MAN/DOLPHIN COMMUNICATION

Final Report

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APPENDIX A

Technical Manual MDT-5

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by

Stephen L. Moshier

LISTENING, INCORPORATED
6 Garden Street
Arlington, Massachusetts

The Listening, Inc. Man-to-Porpoise Translator MDT-5 is an instrument designed to facilitate communication between man and dolphin. A word spoken into the microphone of the MDT is translated into a frequency-modulated whistle which is coupled into the dolphin's aquatic environment via a hydrophone. The modulated whistles thus produced are potentially comprehensible to a dolphin, inasmuch as dolphins use similar whistles as a mode of communication among themselves.

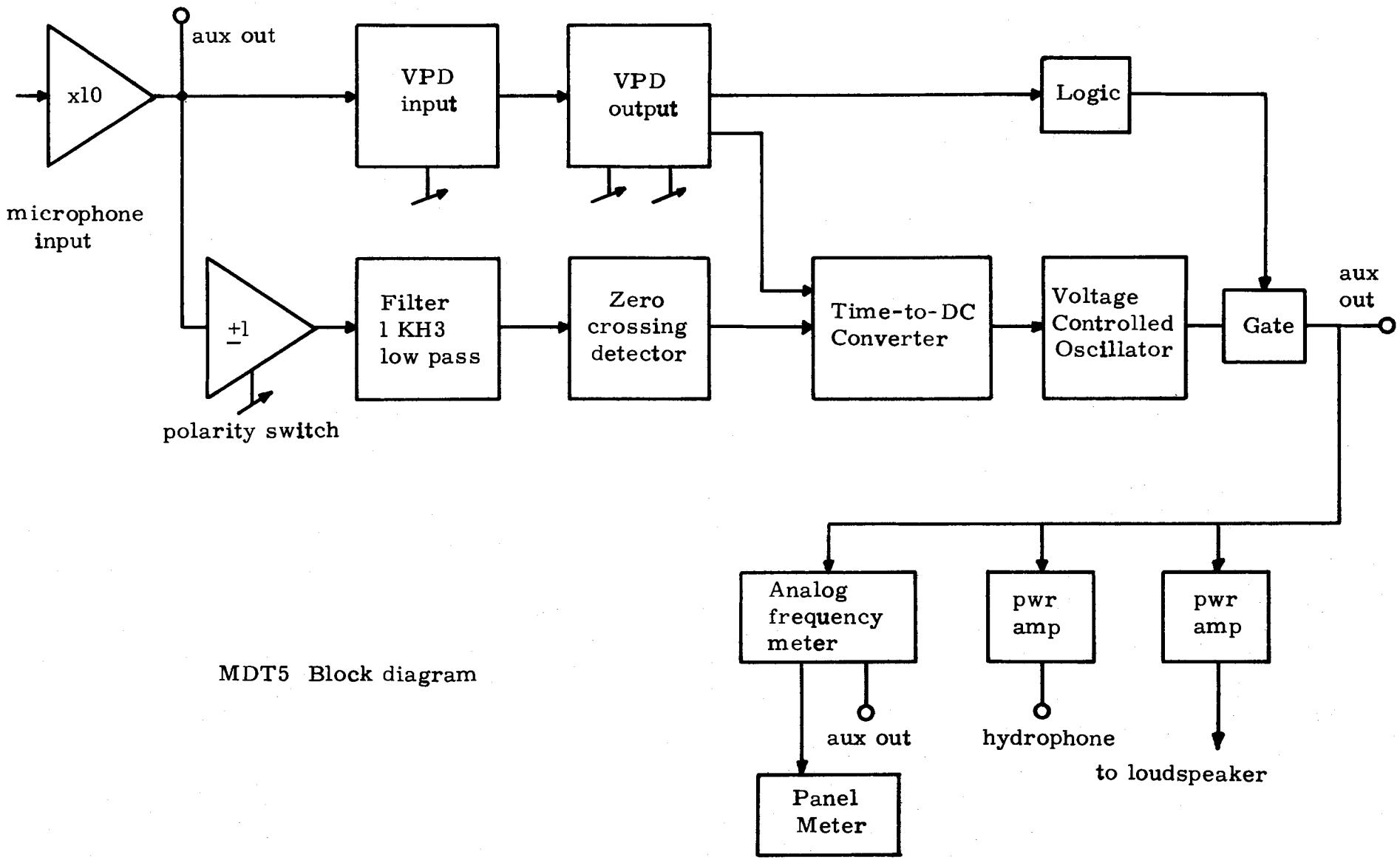
A block diagram of the equipment appears in Figure 1. In speaking a voiced sound, a person causes his vocal cords to generate a series of sharp acoustical pulses, with fast rise times and relatively long decay. Each pulse then undergoes a series of reflections in the mouth and throat cavities which provide information; the result is the series of decaying wave trains which make up a voiced speech signal. In analyzing the speech signal the first step used in the MDT-5 is to extract the time at which the vocal-chord pulse occurs in each wave train. This is done in the vocal pulse detector, which generates a series of positive or negative-going pulses that correspond to the detected vocal cord pulses.

In the voice-to-dc converter one particular time delay in the speech output is measured, corresponding approximately to the first formant, lying in a resonance band of roughly 500 to 800 Hz. It is produced by the portion of the vocal tract that extends from the back of the throat to the middle of the tongue. The rest of the speech signal is removed by a 1-kHz low-pass filter. The output is a dc voltage proportional to the measured interval.

The whistle generator is a voltage-controlled oscillator that transforms the dc level into a tone with a frequency that depends on the characteristic time interval measured by the voice-to-dc converter. The logic and whistle gate defines a minimum and maximum interval between successive vocal pulses for which the whistle output will be gated on. This ensures that a whistle will be produced only when there is a voice input. The gate is turned on as soon as the logic circuitry recognizes speech. The whistles are amplified and coupled into the dolphin's tank through a transmitting hydrophone. The whistle amplitude is approximately constant, but the pitch is modulated.

Six electronic regulator circuits are used in the line-operated power supply to isolate the pulse and analog modules from one another. A total of twelve circuit cards are employed in the translator, as follows: two power supply cards, PC 51; vocal pulse detector input PC 24; vocal pulse detector output PC 32; zero crossing detector PC 26; voice-to-dc converter PC 31; whistle gate-off logic PC 36; whistle gate-on logic PC 34; output amplifiers PC 39; analog frequency meter PC 38; voltage controlled oscillator PC 16; and signal gate PC 40. These circuit cards are described in detail in the schematic diagram section.

Various sounds spoken into the translator are transformed into whistles, such that a definite, repeatable pitch corresponds to each acceptable sound. The functional



MDT5 Block diagram

relationship for sounds commonly used in the dolphin language is given in the following table.

