots, otherwise make use of the mounting holes.

The main components are completely Through-hole, despite1206 SMD bypass caps on the bottom of the PCB. If you are really not into SMD you could make use of DIP Sockets including a mounting space for bypass caps as found at (4). All Trimmers are multiturn precision trimmers with a 3296W footprint and should also be placed on the bottom side. The corresponding function is marked on the silkscreen. C24 acts as timing cap and therefore should be as precise as possible. I recommend a Mica with 1 % tolerance. All other caps have a 2.5mm footprint and at current prices you should go for C0G MLCC or WIMA FKP/MKP. Resistors are standard MF-0207 type, except the ones used in the octave switch (see notes below). Assemble the board beginning with the lower components and ending with the higher ones. The following graphic depicts the Mainboardlayout and the aforementioned extensions.

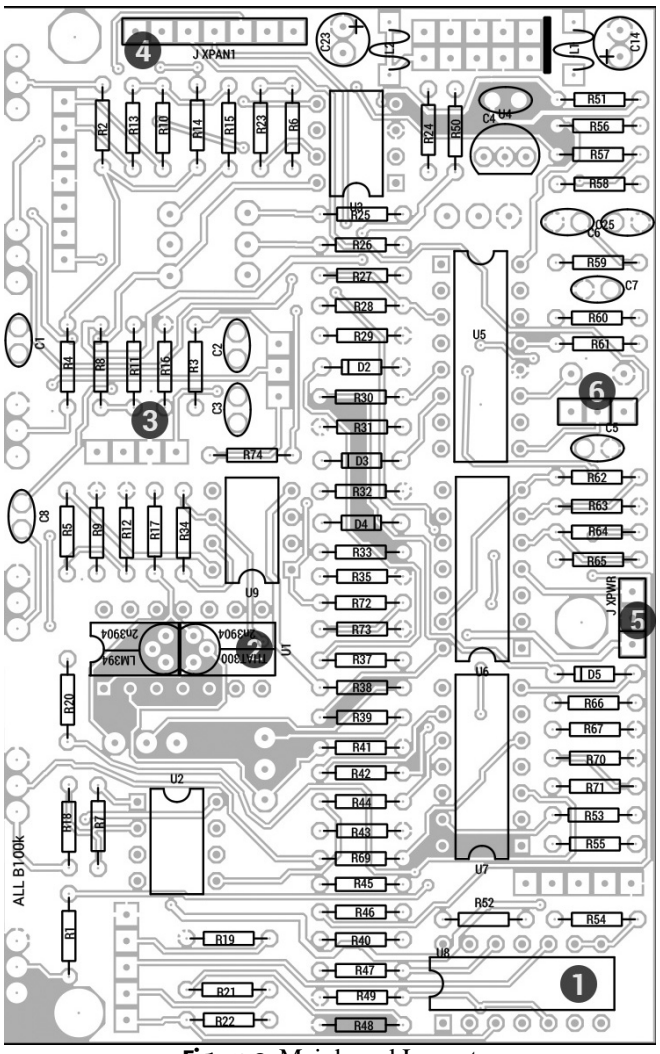


Figure 2. Mainboard Layout

1. Optional Copy-buffer for secondary independent output of the main waveforms
2. Triple Footprint to install either a matched pair of 2N3904 Transistors,LM394 in DIP-package or a THAT320 IC to act as diffrential pair
3. Optional octave switch. Use any suitable SP3T switch and install precision resistors for R8, R11 and R16
4. Top expansion header, that breaks out most of the pin functions of the 3340.
5. additional power header, supplying +12V and -12V. Use only for small current draws
6. jumper to either ground the Softsync input if it is not used or make it available to the expansion header

The expansion header at the right top of the board breaks out most of the main functions of the 3340 chip. I would recommend to use a Flat ribbon cable to make connections to other

modules. The following table describes the pinout
The expansion header at the bottom right provides a buffered

Table 1. Pinout Top Header

Pin	Name	Function
1	EXT_TRI	buffered copy of the Triangle Wave
2	EXT_HS+	positive pulses to HSync the VCO
3	EXT_HS-	negative pulses to HSync the VCO
4	EXT_LFM	additional uncoupled LFM input
5	EXT_SSYNC	direct connection to the SSYNC Pin
6	EXT_SAW	buffered copy of the SAW Wave
7	EXT_P	additional CV Input

copy of all waveform outputs and has the same output impedance as the main output. Actuallly you could use either one or another to wire your jacks. It may be used for backwirering and crossmodulation between other modules. If you do not want to make use of this feature, you may neglect Op amp U9 aswell as Resistors R52-R55.

