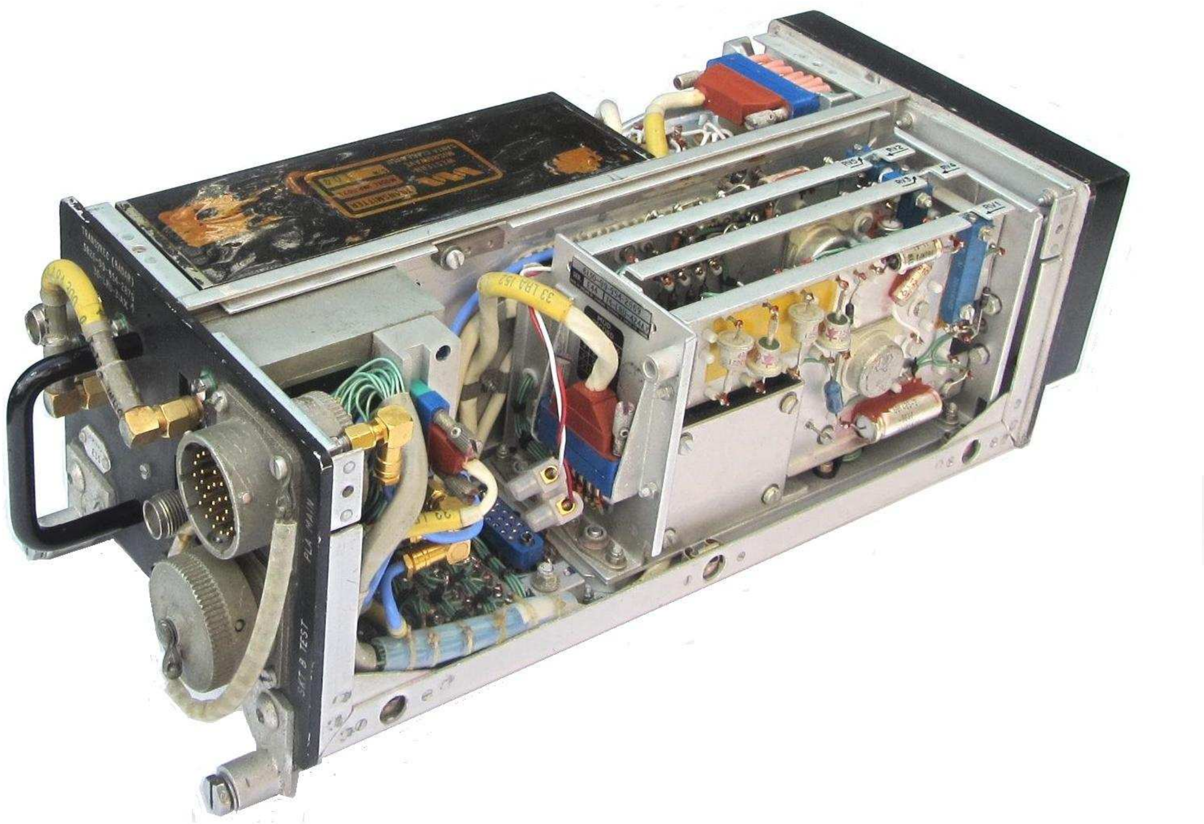
Radar Altimeter



TRANS / REC (RADAR)

5826 - 99 - 954 - 2879

APN-117 ?

Made by STC (UK) in 1966

Reverse engineered 1 july 2014

What is it

This radar transmitter/receiver is a distance meter or altimeter, based on the FM-CW principle. I don't have an instrument to measure the frequency and power, but I guess it is in the 4.2-4.4 GHz range. The transmitter is a temperature controlled box, with a microwave transistor as power oscillator, tuned with a varactor, followed by a tripler. The oscillator supply is -30Vdc at 250mA., so the RF output might be approx. 200mW
The transmitter is frequency-modulated with a 300Hz triangle in one of 3 modes:

1. Maximum amplitude is selected for low altitude,
2 Controlled amplitude at higher altitude (above 200 feet ?)
3. Dithering superimposes a 37.5Hz sinewave-like signal on the 300Hz triangle

The receiver has a mixer with a part of the transmitter signal as LO. The "IF" amplifier has a bandwidth of 1 .... 100 kHz. The output of the unit is a DC voltage, proportional to the range.
The unit is built in 1965 by STC in the United Kingdom.

Technology of 1965

Typical is the use of the *very first* integrated circuits in original flatpak :
-- first opamps from Texas Instruments (SN523A en SN524A)
-- first opamps from Fairchild (uA702 in flatpak)
-- first digital IC's from Texas Instruments (SN511 B)
-- first digital IC's from Motorola (MC253G)
-- 1.4GHz oscillator with transistor and diode tripler.
Strange: - The power supply has a missing diode in each diodebridge

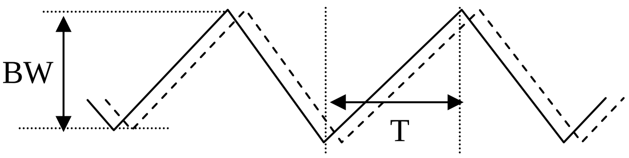
Modules

Radar R/T	5826 - 99 - 954 - 2879
Transmitter	IMP-5024 Western Microwave Inc.
Receiver	IMP-5023 Western Microwave Inc.
Chassis	5826 - 99 - 954 - 2870
Electronics	5826 - 99 - 954 - 2875
amplifier	5826 - 99 - 954 - 2884
sweep & control	5826 - 99 - 954 - 2871
deglitcher	5826 - 99 - 954 -
Relay module	5826 - 99 - 954 - 2877
Power Supply	6130 - 99 - 854 - 2869

Also from STC in pressurized case:
30-LRU-20J-1 TRANS/REC

Theory

Radar altimeters with the CW-FM principle have a small transmitter which transmits a continuous , frequency modulated wave. The modulation is a symmetrical triangular wave with a peak-to-peak deviation (BW) of approx. 150MHz, and a frequency of 300Hz (T=1.667 ms)
The receiver receives the ground echo with a second antenna. The echo has the transmitted frequency of a few microseconds ago, and is mixed with the actual transmitted signal.
The frequency difference is proportional with the altitude.