PHONEME	SYMBOL	WHISTLE FREQ.
Ah	A	7 kHz
a as in bait	E	10
i as in sit	i	11
r as in burr	R	11.5
oo as in boot	U	12
ee as in beet	I	14
i as in Spanish si	Y	15

POSITION OF CARDS IN MDT5:

from left (meter end) to right:

A: PC 51

B: PC 51

C: PC 24

D: PC 32

E: PC 26

F: PC 31

G: PC 34

H: PC 36

I: PC 39

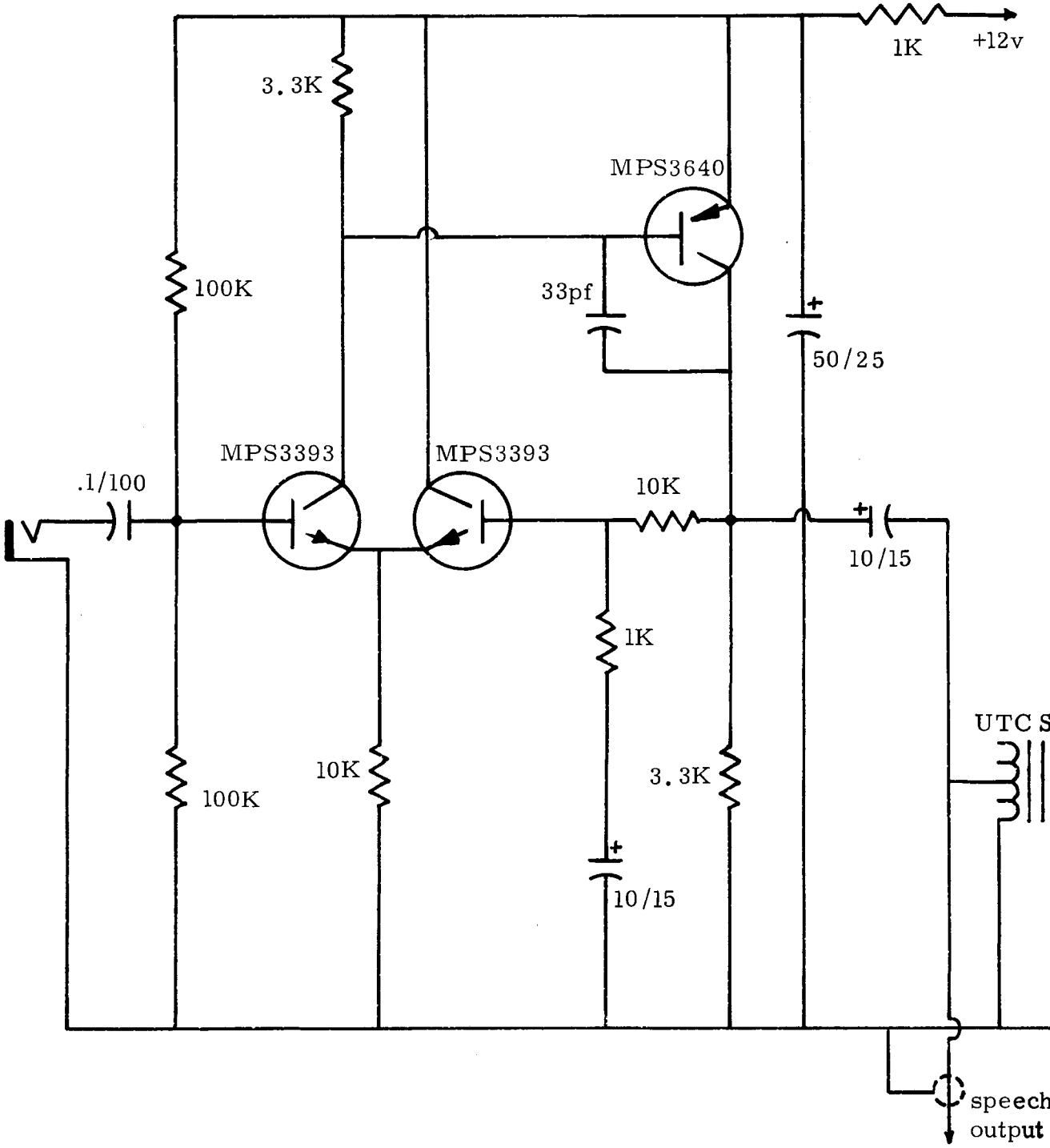
J: PC 38

K: PC 16

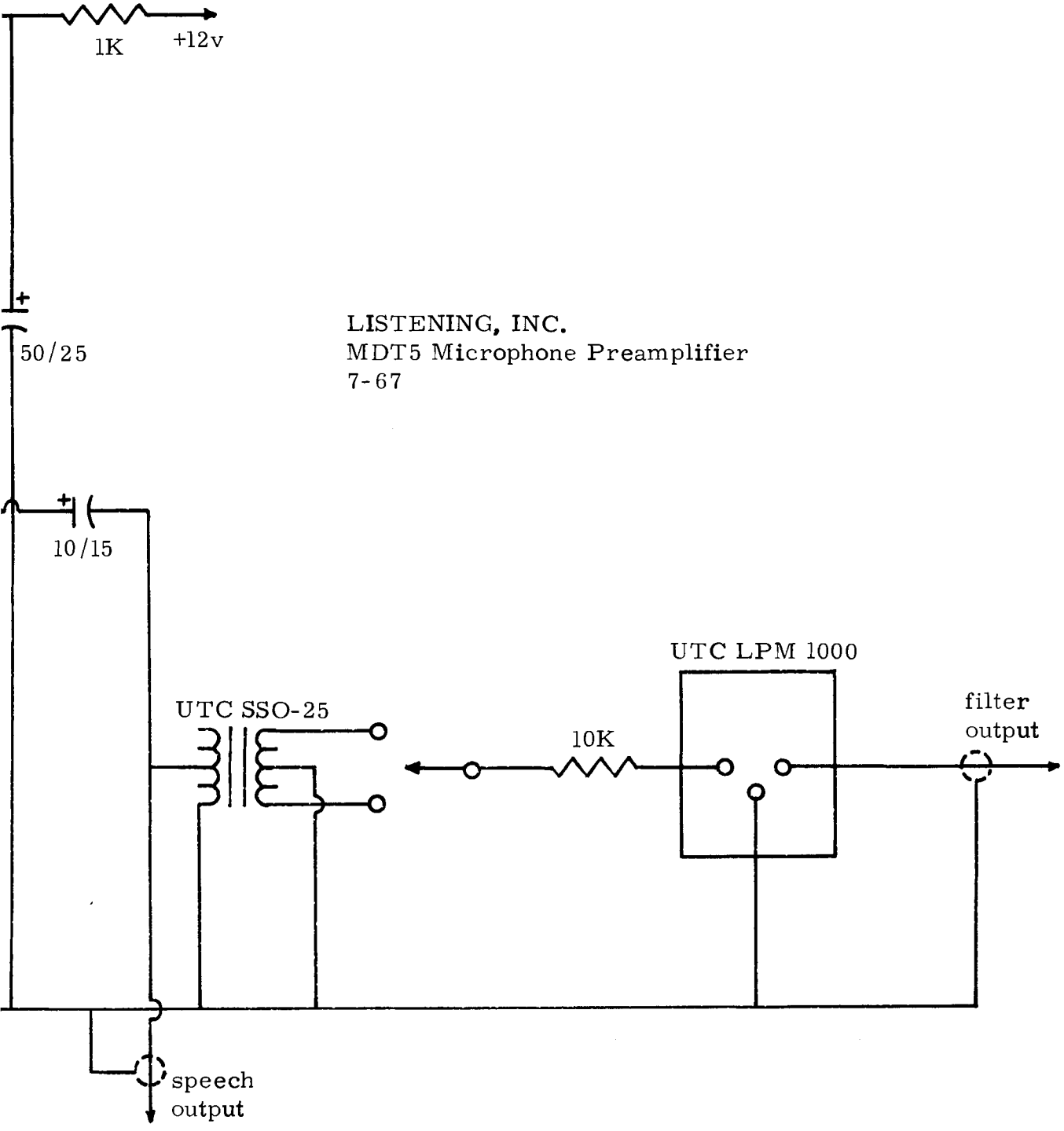
L: PC 40

Input Preamplifier

The housing for the input preamplifier is mounted immediately behind the front-panel microphone jack. It contains a preamplifier with a gain of 10 and input impedance of 50K ohms, in addition to a phase reversing transformer and 1000 Hz low pass filter. Unfiltered speech is fed to the vocal pulse detector, PC 24. The filtered speech goes to the zero-crossing detector and time-to-dc converter. A phase reversing switch for the filtered speech is located on the top of the preamplifier housing. Symptoms of improper phasing are rough whistle sound and whistle frequency varying over only a narrow range for widely different phonemes such as "ah" and "ee".


1K
+12v
3.3K
MPS3640
100K
33pf
50/25
MPS3393
MPS3393
.1/100
10K
10/15
1K
UTC S
10K
3.3K
100K
10/15
speech
output

LISTENING, INC.
MDT5 Microphone Preamplifier
7-67



PC 24: Vocal Pulse Detector-input

This module requires speech input at a level of 0.1 to 3 volts p-p. Together with PC 32, it identifies the vocal pulse epoch in voiced speech signals. Input impedance is 1 megohm.