Table 2. Pinout Bottom Headers and XPR

Pin	Name	Pin	Name
1	SINE	1	+12V
2	PULSE	2	GND
3	TRIANGLE	3	-12V
4	SAW		
5	GROUND		

1.2 Octave Switch

The board provides a very basic octave switch which allows to shift the output up by 1 or 2 octaves. The circuitry is a basic voltage divider fed by the 5V reference. It is recommended to use 0.1% precision resistors for $R8$, $R11$ and $R16$. As switch you can utilize everything which will give you a SP3T behavior. If you find it hard to find a suitable one, you could also use a DP3T toggle switch, which are cheaply available at Tayda. Handwire the switch to the SW_OCT header. If you do not want to make use of that feature, neglect the above mentioned components. Further information on octave switching can be found here (6)

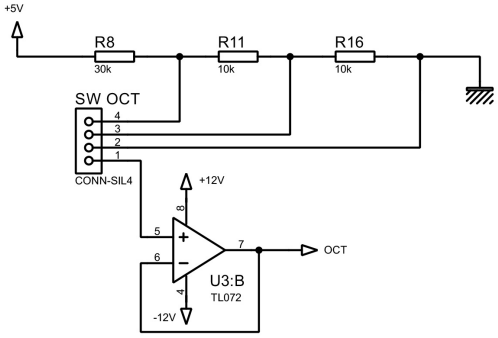


Figure 3. Octave Switch

1.3 PWM Control

As the PWM control circuit of Rev. 2 was a bit hit and miss regarding dead zones in the extreme positions, the circuitry has been revised and should act more precise and intuitive. It is inspired by an implementation found in the Aries VCO (3).

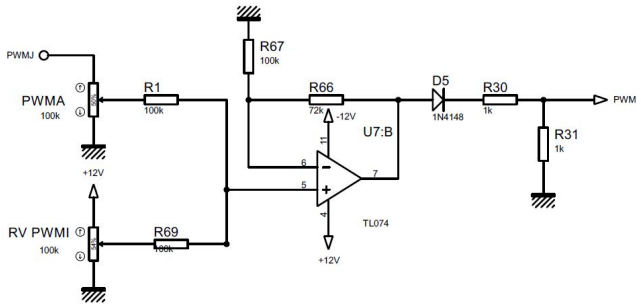


Figure 4. PWM Control

1.4 Sync

The implementation of the Hardsync has been copied from the original datasheet and provides two seperate, which are selectable via a switch on the frontpanel and sync to either positive or negative edges. As this version is reliant on a rather strong input signal of 5-6V, which most Eurorack VCO don't produce, some preamplification has been introduced to guarantee stable operation. In order to make both inputs separately available to the expansion header, with the intention to unlock the whole power of this unique feature for various experiments, each channel is amplified independently. You may note missing input impedance resistors on the external inputs. I suggest to select resistors of reasonable values around 100k regarding the strength of the input signal and wire them externally. If you don't want to use any expansion or there are noise issues causing unwanted syncing, I suggest to make a external connection to ground by wirering the external inputs to the ground pin of the XPR header.

1.5 Sineshaper

The Sineshaper is a very common design around an differential Pair of NPN Transistors. The board provides a triple

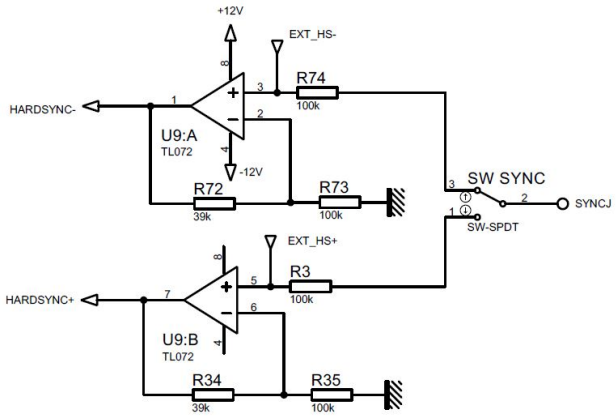


Figure 5. Sync Amplification

footprint which allows to choose if you either go with two 2N3904 transistors, which is really cheap and sufficient, or use a LM394 super matched pair, which is still available on Ebay from China, or use half of a THAT320 IC, which is really overkill and expensive but not obsolete and should provide highest quality. If you look for more detailed information on the matter of Sineshaping, I recommend (11)