BW = peak-to-peak frequency deviation (100 MHz)
T = min to max frequency deviation time, (1.667 ms)
dF = frequency difference between received and transmitted signal;
c = speed of light (3.10 ^ 8 m/s = 983 feet / µs)

gives 2 x altitude = c x dF x T / BW

Twice the height of the antenna's above the ground plus the length of the cables to the antenna's should be subtracted from this value. Say this is Ho [feet], and with dF in kHz and BW in MHz, this formula reduces to

Altitude [feet] = 820 x dF/ BW - Ho

This set has a fixed triangle amplitude (=BW) up to dF=32kHz from the receiver, then the bandwidth is gradually reduced down to a factor 5 at dF=63kHz. The relation of the output voltage to altitude becomes non-linear. The beat frequency amplifier has a bandwidth of 3-100 kHz.
When I assume Ho= 60 feet (20 meters) and the initial BW is 100 MHz, then

- The lowest frequency is 7.3 kHz at 0 feet
- The altitude at 32 kHz is 202 feet
- The altitude at 63 kHz and BW=100/5 is 2520 feet

The "valid" relay output is active from dF= 5 to 70 kHz. with 5mV input to the amplifier, or from 8 to 100 kHz with 2 mV input.
Radar altimeters operate in the 4200 - 4400 MHz "C" band.

Doppler shift
If the altitude increases, the echo frequency rises both in the up, and downward part of the triangle, so the difference frequency is smaller in the upward part, and higher in the downward part of the triangle. If the modulating wave is symmetrical, and perfectly linear, these effects average out, and true altitude is measured, independent of doppler shift when the altitude changes.
When the altitude changes with 10m/sec, the doppler shift is 10m/s x 4.2GHz/c= 140 Hz

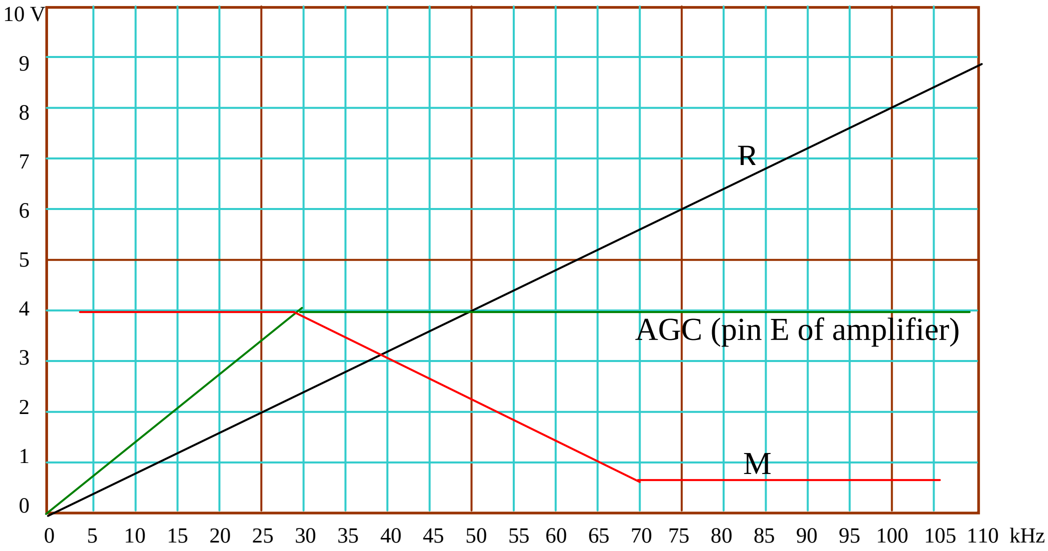
Typical altimeters

Radar altimeters exist with maximum altitude 2,500 or 5,000 ft, The circular display is linear up to 500 feet and logarithmic from 500 - 2,500 (or 5,000) feet, making the lower range of heights easier to read.

All radio altimeter displays have a setting control for a decision height, at which point a warning will be given. The height can be set by positioning an outside cursor against the required height on the scale. The setting control will normally double as a PTT (press-to-test) facility which, when engaged, drives the display to a predetermined value - normally 100 feet.

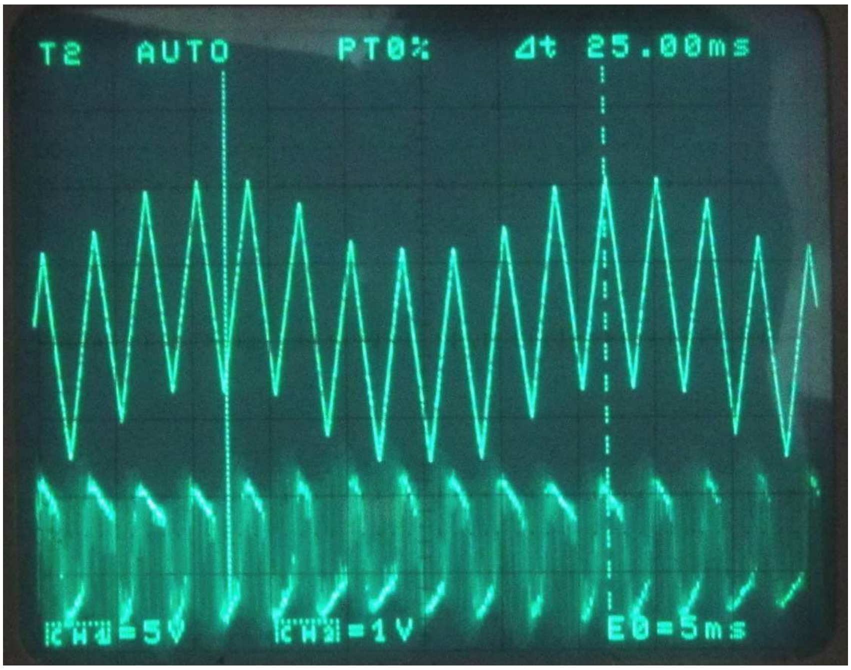
Measuring results

The beat frequency amplifier has a relatively flat gain from 5 to 100 kHz. With open P and E inputs, a square wave of 3mVpp on the SMA connector is sufficient for a stable, symmetrical square wave to the deglitcher.