The first operation performed on the speech input is an automatic gain control circuit. The potentiometer is set for an average p-p output of about 0.8 volts, such that the phoneme "ah" has a single prominent excursion beyond the average envelope at the output. AGC attack time constant is 80 usec, and decay time constant is 15 msec.

The signal is next R-C differentiated with a time constant of 0.1 msec and amplified by a factor of 25. After this operation the signal has a relatively large spike, whose height depends on the phoneme, followed by lesser peaks. The signal is now full-wave peak rectified using a transformer driving a pair of unbiased emitter followers. The rectification decay time constant is 7 msec. Full-wave rectification makes it possible to detect vocal pulses regardless of input polarity. The output of the rectifier is a pulse train with long, occasionally irregular trailing edges. In order to remove the irregularities the signal is again differentiated with a time constant of 0.1 msec, amplified by a factor of 5, and half-wave rectified. The output, appearing at pin 14, is a long-decay pulse train with smooth decay; the leading edge accurately identifies the vocal pulse epoch, which is the onset of a reverberant wave train.

PC 32: Vocal Pulse Detector-output

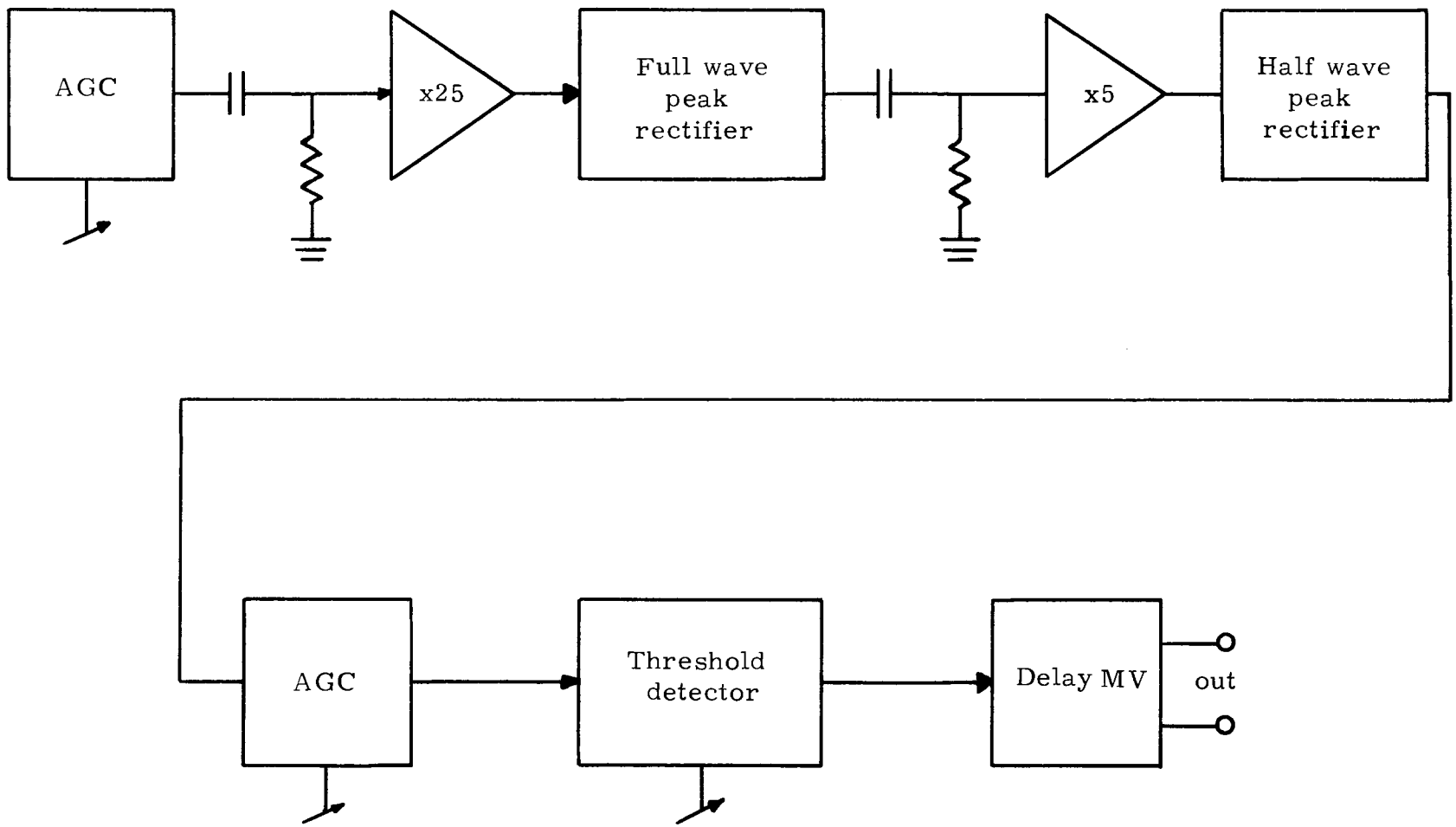
(Refer to description of PC 24, vocal pulse detector-input)

