100-1007 No Tempco VCO

1. Theory Of Operation.

The VCO uses a purely electronic means of compensating for the scale drift in exponential transistor pair. This is not a new concept. The Curtis CEM3340 VCO did this some twenty years ago. But, that part is no longer being made. So, coming up with a way to do this was not an easy thing to do. In fact, I have been trying to do it ever since the CEM3340 first came out simply because it was a puzzle to solve. It wasn't until 1998, however, that I really started working on this problem in earnest. And, there were a few false starts, but it would seem I now have a circuit that does this job fairly nicely. While this does a considerable complexity to the circuit, it does not cost a whole lot, compared to the solution using a temperature compensating resistor. Those resistors can cost between $5 to $10 each. There are less expensive parts, however, they don't have the exact temperature dependence needed. There are ways to get around all this, but some of the solutions are not very satisfactory.

Looking at the schematic, U9A and U9B make up the gain control element that controls the temperature coefficient of the voltage applied to the base of Q6A (pin 2). The LM13700 connect in this fashion does two things. First the Tempco of U9A is canceled out by the Tempco of U9B, and second, the non linearity's of the two amplifiers also cancel each other out. The overall linearity is about 0.1%.

The transfer function for this combination is:

$$\mathbf{V_O = R_{47} * g_{mU9B} * V_{IN} / (g_{mU9A} * R_{44} + 1)} \qquad \mathbf{(1)}$$

G_{mU9A} will nominally be 0.0081 mhos.

The current that controls G_{mU9B} is a bit more problematic. Q6C and the reference leg of Q6A (Pins 3,4,5) form a band gap reference. The output voltage will be proportional to absolute temperature. For room temp it should be:

$$\mathbf{V_{BG} = V_T * \ln(500);\ V_T = 0.026V\ @\ room\ temp} \qquad \mathbf{(2)}$$

The 500 value is the ration of the two currents, which is set by the ration of R43/R101 = 500. The amplifier supplying the current has a gain of 10. So, IABC2 will be:

$$\mathbf{I_{ABC2} = 10 * V_{BG} / R_{57} = 10 * 0.1616 / 4.02K} \qquad \mathbf{(3)}$$

So I_{ABC2} will be about 0.4 mA.

This will make GMU9B nominally 0.0077 mhos. So, substituting all of this into the above equation (1) we get:

$$V_O = 0.01905 * V_{IN} \quad (4)$$

So, as you can see, we will get about 19mV/V at the base of Q6A (Pin 2), which is a bit high perhaps, but that is what the pot is for.

IABC2 will vary with temperature, because, that is what it is supposed to do, always adjusting the gain of the VCA so that the scale factor will remain constant with temperature.

Q6B is used to generate a current that can be used to correct for the bulk resistance of the exponential transistors. The collector of Q6B is fed into an opamp that converts the current to voltage. R39 then allows you to adjust the amount of voltage that gets fed back into the converter. This seems to be a very clean way of generating this signal. We don't need to worry about offsets added by the usual method of using the output of the reference leg servo amp.

The oscillator itself is just a standard sawtooth oscillator that has been around for a long time. You will find this oscillator in past issues of Electronotes. The circuit is one that was done by Terry Michaels. It is also sometimes referred to as the ASM-1 oscillator. The sawtooth output of the oscillator then goes into wave shapers that are pretty much standard. I did add a divider that will produce divide by 2,3, and 4 ratios.