The output at pin R of the main connector is proportional with the beat frequency at 80 mV/kHz *without load* . With a 270 deg, 1mA meter with 5k total resistance, full scale is at
The "zero" position of the pointer is masked. The pointer appears at 0 feet when dF=7 kHz
Up to 32 kHz, the bandwidth is 100 MHz, and the altitude is proportional with the beatfrequency. Above 32 kHz, the BW is reduced (pin M of main connector) , and the altitude scale becomes non linear. The Valid relays K3-4-5 are on from 5 to 75 kHz. with only 2mV signal (5mV below 10kHz) to SMA connector

Below 32 kHz, a 37.5Hz sinewave is superimposed on the frequency modulating 300Hz triangle to give some dithering. The occupied bandwidth is 150MHz (100MHz without dithering)



Testpoints

The Radar Transmitter/Receiver has a 32 pin main plug and a 26-pin testplug.

The 26 pin test connector has the following signals.
Pins A,B,C,D, G , N and R are supply voltages

A	+ 70V	pwr supply varactor diode
B	+ 12V	pwr supply opamps
C	- 12V	pwr supply opamps
D	- 30V	pwr supply transmitter (gunn diode?)
E	**gnd**	
F	+ 21V	AGC signal ?
G	-0.4 V	adj offset output
H	-	selftest module
J	-	selftest module
K		df/dt slope
L	+ 3.5V	Valid relay K3-4-5 coil --> +3V=VALID
M	Pwr ON	when connected to 115Vac LO
N	+ 32V	pwr supply totempoles
P	+ 3.9V	varactor drive signal (a 300Hz triangle)
R	+ 25V	pwr supply for relays
S	115V ac LO	
T	115V ac HI	
U	115Vac	on transformer
V	*no pin*	
W	0..10V	main output
X	*no pin*	
Y	disable dithering	
Z	to main connector pin S	
a	*no pin*	
b	28Vac from transformer	
c	to main connector pin F	

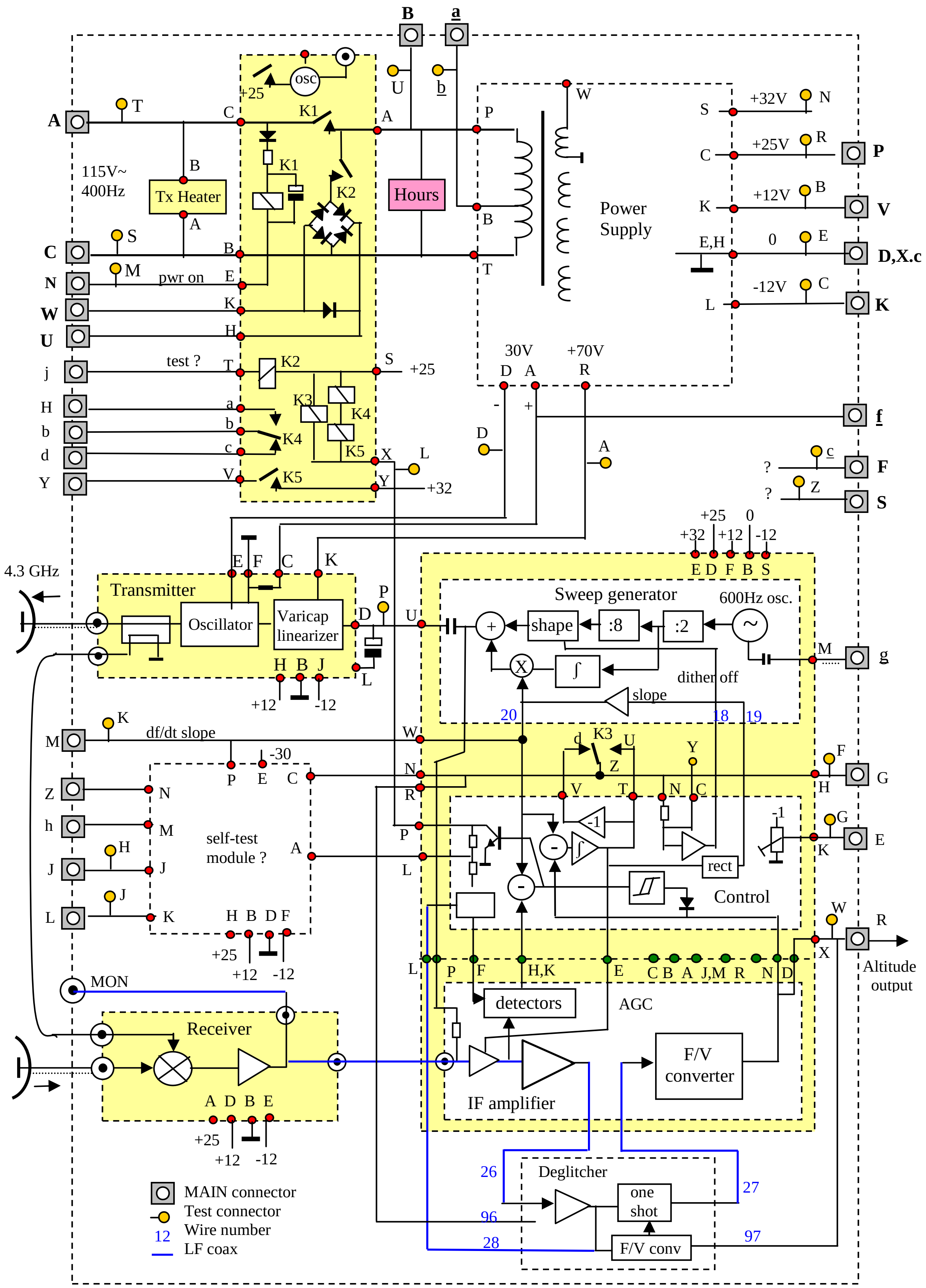
Frequency measurement 24 aug 2014

It was not possible to measure the altimeter frequency directly, I have no equipment at 4 GHz. However, I could use my Tek2712 spectrum analyser with 10cm whip, coupled to altimeter transmitter output, terminated with 50 ohm and also short whip, which revealed a signal at 1610 MHz, swept over a 24 MHz bandwidth. This is with open tx module.