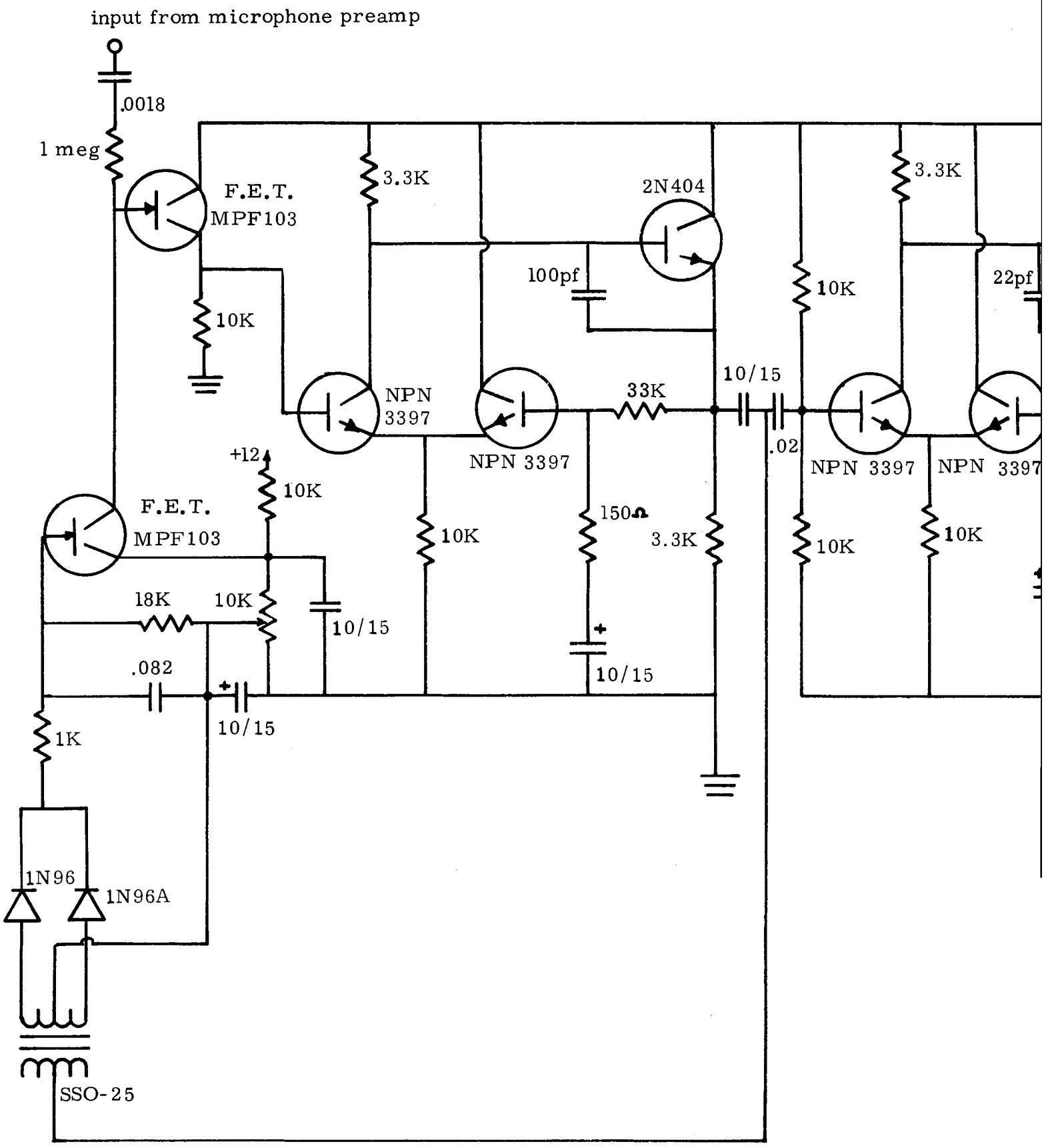
The pulse train output from PC 24 is applied to an AGC circuit with fast attack and 65 msec decay time constant. This AGC is necessary to provide equalization for different phonemes, as well as for variations in the speech input signal level. The AGC level potentiometer (parallel to the long axis of the printed circuit card) is adjusted for a signal level of two to four volts p-p at the output of the AGC amplifier.

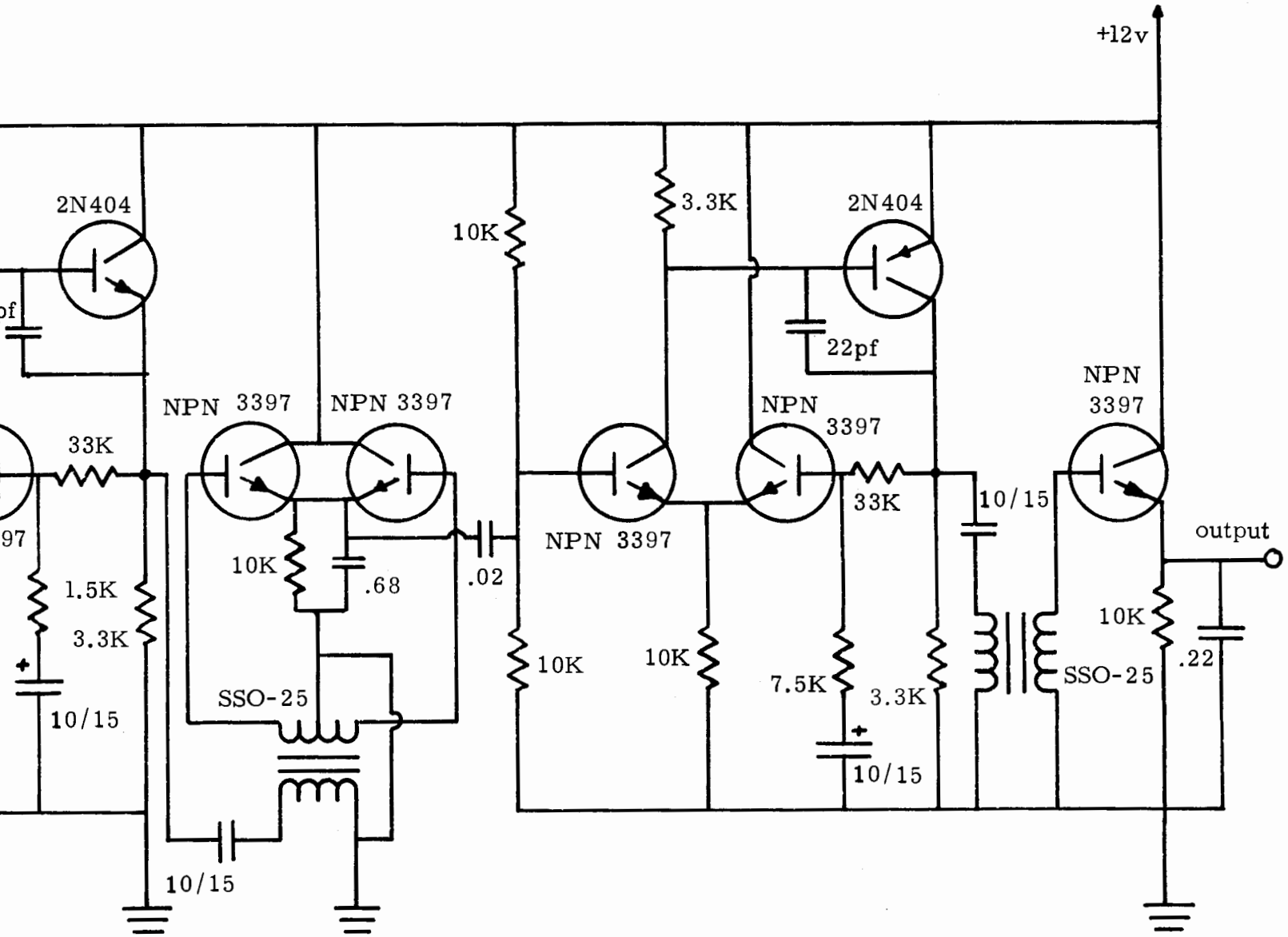
The signal is then applied to a voltage threshold detector, for which an adjustment potentiometer is provided. The two controls on this card should be set for a best compromise between noise immunity and reliable response to vocal pulses. The output of the threshold detector triggers a 10 msec delay multivibrator which generates uniform output pulses. Both positive and negative going pulses are available at the output.