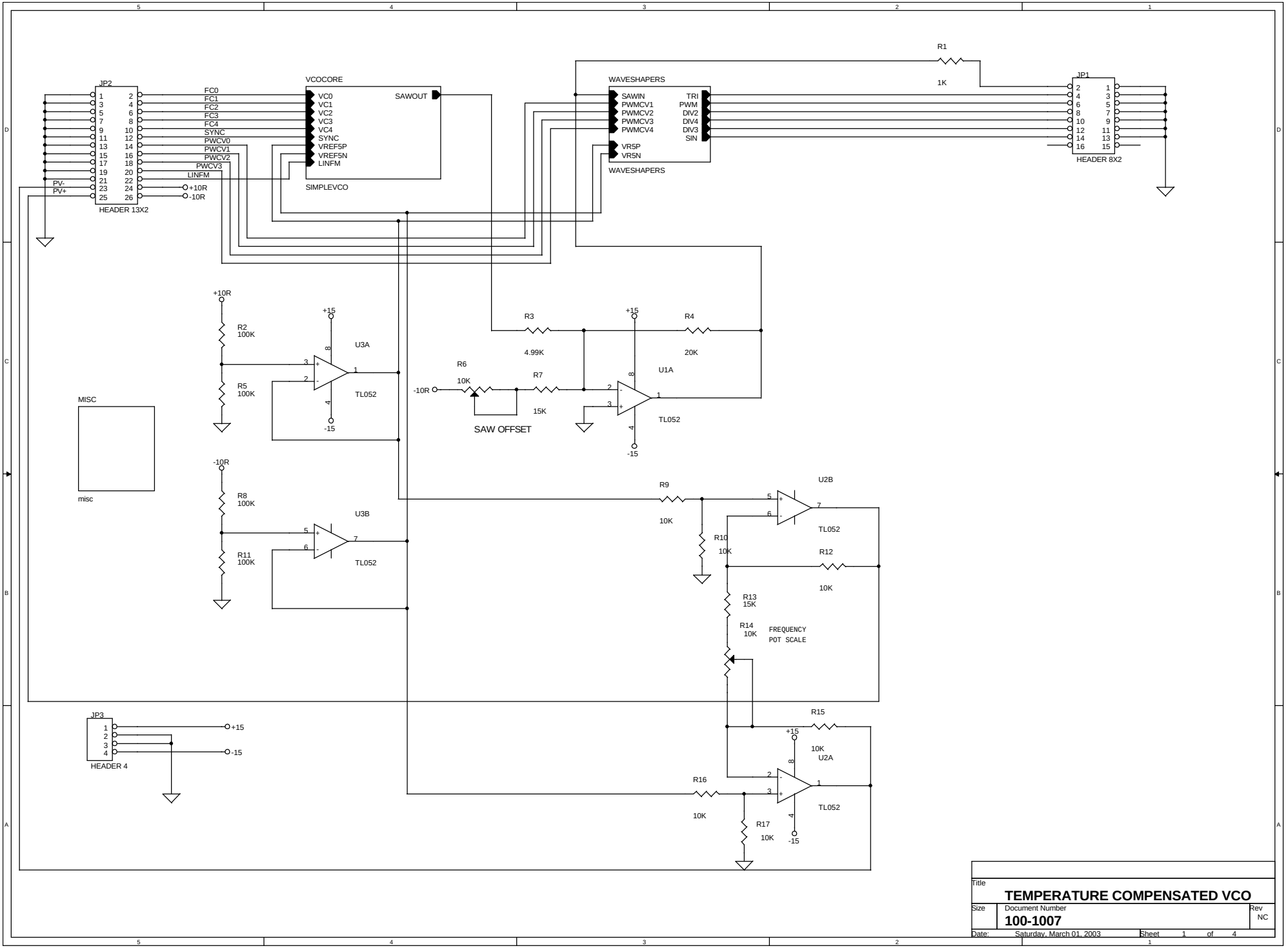
II. Construction

You should note the following changes.