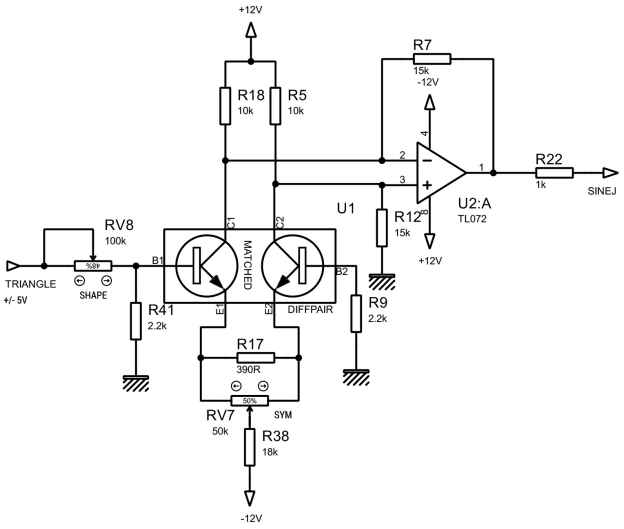


Figure 6. Sineshaper based on differential matched pair

1.6 Hints for designs based around the 3340

The OpenCem3340 board has been adjusted to suit the Eurorack standards of +12/-12V supply voltage and provides a signal strength of +/-5V. Input impedance is standard 100k, while output impedance on the output headers at the bottom is around 1k. In order to adjust or adapt this design to other conditions the following hints might be useful. If you are looking for a +/-15V adaption you will find a wealth of information in (5) (7)

- R27 is calculated by $(V_{EE} - 7.2)/.008$
- R56 sets the reference current, which should be arround 10μA, the corresponding maximum/minimum LFM signal should match that figure
- Saw,Pulse and Triangle signal strenght is produced by Opamps in either non- / or inverting configuration. You may adjust resistors to your needs
- The sineshaper requirs +/-5V input, the output may be adjusted by altering R12 and R7
- Relation between Supply voltage and Output levels

SAW	$2/3V_{DD}$
TRI	$1/3V_{DD}$
PLS	$V_{DD} - 1.5V$

- Saw is actually a rising ramp
- Do not load the triangle output as it will cause pitch drifts. I recommend to buffer before further processing.
- R59 should ideally be a precision resistor and bypassed to ground by 1nF.

1.7 Further Notes on components

- All Audio related Opamps (U2,U6,U7,U8) should be replaceable with OPA2134,OPA4134.NE5532 to gain slightly different sound characteristic.
- the listed resistor prices refer to Tayda. They are not the highest quality as leads are very thin. Nevertheless never had any problems with them
- the listed Mica cap is well overpriced. You may find much better value at other suppliers (e.g. Reichelt)

2. ThruZero Sync Expander

During my research and the long hours I've been working on this project I naturally stumbled upon J.Haibles JH3 VCO. It is a very strange implementation at many points far away from the original datasheet recommodations. Nevertheless after Version 2 does quite a good job in my rack, but is as Version 3 a well equipped but pretty stock Oscillator I had to go for some more special functions. I tried to understand how Haible's version might work and the Expander is the intermediate result. I must admit the Thru Zero Expander in its current state is not perfect, and further investigation is needed especially on timing delays and frequency dependency, but it is capable of producing nice Thru Zero tones, Hard and Softsyncing. Regarding this unsolved riddles and the limitation of breadboarding on this matter, I decided to make this module as flexible as possible. Hence I neglected the old CMOS stuff and went for a programmable device, which wont cost a lot and is easy to handle. I believe the functionality of this little module can be easily driven in different directions such as Waveshaping purpose, a stand-alone Clocker/Syncer or a Tuner. I will try some of this in the near future at least.

2.1 Theory of Thru Zero Operation

As stated before thr basic idea of the board is a clone of a design by J.Haible (8), but has been customized heavily to suite the main-board design. It makes use of the fact that the Cem3340 Hard-sync input reverses the shape of the produced waveform. The timing and polarity of these pulses is determined by the point when the VCO has been modulated to stop and whether the VCO is in its rising or falling Triangle cycle.