Pin connections:

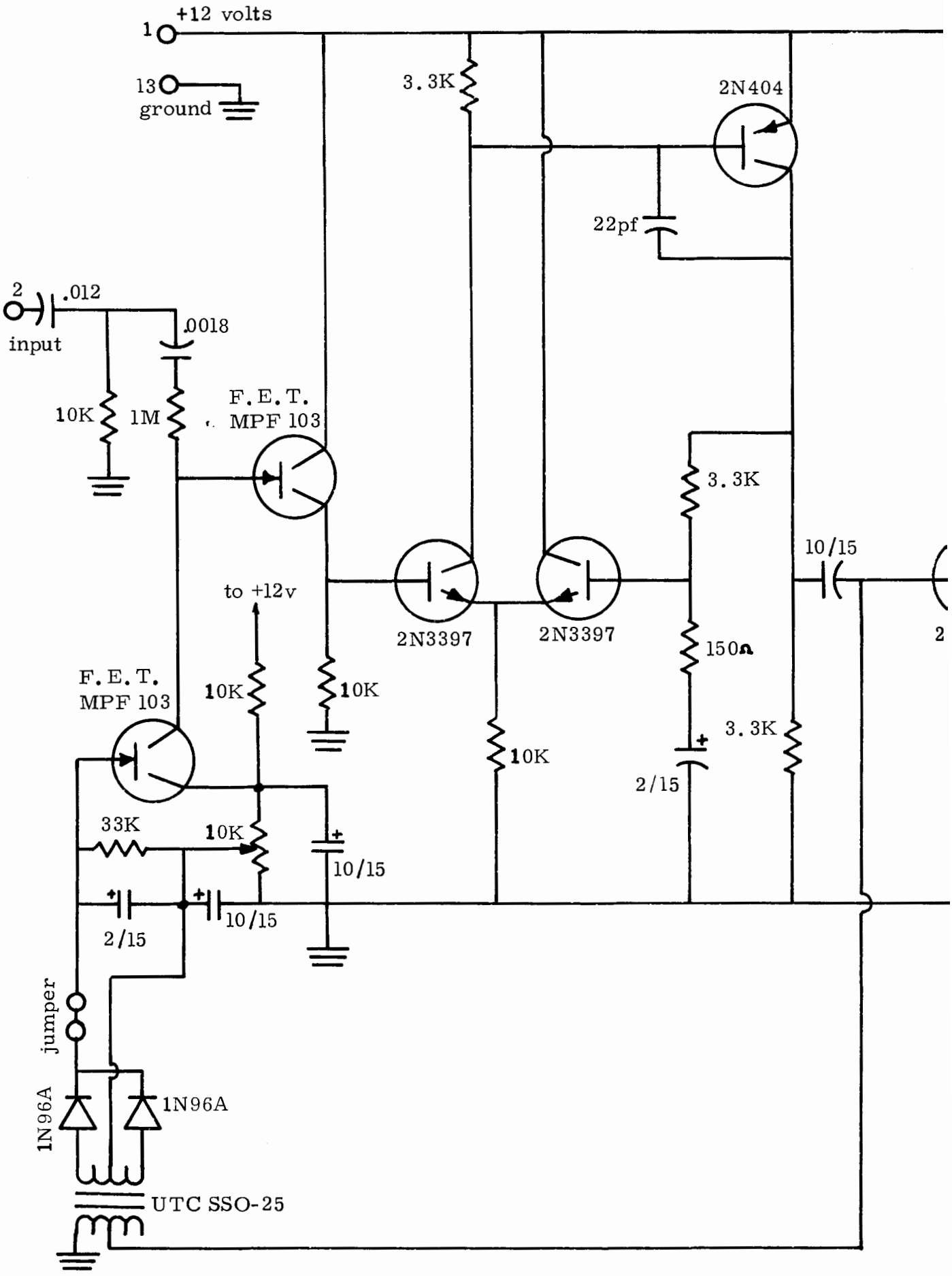
1. +12 volts
2. input signal from PC 24
13. ground
14. positive-going output (direct coupled)
15. negative-going output (direct coupled)