The real frequency of the altimeter is :
- The altimeter tx has an oscillator at 1610 MHz, followed by a tripler

With a closed module : 1433 MHz x 3 = 4.3 GHz center freq . Swept from 4200 - 4400 MHz.

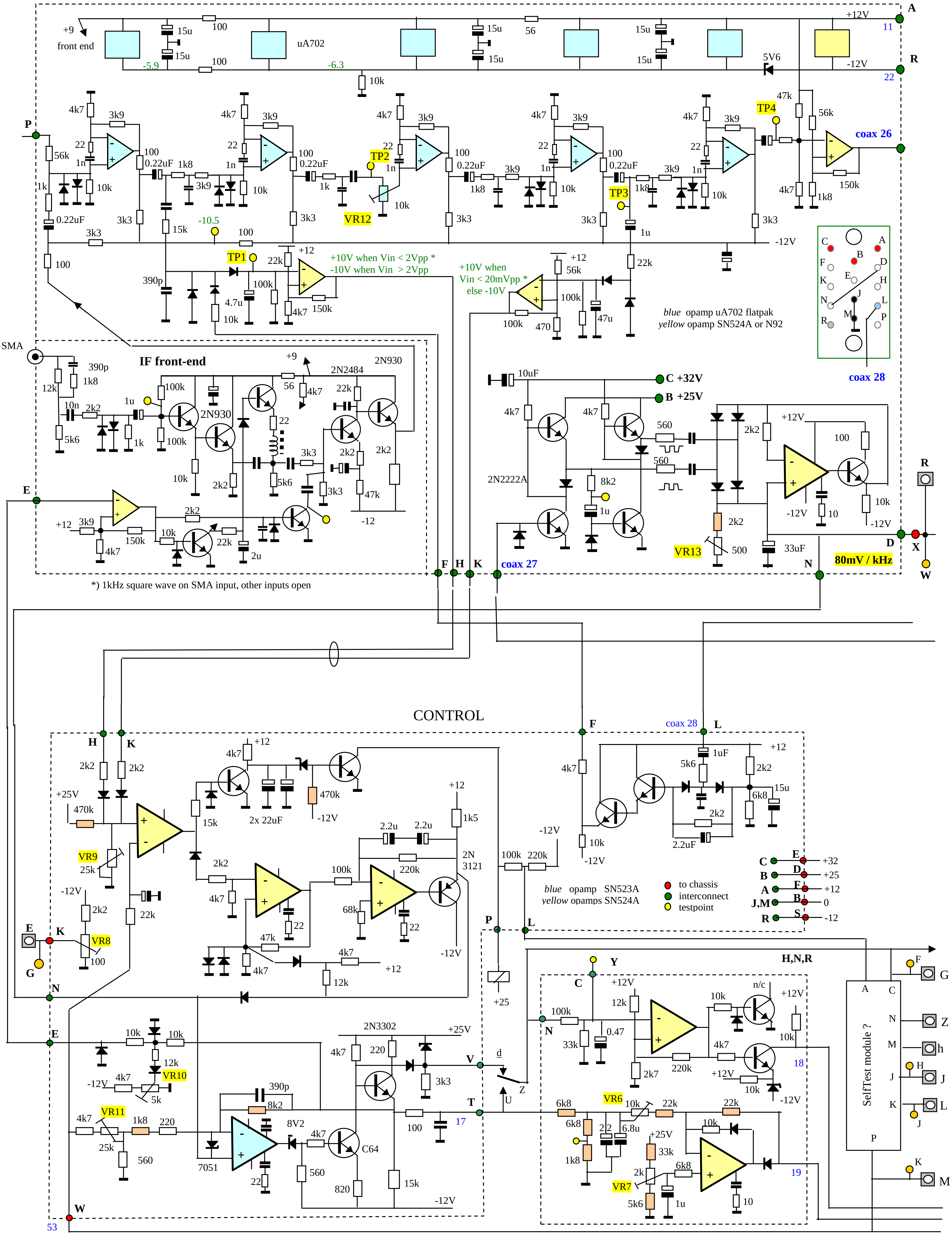
Internal wiring

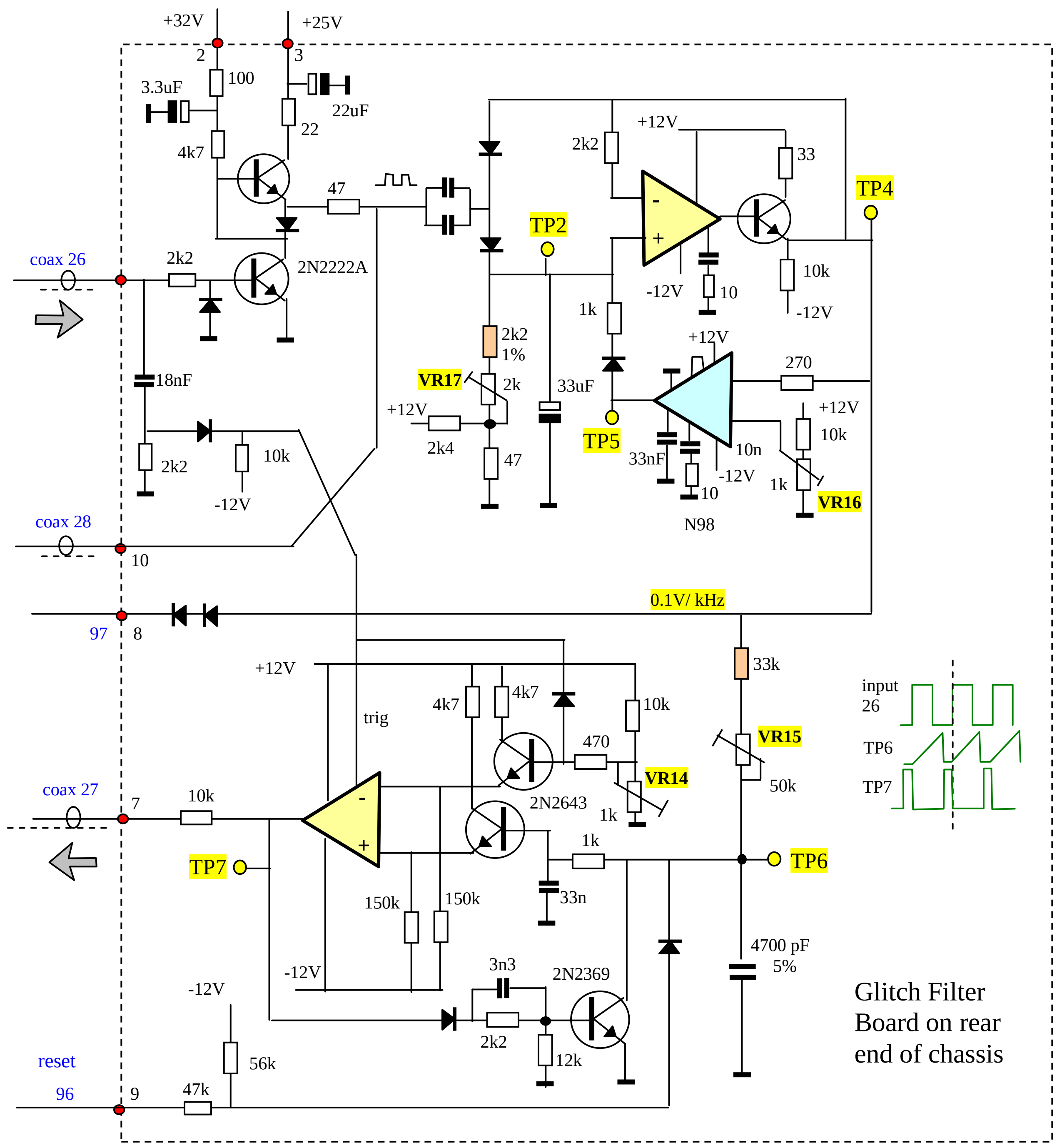