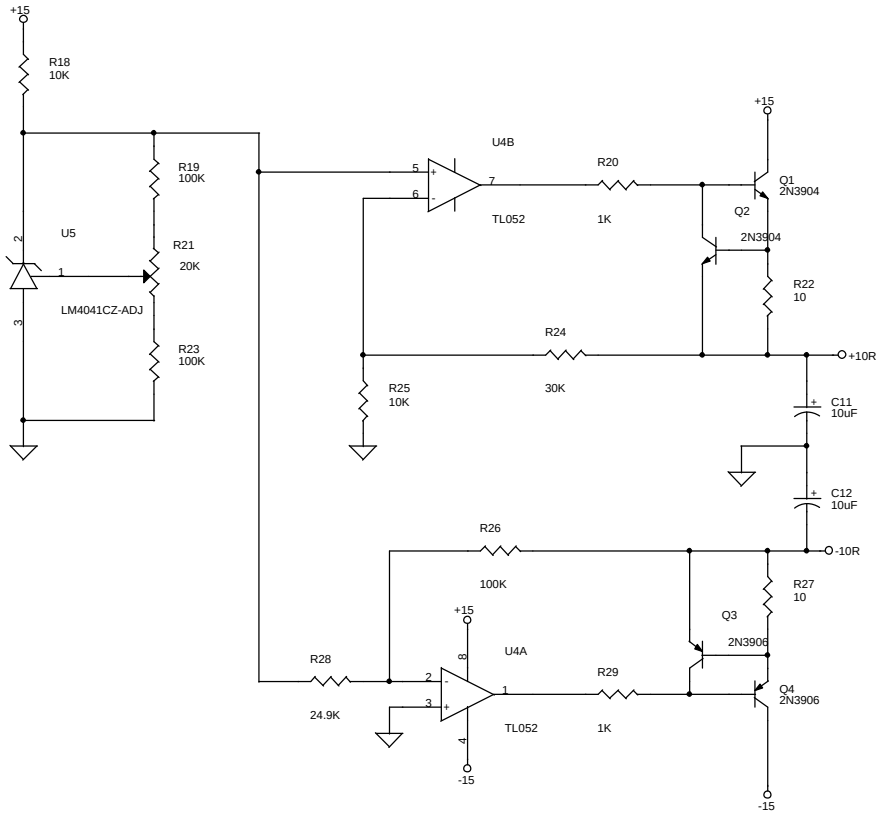
For the REV N.C. board, the silkscreen reads wrong for the following parts.

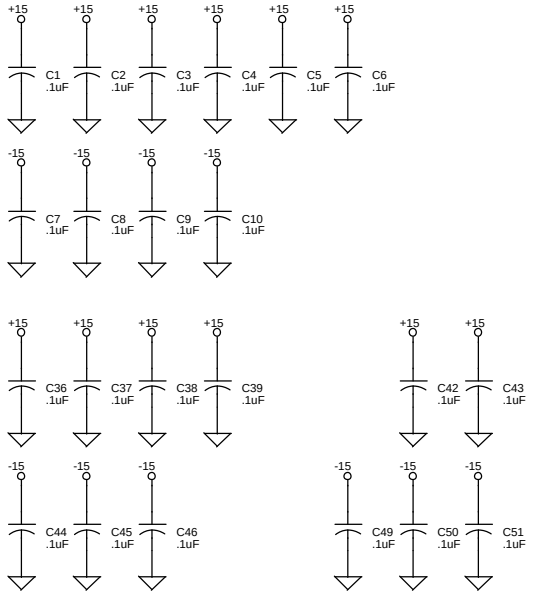
Reference Designator	Silkscreen Reads	The value should be
R47	200	1K
R57	11.3K	4.02K
R58	10K	11.3K

The only part you may have difficulty finding is the CA3280. All of the other parts should be commonly available. Most can be purchased from either Digikey or Mouser.



Title	**TEMPERATURE COMPENSATED VCO**	
Size	Document Number **100-1007**	Rev NC
Date: Saturday, March 01, 2003	Sheet 1 of 4	