Detecting if the VCO has been modulated to stop:
The linking factor between the incoming modulation signal and the VCO output frequency is the reference current applied to pin 13. In case of the OpenCem3340 Mainboard a voltage of +5/-5V applied to the LFM input nullify or doubles that current. Hence, if the modulation input is rectified, doubled and shifted down by 5V the original zero crossing will be the point when the Oscillator stops. This is detected by comparator one and fed into the logic IC.

Detecting whether the VCO is in its rising/falling cycle

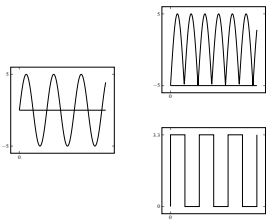


Figure 7. Modulation Input, Processed Signal and ZCD Output

To determine the Cycle the Saw output is compared against the output of the SSync Pin, which is half of the maximum Saw level. Hysterisies is added to the comparator in order to get noiseless sharp transitions.

The Logic

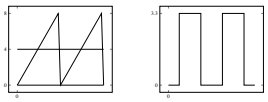


Figure 8. Comparision of SSYNC against SAW detects Cycle

Its rather simple and is expressed in two simple steps.

1. If a Zero Crossing of the Modulation Signal is detected create a sync pulse
2. Regarding the Cycle of the VCO reverse polarity or not

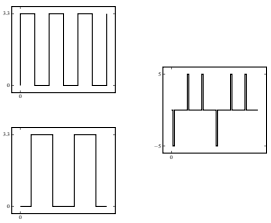


Figure 9. Logic input and output (simplified)

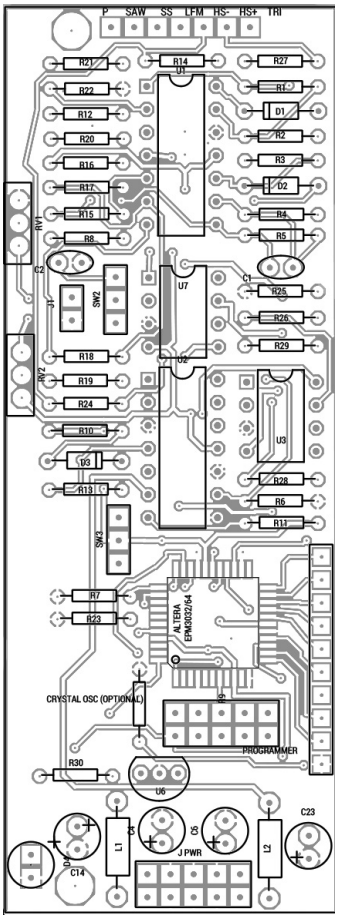
2.2 Handle the Altera

The Altera MAX3000A EPM3032/64 is a CPLD in TQFP44 package (1). It was chosen over a standard CMOS Implementation, as it is flexible programmable, nearly the same price and offers much more functionality for further experiments without eating up board space.
Regarding soldering techniques I recommend to tag the chip to the board by soldering 2 Pins. Once the alignment is good, put a lot of flux on all pins and swipe with the tip of your soldering iron and a fairly amount of solder on it quickly over a whole row of pins. If you get a few shorts, just clean them using a bit solder wig. It is not hard at all.
In order to program it a Altera USBBlaster is needed, which can be purchased on Ebay for around 4 Euro. The programming software is available at the Altera website (2) at no extra cost and fairly easy to use. The Quartus II Web Edition **13 SP1** aswell as the MAX3000 Device Files and the Quartus Programmer is needed. To program follow these steps:

1. Plug in Altera USBBlaster into the Board
2. Open Quartus Software
3. Select Programmer in Menu Tools
4. Power Up the Expander
5. Press Auto-Detect Device
6. Select Add File and choose provided *.sof file
7. tick box Programm/Configure

2.3 Layout

The dimension of the expander board is 36.4x100mm. It is not completely through hole as the logic is handed to an Altera Max3000A CPLD CHIP in TQFP44 package. Nevertheless it is still a fairly large package with 0.8mm pin pitch and can be soldered by hand easily. In order to make full use of this IC and offer its capibility for further experiments, an optional Crystal Oscillator for Clocking and a breakout header which offers access to 9 I/O has been added. A DG419 Analog Switch IC handles the switching of the Sync inputs regarding the used mode. The incoming signal might be amplified and shifted via two pots. As toggle switches use one standard SPDT on/on and one SPDT ON-OFF-ON one.