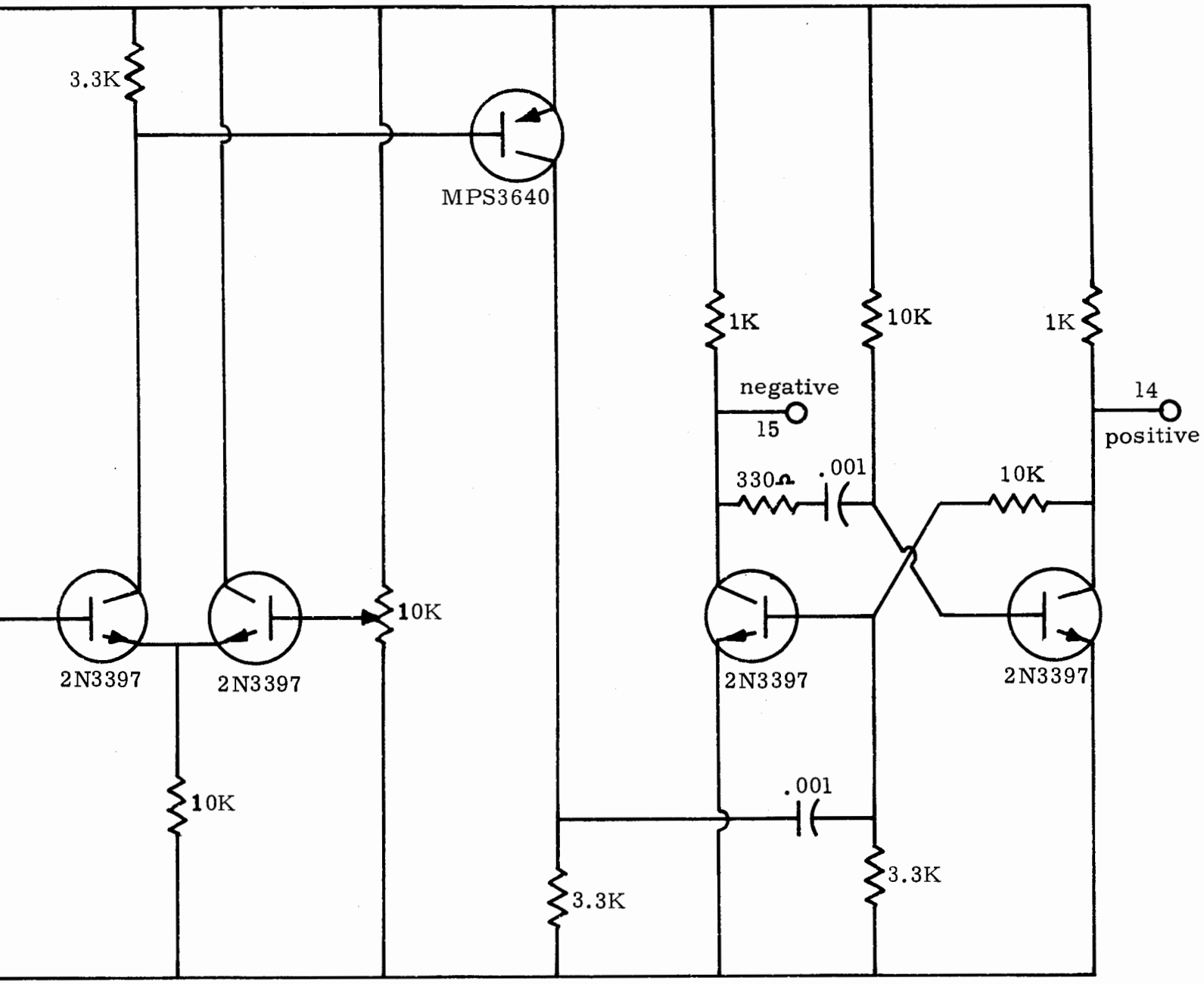

AGC
x25
Full wave peak rectifier
x5
Half wave peak rectifier
AGC
Threshold detector
Delay MV
out


input from microphone preamp
.0018
1 meg
F.E.T.
MPF103
3.3K
2N404
100pf
10K
22pf
10K
NPN
3397
NPN 3397
33K
10/15
.02
NPN 3397
NPN 3397
+12
10K
F.E.T.
MPF103
10K
150Ω
3.3K
10K
10K
18K
10K
10/15
10/15
.082
10/15
1K
1N96
1N96A
SSO-25