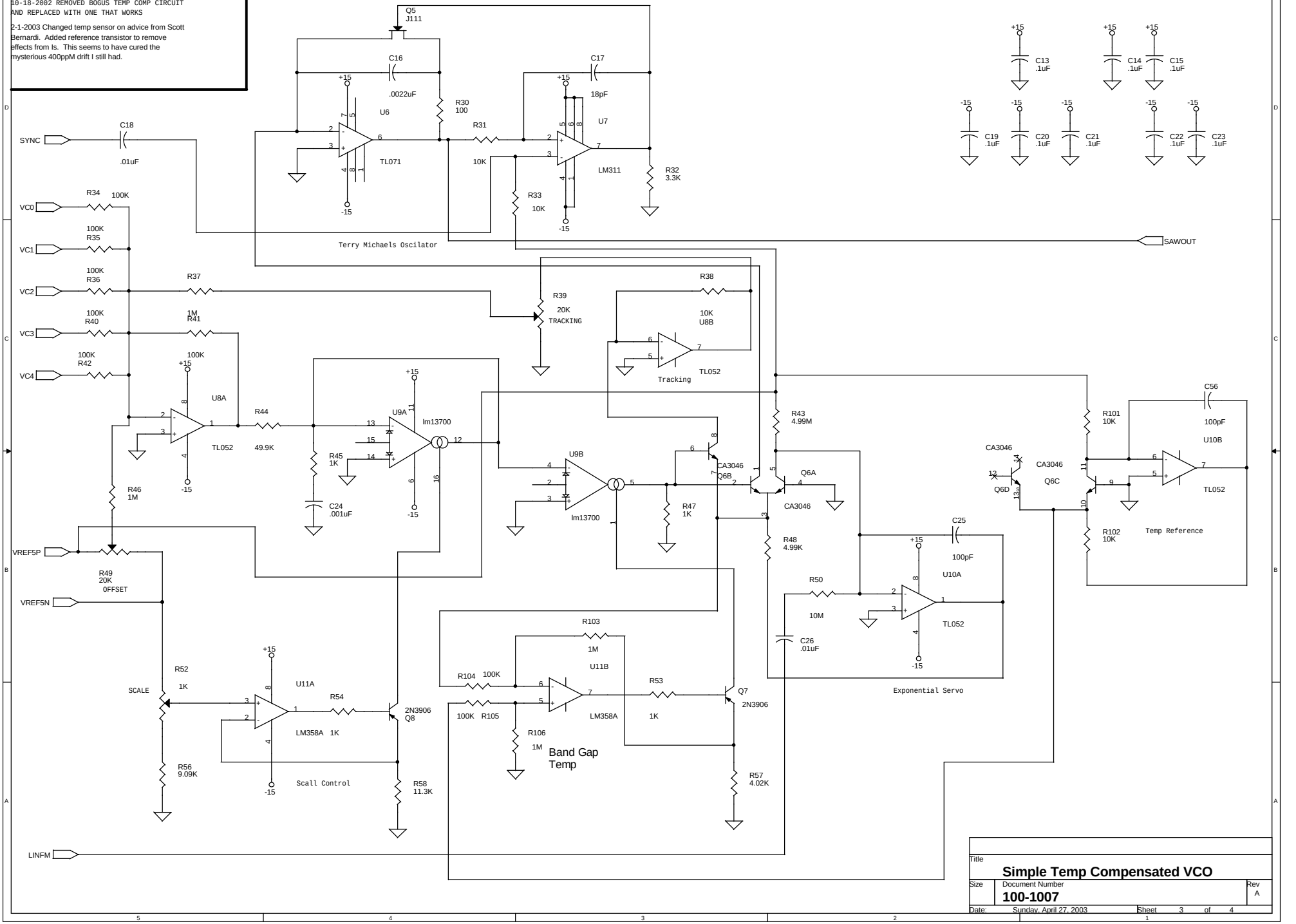




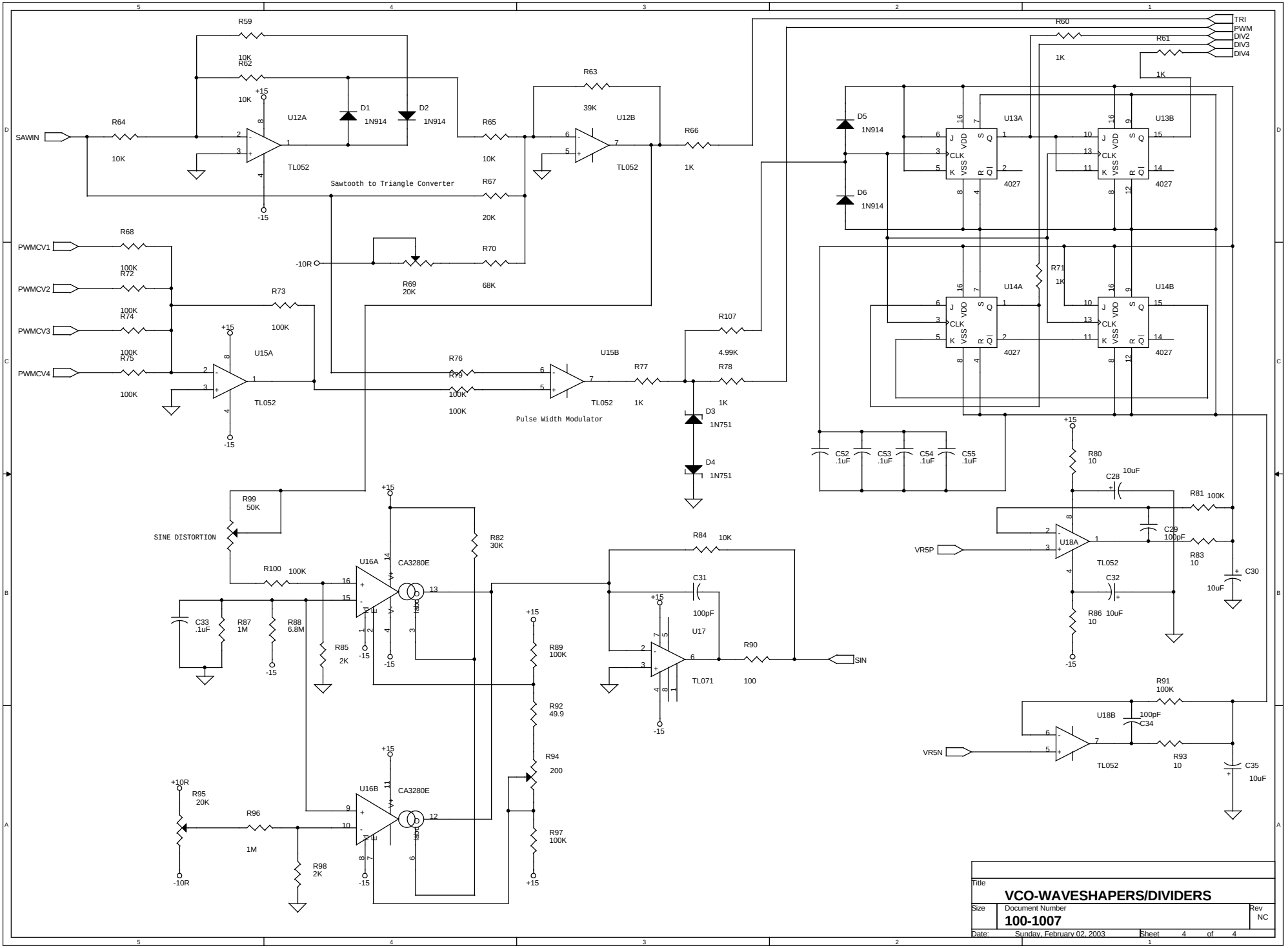
Title	**POWER SUPPLY/REFERENCES**	
Size	Document Number **100-1007**	Rev A
Date: Tuesday, January 14, 2003	Sheet 2 of 4	

REVISION HISTORY
10-18-2002 REMOVED BOGUS TEMP COMP CIRCUIT AND REPLACED WITH ONE THAT WORKS

2-1-2003 Changed temp sensor on advice from Scott Bernardi. Added reference transistor to remove effects from Is. This seems to have cured the mysterious 400ppM drift I still had.



Title	**Simple Temp Compensated VCO**	
Size	Document Number **100-1007**	Rev A
Date: Sunday, April 27, 2003	Sheet 3 of 4	


SAWIN
R64
10K
R59
10K
R62
10K
+15
U12A
TL052
D1
1N914
D2
1N914
-15
Sawtooth to Triangle Converter
R65
10K
R63
39K
U12B
TL052
R66
1K
R67
20K
-10R
R69
20K