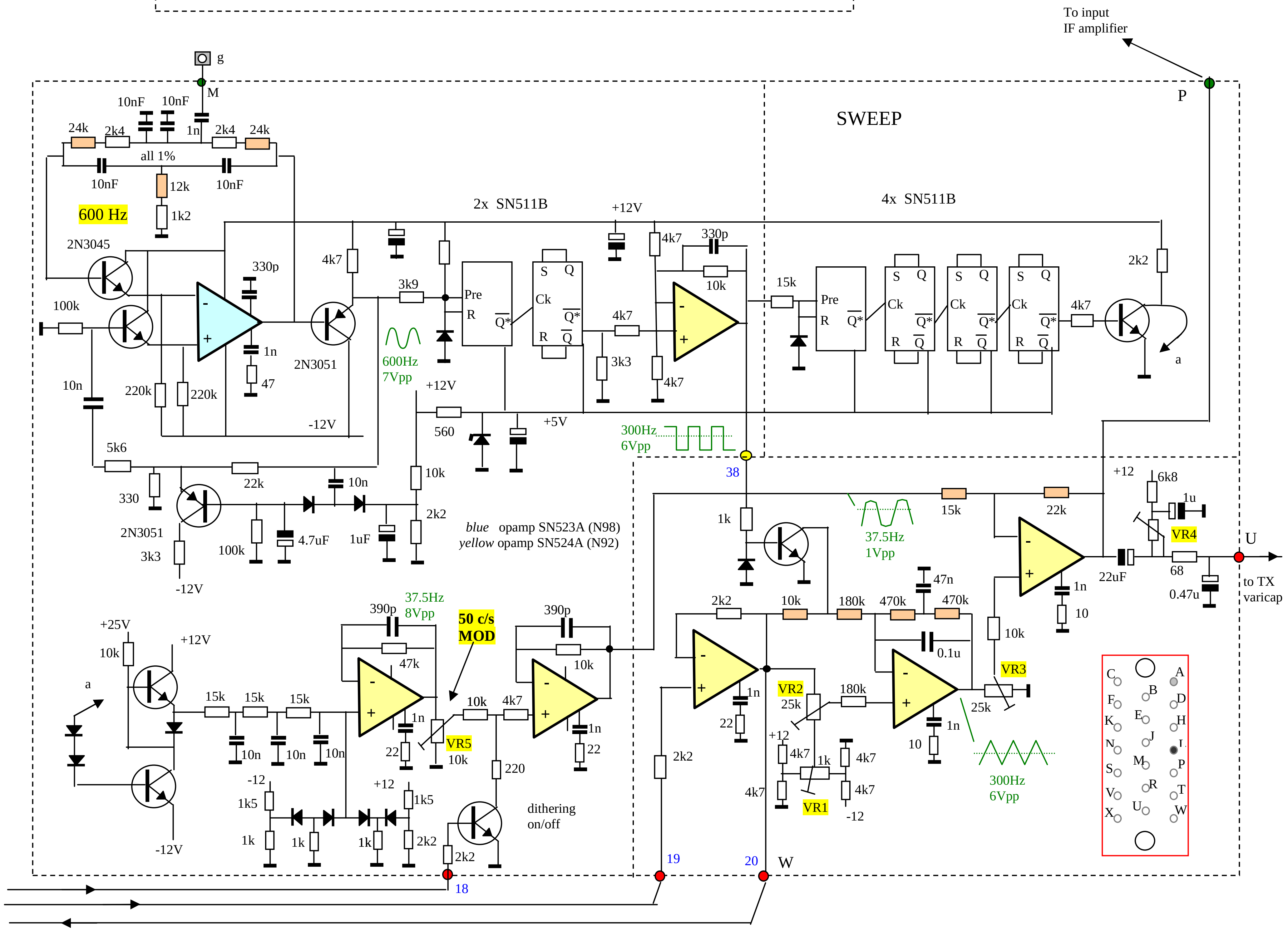
RADAR ALTIMETER

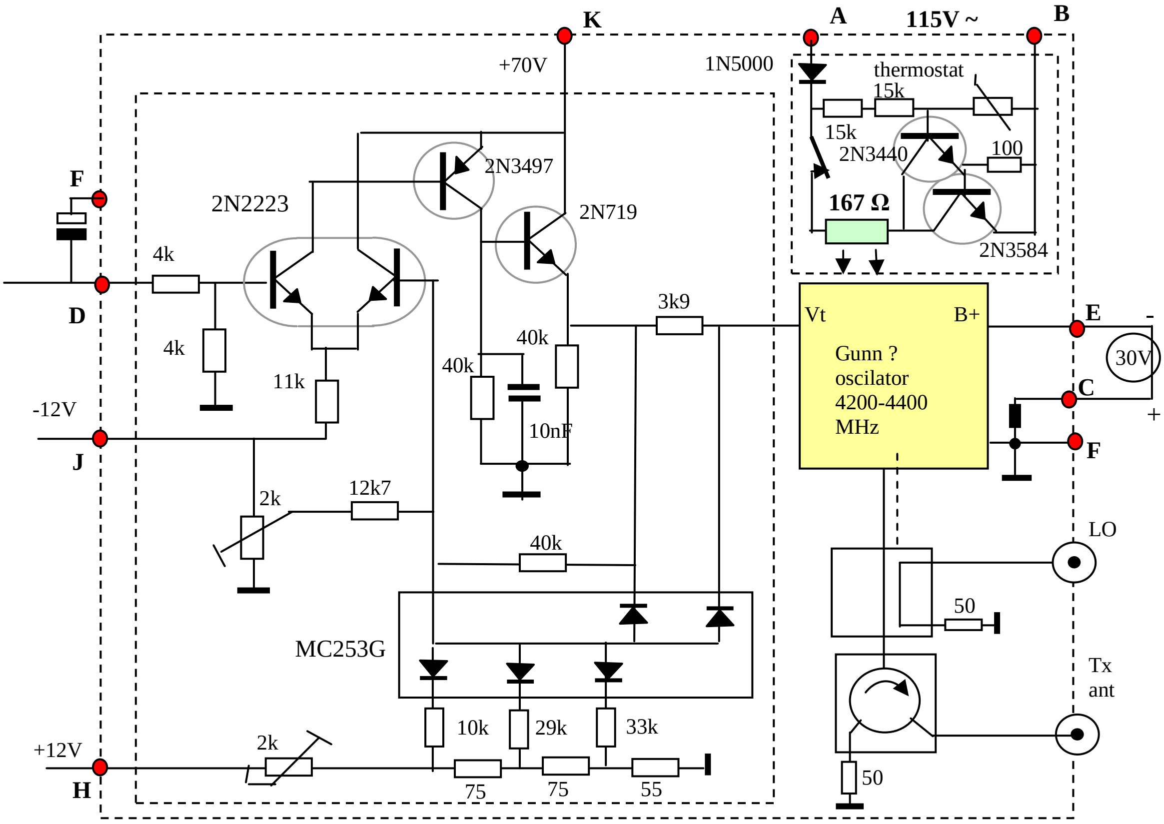
25 june 2014 kb

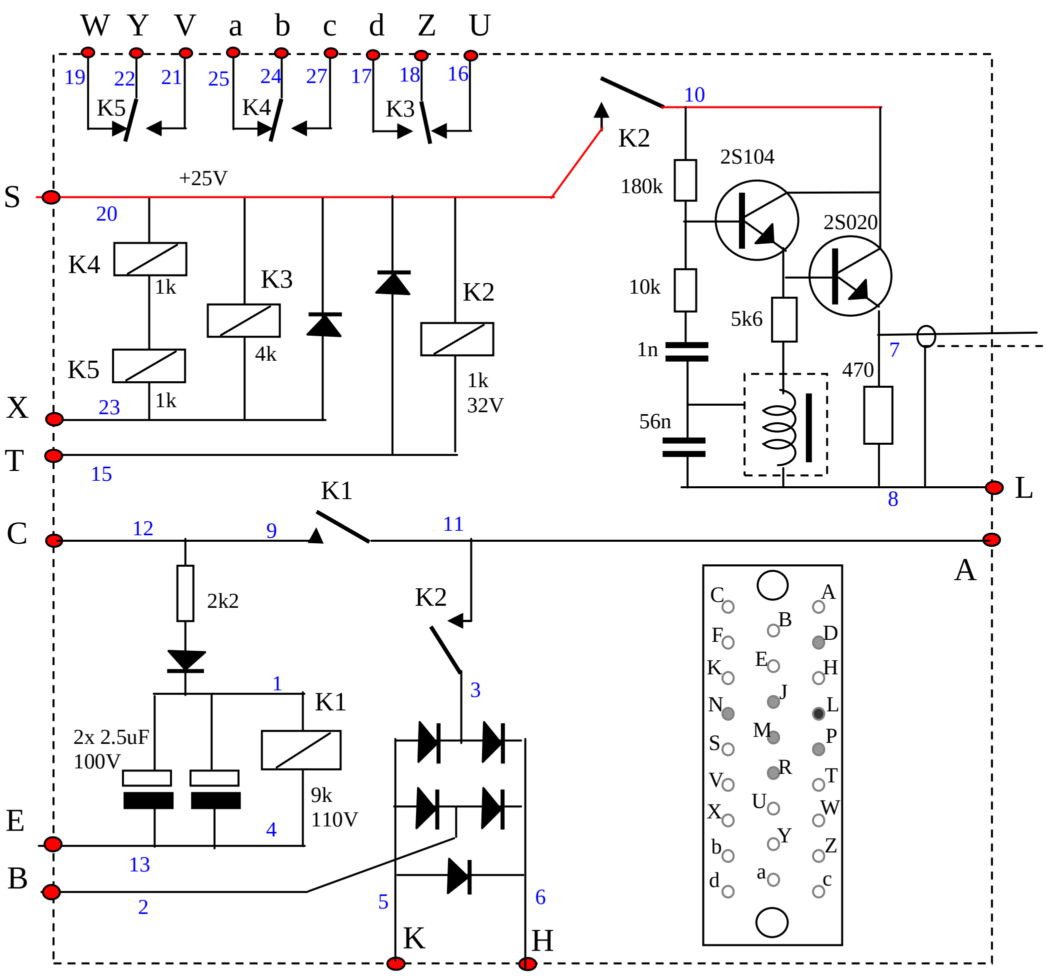
IF AMPLIFIER




+32V
+25V
3.3uF
100
22uF
22
4k7
47
2N2222A
2k2
coax 26
18nF
2k2
10k
-12V
coax 28
10
97
8
TP2
TP4
TP5
VR17
2k2 1%
2k
+12V
2k4
47
33uF
1k
+12V
-12V
33
10k
-12V
270
33nF
10n
10
N98
1k
VR16
0.1V/ kHz
33k
VR15
50k
+12V
trig
4k7
4k7
10k
470
VR14
2N2643
1k
coax 27
7
10k
TP7
TP6
150k
150k
33n
-12V
3n3
2N2369
4700 pF 5%
-12V
56k
2k2
12k
reset
96
9
47k
input 26
TP6
TP7
Glitch Filter
Board on rear
end of chassis