2.4 Controls

Table 3. Controls of the TZSync-Expander

Name	Function
TZ-SWITCH	Break/Connect processed Signal to the VCO
AMP	Attenuates the Modulation Signal
OFF	DC-Bias the incoming Signal
SS/HS-Switch	Select used Syncing Method

In order to use the intended Thru-Zero Modulation you need to activate the TZ-switch to forward the rectified Modulation Signal and use the Hardsyncing mode. Through shifting and attenuating the Signal with the pots you further can shape and influence the modulation depth. If you turn of the modulation feature you will have the possibility to sync the VCO in a very flexible manner.

3. Schematics

4. Bill of Materials

Cat	Q	References	Value	Stock Code	Cost
Cap	5	C1-C3,C5,C25	1nF	810-FG18C0G1H102JNT6	0,22 €
Cap	1	C4	220pF	810-FK18C0G2A221J	0,27 €
Cap	2	C6-C7	10nF	810-FG18C0G1H103JNT6	0,35 €
Cap	1	C8	100nF	810-FK16C0G1H104J	0,72 €
Cap	12	C10-C13,C15-C22	100nF	77-VJ1206Y104JXBTBC	0,07 €
Cap	2	C14,C23	22uF	667-ECE-A1EKA220I	0,19 €
Cap	1	C24	1nF	598-CD15FA102FO3	5,23 €
Res	11	R1-R2,R4,R10,R13-R14,R23,R35,R67,R69,R73	100k	TAYDA 1% MF	0,01 €
Res	4	R3,R20,R40,R74	100k	TAYDA 1% MF	0,01 €
Res	14	R5,R18,R21,R24,R28,R32,R43-R44,R47-R48,R50,R63,R65,R71	10k	TAYDA 1% MF	0,01 €
Res	1	R6	3,3M	TAYDA 1% MF	0,01 €
Res	3	R7,R12,R29	15k	TAYDA 1% MF	0,01 €
Res	1	R8	30k	71-RN55C3002B	0,50 €
Res	2	R9,R41	2,2k	TAYDA 1% MF	0,01 €
Res	2	R11,R16	10k	71-RN55C-B-10K	0,30 €
Res	1	R15	200k	TAYDA 1% MF	0,01 €
Res	1	R17	390R	TAYDA 1% MF	0,01 €
Res	2	R19,R49	1,6k	TAYDA 1% MF	0,01 €
Res	10	R22,R30-R31,R33,R39,R51-R55	1k	TAYDA 1% MF	0,01 €
Res	1	R25	24k	TAYDA 1% MF	0,01 €
Res	1	R26	5,6k	TAYDA 1% MF	0,01 €
Res	1	R27	620R	TAYDA 1% MF	0,01 €
Res	2	R34,R72	39k	TAYDA 1% MF	0,01 €
Res	1	R37	2k	TAYDA 1% MF	0,01 €
Res	1	R38	18k	TAYDA 1% MF	0,01 €
Res	2	R42,R45	12,5k	TAYDA 1% MF	0,01 €
Res	1	R46	11k	TAYDA 1% MF	0,01 €
Res	1	R56	1,5M	TAYDA 1% MF	0,01 €
Res	1	R57	1M	TAYDA 1% MF	0,01 €
Res	2	R58,R60	470R	TAYDA 1% MF	0,01 €
Res	1	R59	1,8k	71-RN55C-B-1,8K/R	0,30 €
Res	1	R61	500K	TAYDA 1% MF	0,01 €
Res	1	R62	30k	TAYDA 1% MF	0,01 €
Res	1	R64	25k	TAYDA 1% MF	0,01 €
Res	1	R66	72k	TAYDA 1% MF	0,01 €
Res	1	R70	4,7M	TAYDA 1% MF	0,01 €
IC	1	U1	DIFFPAIR	610-2N3904	0,06 €
IC	3	U2-U3,U9	TL072	595-TL072CP	0,26 €
IC	1	U4	LM4040	926-LM4040AIZ5,0NOPB	1,50 €
IC	1	U5	CEM3040	OnChip	18,00 €
IC	3	U6-U8	TL074	595-TL074CN	0,24 €
Diodes	1	D2	1N4740A	78-TZX10D	0,18 €
Diodes	3	D3-D5	1N4148	512-1N4148	0,05 €
Misc	10	J1-J4,J6-J11	16PJ138	16PJ138	0,29 €
Misc	1	J CONTROLS	CONTROLS	SIL STD 2,54 Male Header	0,05 €
Misc	2	J OUT,J OUT2	OUTS	SIL STD 2,54 Male Header	0,05 €
Misc	1	J PWR	CONN-DIL10	DIL STD 2,54 Male Header	0,05 €
Misc	1	J XPAN1	CONN-SIL7	SIL STD 2,54 Male Header	0,05 €
Misc	1	J XPWR	CONN-SIL3	SIL STD 2,54 Male Header	0,05 €
Misc	1	JP SSYNC	JUMPER2	STD 2,54	0,01 €
Misc	2	L1-L2	BEAD	875-28L0138-10R-10	0,11 €
Misc	6	PWMA,RV COARSE,RV FINE,RV LFM,RV PWMI,RV XFM	100k	ALPHA 9MM	1,29 €
Misc	2	RV5,RV8	100k	72-T93WB-100K	1,29 €
Misc	2	RV6,RV9	10k	72-T93WB-10K	0,28 €
Misc	1	RV7	50k	72-T93WB-50K	0,28 €
Misc	1	SW OCT	CONN-SIL4	SP3T SWITCH	0,89 €
Misc	1	SW SYNC	SW-SPDT	506-A101SYCQ04	0,47 €
					48,66 €