R70
68K
PWMCV1
PWMCV2
PWMCV3
PWMCV4
R68
100K
R72
100K
R74
100K
R75
100K
R73
100K
U15A
TL052
R76
100K
R79
100K
U15B
TL052
R77
1K
R107
4.99K
R78
1K
D3
1N751
D4
1N751
Pulse Width Modulator
TRI
PWM
DIV2
DIV3
DIV4
R60
1K
R61
1K
D5
1N914
D6
1N914
U13A
U13B
4027
R71
1K
U14A
U14B
4027
C52
.1uF
C53
.1uF
C54
.1uF
C55
.1uF
R80
10
C28
10uF
R81
100K
U18A
TL052
C29
100pF
R83
10
C30
10uF
C32
R86
10
10uF
VR5P
R99
50K
SINE DISTORTION
R100
100K
U16A
CA3280E
R82
30K
C33
.1uF
R87
1M
R88
6.8M
R85
2K
R84
10K
C31
100pF
U17
TL071
R90
100
SIN
R89
100K
R92
49.9
R94
200
R97
100K
+10R
R95
20K
R96
1M
R98
2K
U16B
CA3280E
-10R
R91
100K
U18B
100pF
C34
VR5N
R93
10
C35
10uF
Title
VCO-WAVESHAPERS/DIVIDERS
Size
Document Number
100-1007
Rev
NC
Date:
Sunday, February 02, 2003
Sheet
4
of
4