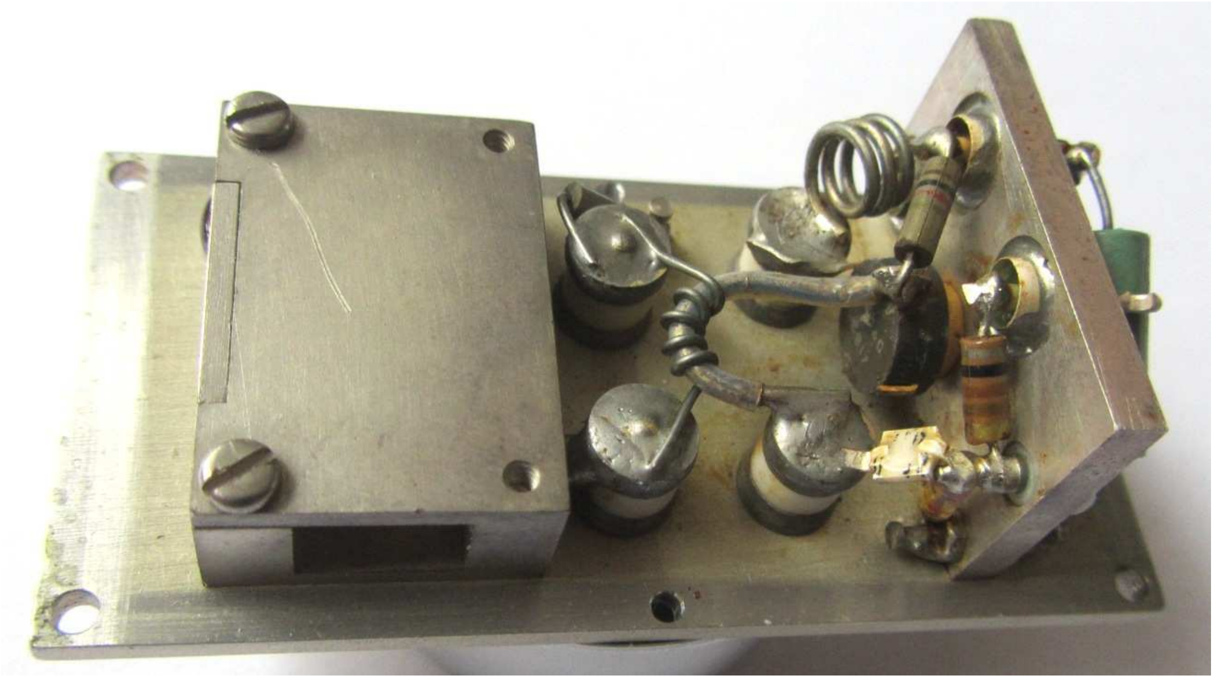

g
M
10nF
10nF
24k
2k4
1n
2k4
24k
all 1%
10nF
12k
10nF
600 Hz
1k2
2N3045
100k
330p
4k7
3k9
1n
47
2N3051
600Hz 7Vpp
10n
220k
220k
-12V
2x SN511B
+12V
Pre
R
Q*
S Q
Ck
Q*
R Q
4k7
330p
10k
4k7
3k3
4k7
+12V
560
+5V
300Hz 6Vpp
5k6
22k
10n
10k
330
2N3051
3k3
100k
4.7uF
1uF
2k2
-12V
blue opamp SN523A (N98)
yellow opamp SN524A (N92)
SWEEP
4x SN511B
15k
2k2
a
To input IF amplifier
P
38
1k
37.5Hz 1Vpp
15k
22k
+12
6k8
1u
VR4
U
22uF
68
0.47u
to TX varicap
1n
10
10k
47n
2k2
10k
180k
470k
470k
0.1u
VR3
25k
VR2 25k
180k
22
10
1n
+12
4k7
1k
4k7
4k7
4k7
VR1
-12
300Hz 6Vpp
2k2
19
20
W
+25V
+12V
10k
a
15k
15k
15k
10n
10n
10n
390p
37.5Hz 8Vpp
47k
50 c/s MOD
390p
10k
10k
4k7
1n
22
VR5 10k
1n
22
220
-12
+12
1k5
1k5
1k
1k
1k
2k2
2k2
dithering on/off
-12V
18
C B A D F E H K J N I M P S R T V U W X


K
A
115V ~
B
+70V
1N5000
thermostat
15k
15k
2N3497
2N3440
100
167 Ω
2N2223
2N719
2N3584
F
4k
D
4k
11k
40k
40k
10nF
3k9
Vt
B+
Gunn ?
oscilator
4200-4400
MHz
E
30V
C
F
-12V
J
2k
12k7
40k
LO
50
MC253G
Tx
ant
10k
29k
33k
+12V
2k
H
75
75
55
50

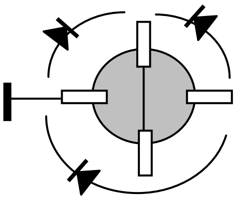

W Y V a b c d Z U
19
22
21
25
24
27
17
18
16
K5
K4
K3
10
K2
S
+25V
20
2S104
180k
K4
1k
K3
K2
2S020
10k
5k6
1n
4k
K5
1k
32V
7
470
X
23
1k
56n
T
15
8
L
K1
C
12
9
11
A
2k2
K2
1
K1
3
2x 2.5uF
100V
9k
110V
E
4
13
B
2
5
6
K
H
C
A
B
F
D
E
K
H
J
N
L
S
M
P
R
T
V
U
W
X
Y
b
Z
a
c
d

Inside the transmitter box

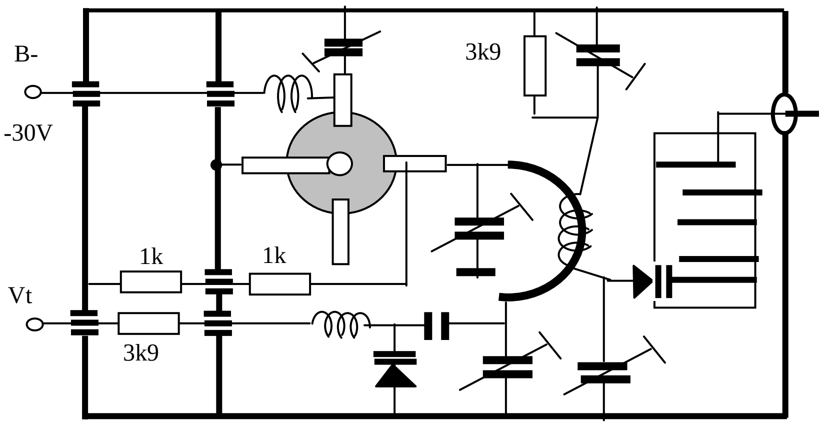
situated inside a thermostaat.