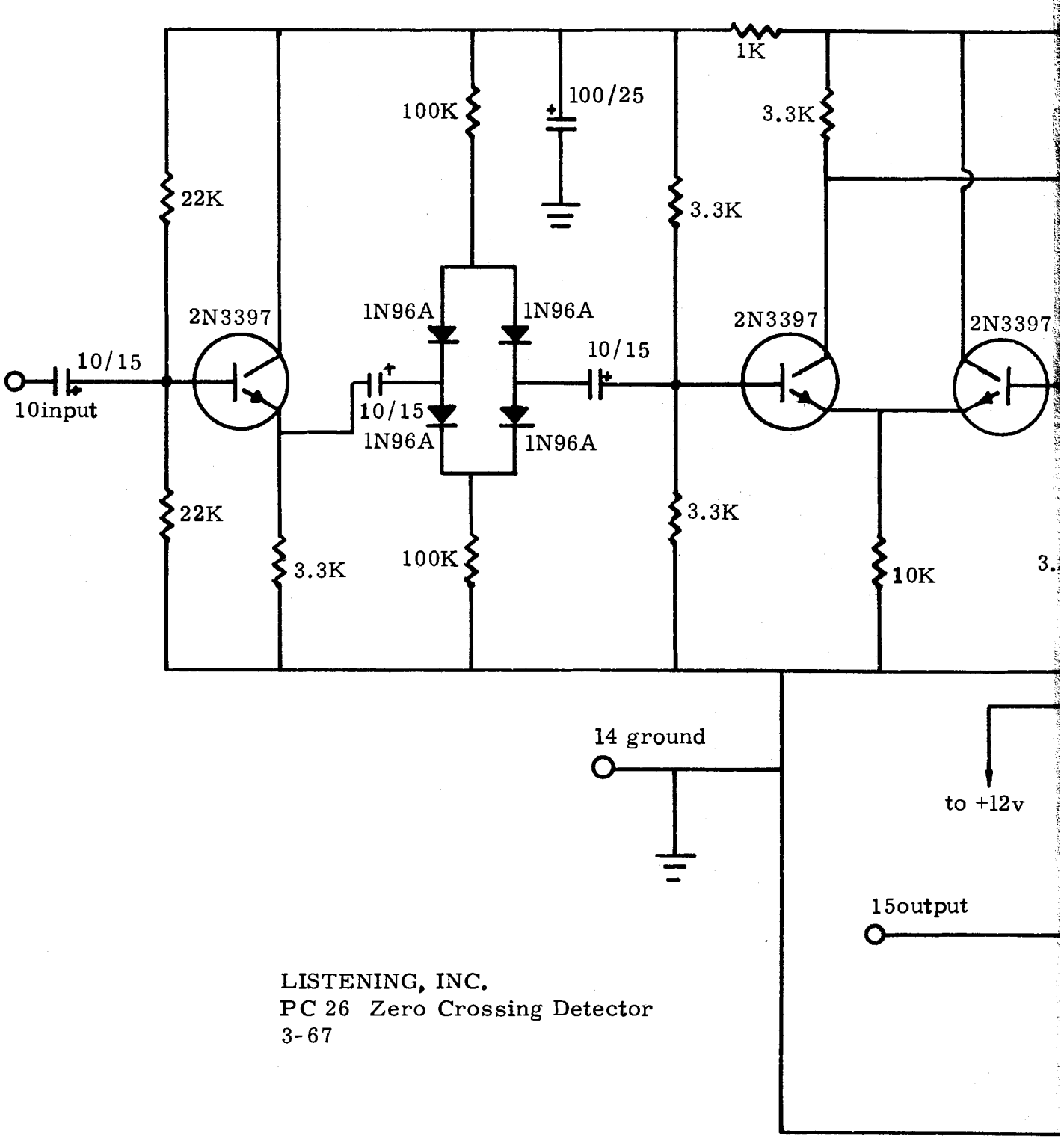


LISTENING, INC.
PC 24 Vocal Pulse Detector (rectifier)
3-67

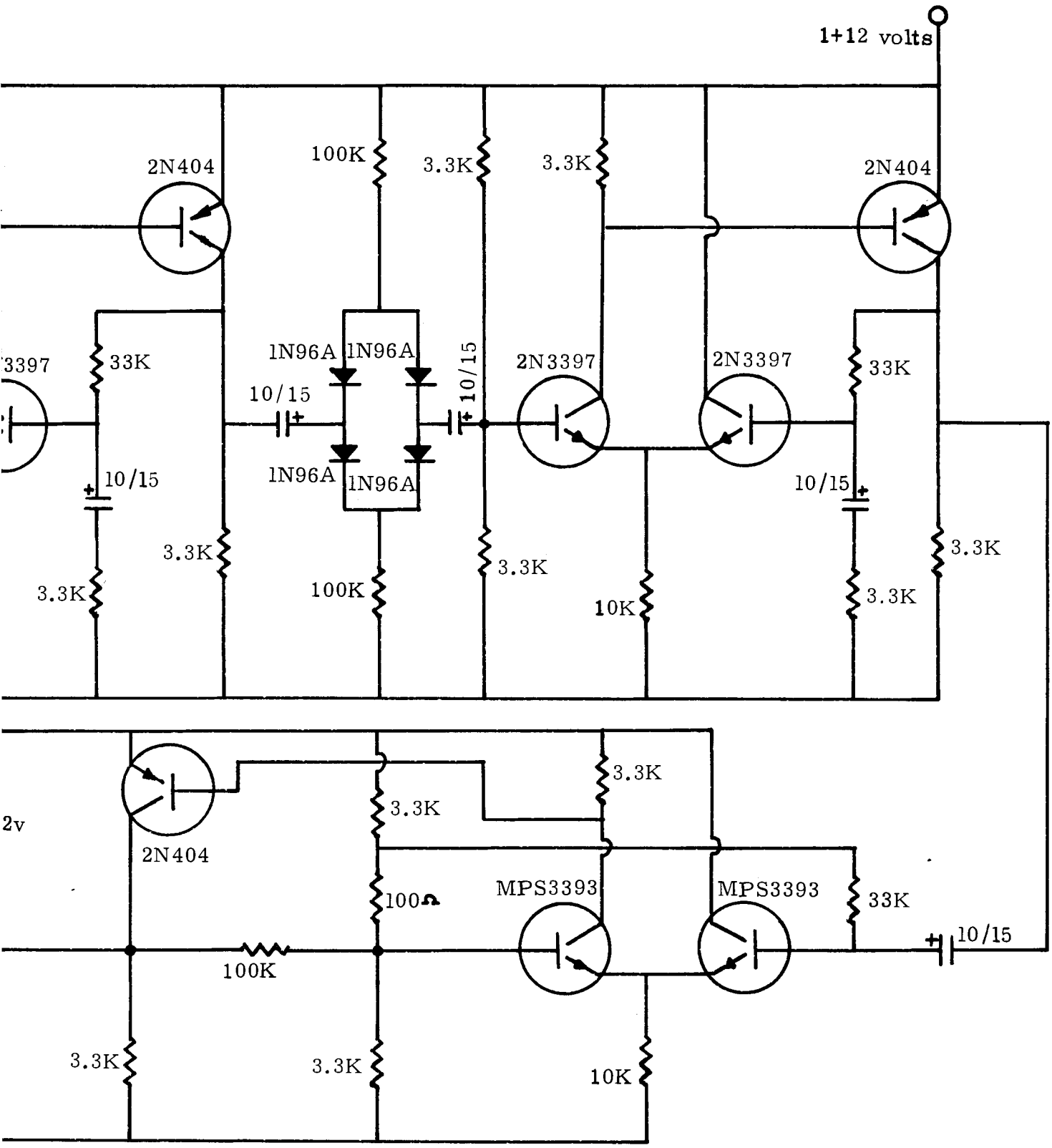

+12 volts
1
13
ground
3.3K
2N404
22pf
2
.012
input
.0018
10K
1M
F.E.T.
MPF 103
3.3K
10/15
to +12v
2N3397
2N3397
150Ω
F.E.T.
MPF 103
10K
10K
10K
3.3K
2/15
33K
10K
10/15
2/15
10/15
jumper
1N96A
1N96A
UTC SSO-25



LISTENING, INC.
PC 32 Vocal Pulse Detector Output Card
3-67



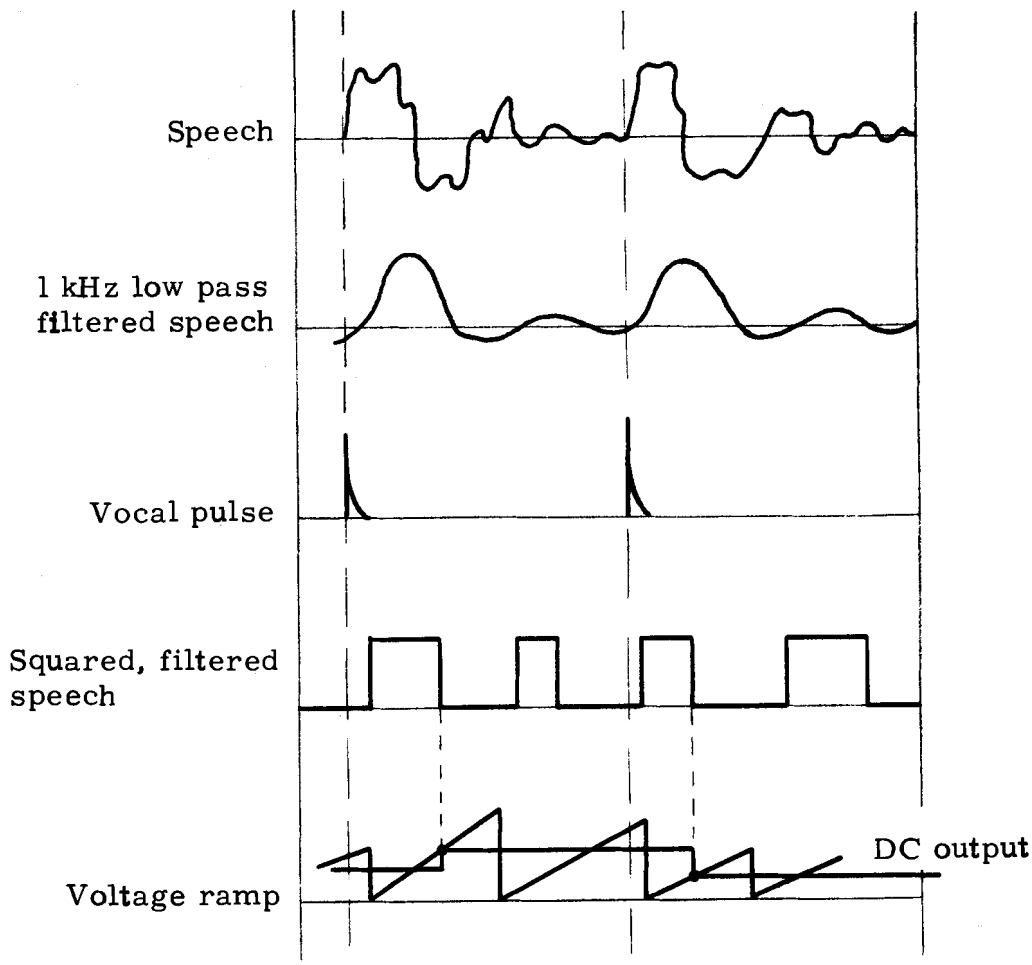
LISTENING, INC.
PC 26 Zero Crossing Detector
3-67


1+12 volts
2N404
100K
3.3K
3.3K
2N404
3397
33K
1N96A
1N96A
10/15
10/15
2N3397
2N3397
33K
1N96A
1N96A
10/15
10/15
3.3K
3.3K
3.3K
100K
3.3K
10K
3.3K
2v
2N404
3.3K
3.3K
100
MPS3393
MPS3393
33K
10/15
100K
3.3K
3.3K
10K

PC 31: Time to Voltage Converter

The squared speech signal from PC 26 resets a 4 volt per msec voltage ramp on each positive-going excursion. The ramp is sampled and held on each negative going excursion which follows a a vocal pulse. Each vocal pulse sets a flip flop which is reset by the negative going squared speech. The output of the flip flop energizes the sampling circuit. Thus, the output voltage is proportional to the time between the first positive and negative-going zero crossings of the filtered speech signal following an enabling vocal pulse. Overall linearity is $\pm$ 1%

The sequence is illustrated in the drawing below.