Figure 10. BOM CEM3340 Main Module

Cat	Q	References	Value	Stock Code	Cost
Cap	1	C1	30pF	80-C315C300J1G	0,60 €
Cap	3	C2-C3,C20	100nF	810-FK16C0G1H104J	0,72 €
Cap	2	C4,C6	4.7uF	667-ECE-A1EKA4R7B	0,19 €
Cap	9	C5,C7-C8,C10,C12,C16-C17,C21-C22	100nF	77-VJ1206Y104JXBTBC	0,07 €
Cap	2	C14,C23	22uF	667-ECE-A1EKA220I	0,19 €
Res	1	R1	20k	TAYDA 1% MF	0,01 €
Res	13	R2-R5,R7,R15,R17,R23-R26,R28-R29	10k	TAYDA 1% MF	0,01 €
Res	4	R6,R8,R10-R11	4.7k	TAYDA 1% MF	0,01 €
Res	3	R9,R19,R30	1k	TAYDA 1% MF	0,01 €
Res	4	R12,R14,R21,R27	100k	TAYDA 1% MF	0,01 €
Res	1	R13	220k	TAYDA 1% MF	0,01 €
Res	1	R16	56k	TAYDA 1% MF	0,01 €
Res	1	R18	18k	TAYDA 1% MF	0,01 €
Res	1	R20	470k	TAYDA 1% MF	0,01 €
Res	1	R22	4.7M	TAYDA 1% MF	0,01 €
IC	1	U1	TL074	595-TL074CN	0,24 €
IC	1	U2	LM319	512-LM319N	0,43 €
IC	1	U3	TL072	595-TL072CP	0,28 €
IC	1	U4	MAX3000A	989-EPM3064ATC44-10N	2,64 €
IC	1	U5	CRYSTAL OSC XO	815-ASV-10-EJ-T	1,55 €
IC	1	U6	TS2950	579-MCP1700-3302E/TO	0,37 €
IC	1	U7	DG419	781-DG419DJ-E3	1,50 €
Diodes	3	D1-D3	1N4148	512-1N4148	0,05 €
Diodes	1	D4	LED-YELLOW	859-LTL-4251	0,09 €
Misc	1	J1	CONN-SIL2	DIL STD 2.54 Male Header	0,05 €
Misc	1	J2	CONN-DIL10	SIL STD 2.54 Male Header	0,05 €
Misc	1	J3	CONN-SIL10	SIL STD 2.54 Male Header	0,05 €
Misc	1	J12	CONN-SIL7	SIL STD 2.54 Male Header	0,05 €
Misc	1	J PWR	CONN-DIL10	DIL STD 2.54 Male Header	0,05 €
Misc	2	L1-L2	BEAD	875-28L0138-10R-10	0,11 €
Misc	2	RV1-RV2	100k	Alpha 9mm	1,29 €
Misc	2	SW2-SW3	SW-SPDT	Tayda ON-ON and ON-OFF-ON	0,47 €
Prgm	1	Altera Byteblaster		Ebay	3,00 €
					18,69 €

Figure 11. BOM TZ SYNC Module

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