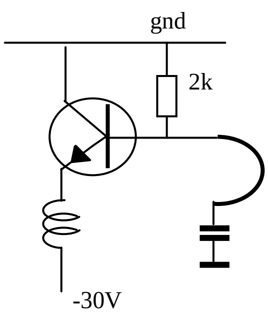


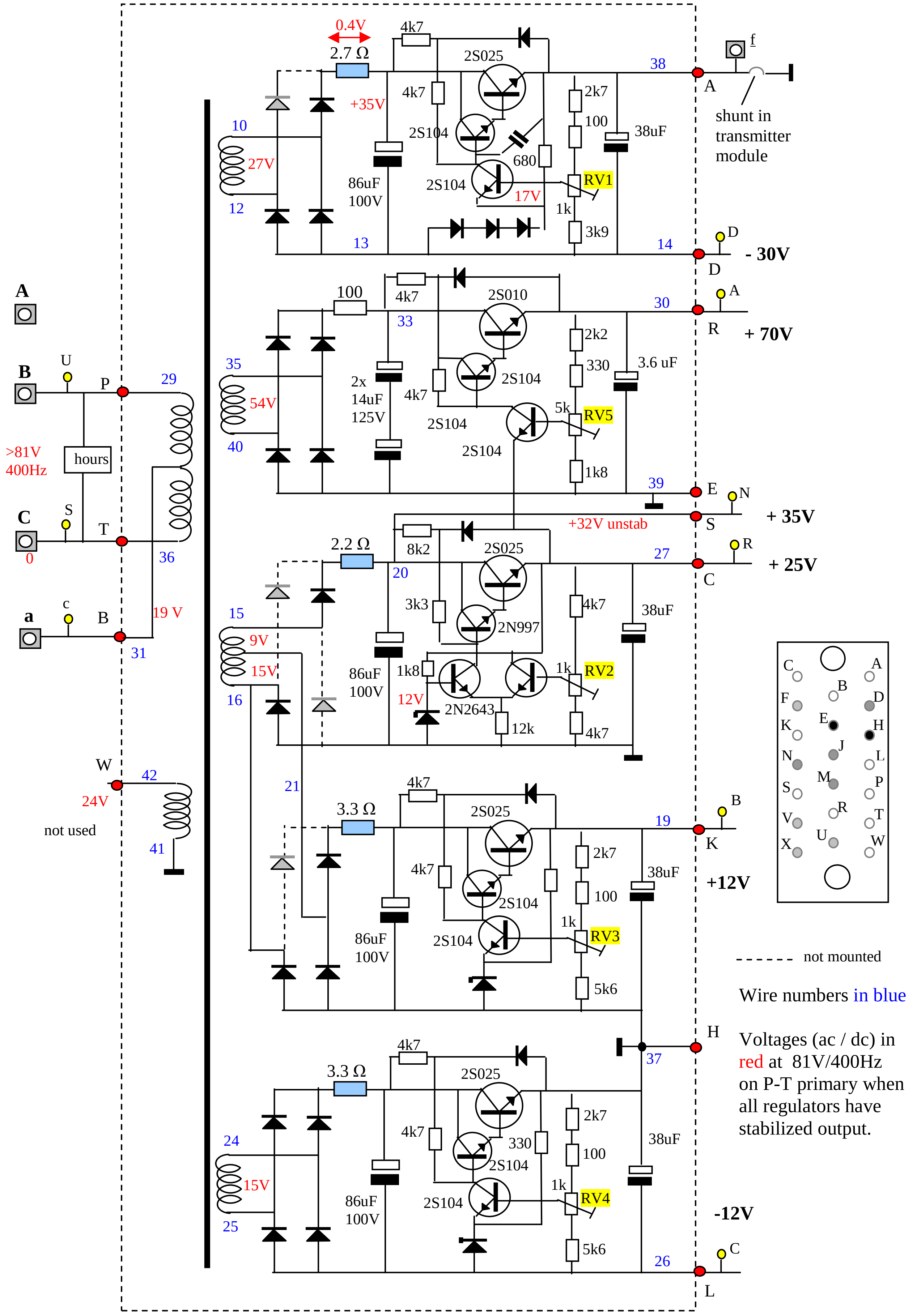
The active element is a bipolar transistor. The type number is nearly unreadable, ending on ..617.



What is the emitter, base, or collector ?






0.4V
2.7 Ω
4k7
2S025
+35V
2S104
680
17V
RV1
1k
3k9
2k7
100
38uF
86uF
100V
27V
10
12
13
14
38
A
f
shunt in
transmitter
module
D
- 30V
100
33
2S010
2x
14uF
125V
54V
35
40
2k2
330
3.6 uF
5k
RV5
1k8
39
30
R
+ 70V
E
N
S
+ 35V
+32V unstab
8k2
2.2 Ω
20
3k3
2N997
1k8
12V
2N2643
12k
4k7
RV2
9V
15V
15
16
27
C
+ 25V
3.3 Ω
21
RV3
5k6
19
K
B
+12V
H
37
24
25
26
L
RV4
-12V
A
B
U
P
29
>81V
400Hz
hours
C
S
T
0
36
a
c
B
19 V
31
W
42
24V
not used
41
not mounted
Wire numbers in blue
Voltages (ac / dc) in
red at 81V/400Hz
on P-T primary when
all regulators have
stabilized output.