TEMPERATURE COMPENSATED VCO Revised: Saturday, March 01, 2003
100-1007 Revision: NC

Bill Of Materials April 27,2003 12:53:25 Page1

Item	Quantity	Reference	Part	PART NO
1	34	C1,C2,C3,C4,C5,C6,C7,C8, C9,C10,C13,C14,C15,C19, C20,C21,C22,C23,C36,C37, C38,C39,C42,C43,C44,C45, C46,C49,C50,C51,C52,C53, C54,C55	.1uF	80-C410C104M5U
2	6	C11,C12,C28,C30,C32,C35	10uF	140-XRL35V10
3	1	C16	.0022uF	23PS310
4	1	C17	18pF	140-50N2-180J
5	2	C18,C26	.01uF	140-PF2A103J
6	1	C24	.001uF	140-PF2A102J
7	4	C25,C29,C31,C34	100pF	140-50P2-101K
8	1	C33	.1uF	140-PF2A104J
9	1	C56	100pF	
10	4	D1,D2,D5,D6	1N914	625-1N914
11	2	D4,D3	1N751	610-1N752A
12	1	JP1	HEADER 8X2	571-1033113
13	1	JP2	HEADER 13X2	571-1033116
14	1	JP3	HEADER 4	
15	2	Q1,Q2	2N3904	512-2N3904
16	4	Q3,Q4,Q7,Q8	2N3906	512-2N3906
17	1	Q5	J111	J111
18	1	Q6	CA3046	
19	13	R1,R20,R29,R45,R47,R53, R54,R60,R61,R66,R71,R77, R78	1K	271-1K
20	27	R2,R5,R8,R11,R19,R23,R26, R34,R35,R36,R40,R41,R42, R68,R72,R73,R74,R75,R76, R79,R81,R89,R91,R97,R100, R104,R105	100K	271-100K
21	3	R3,R48,R107	4.99K	271-4.99K
22	2	R67,R4	20K	271-20K
23	2	R6,R14	10K	594-43P103
24	2	R13,R7	15K	271-15K
25	18	R9,R10,R12,R15,R16,R17, R18,R25,R31,R33,R38,R59, R62,R64,R65,R84,R101, R102	10K	271-10K
26	5	R21,R39,R49,R69,R95	20K	594-43P203
27	6	R22,R27,R80,R83,R86,R93	10	271-10
28	2	R82,R24	30K	271-30K
29	1	R28	24.9K	271-24.9K
30	2	R90,R30	100	271-100
31	1	R32	3.3K	271-3.3K
32	6	R37,R46,R87,R96,R103, R106	1M	271-1M
33	1	R43	4.99M	4.99M
34	1	R44	49.9K	271-49.9K
35	1	R50	10M	
36	1	R52	1K	594-43P102
37	1	R56	9.09K	271-9.09K
38	1	R57	4.02K	271-4.02K
39	1	R58	11.3K	271-11.3K
40	1	R63	39K	271-39K
41	1	R70	68K	271-68K
42	2	R98,R85	2K	271-2K
43	1	R88	6.8M	
44	1	R92	49.9	271-49.9

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74: 45  1   R94 200 594-43P201
75: 46  1   R99 50K 594-43P503
76: 47  5   U1,U2,U3,U4,U8  TL052   595-TL052CP
77: 48  1   U5  LM4041CZ-ADJ    511-LM336Z
78: 49  1   U6  TL071   511-TL071
79: 50  1   U7  LM311   511-LM311
80: 51  1   U9  lm13700 LM13700N
81: 52  1   U10 TL052
82: 53  1   U11 LM358A  511-LM358AN
83: 54  3   U12,U15,U18 TL052   595-TL052CN
84: 55  2   U13,U14 4027    511-4027
85: 56  1   U16 CA3280E
86: 57  1   U17 TL071   511-TL071CN
87:
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100-1007-06 REV NC FAB DRAWING
100-1007-05 REV NC COMPONENT SIDE LEGNED

100-1007-02 REV NC COMPONENT SIDE
100-1007-01 REV NC CIRCUIT SIDE