Pin connections:

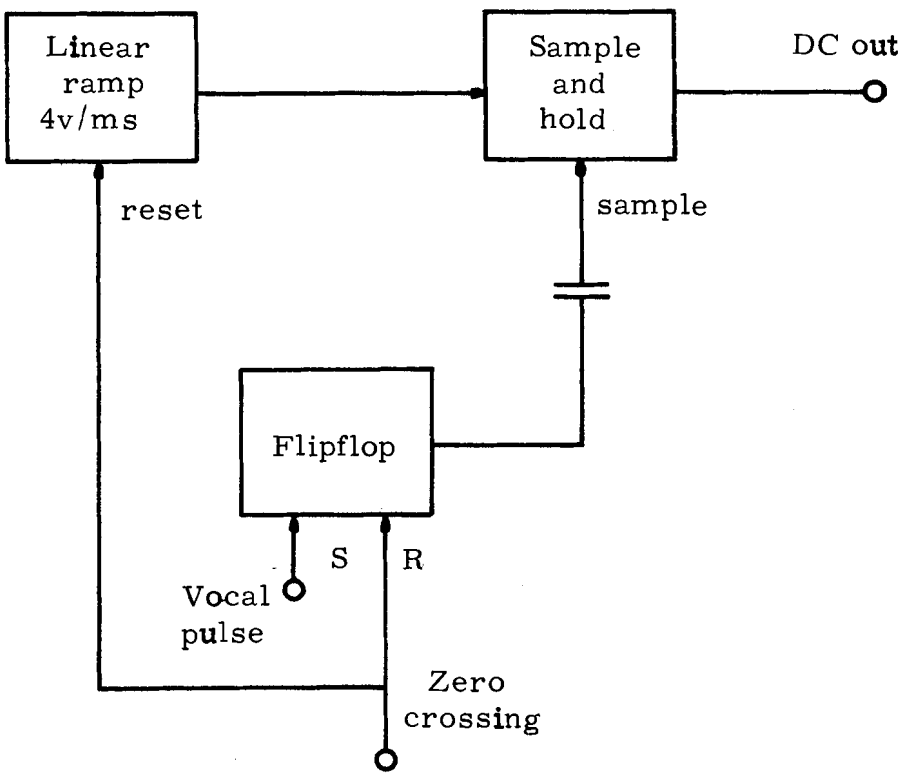
1. + 12 volts dc

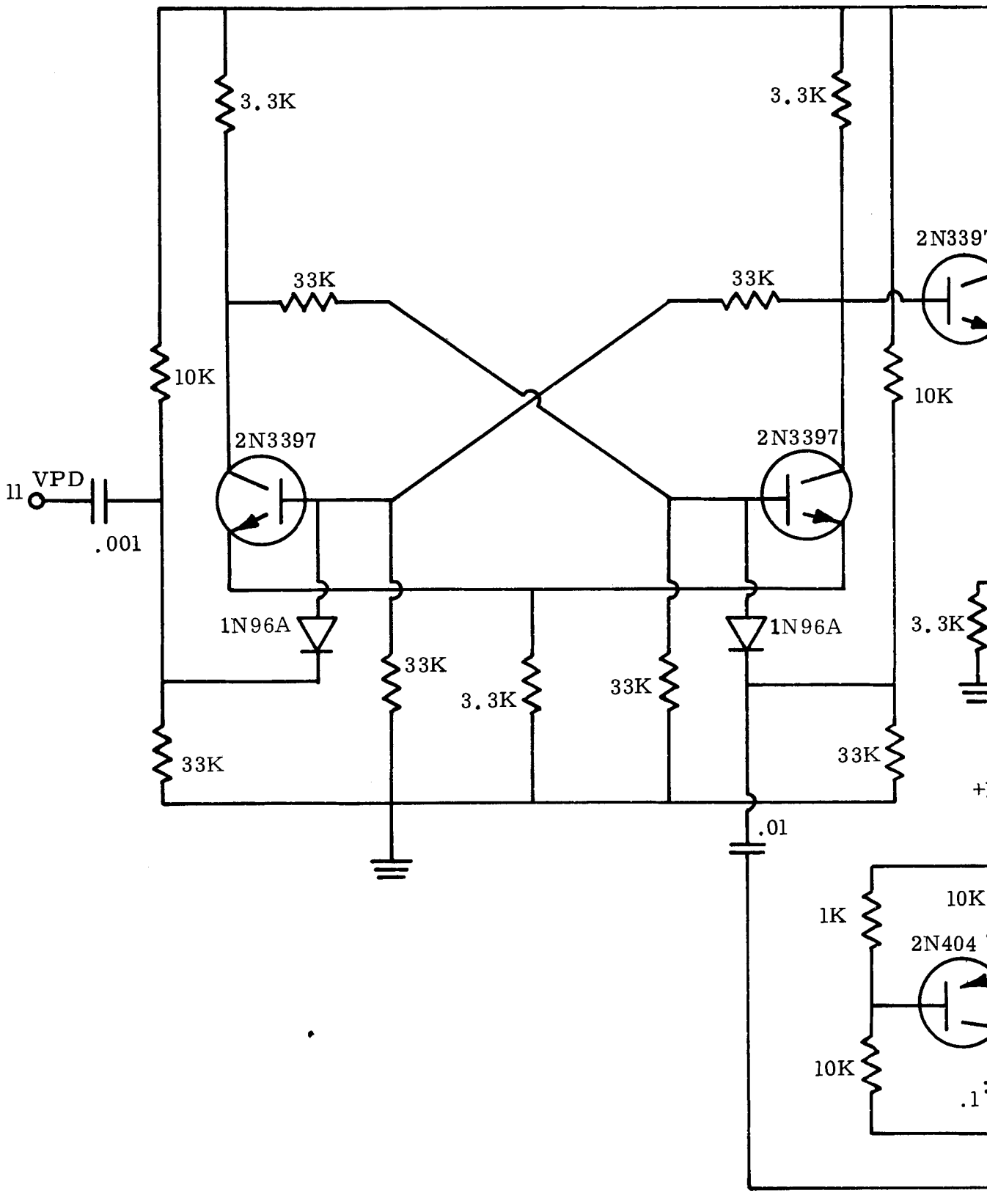
9. ground

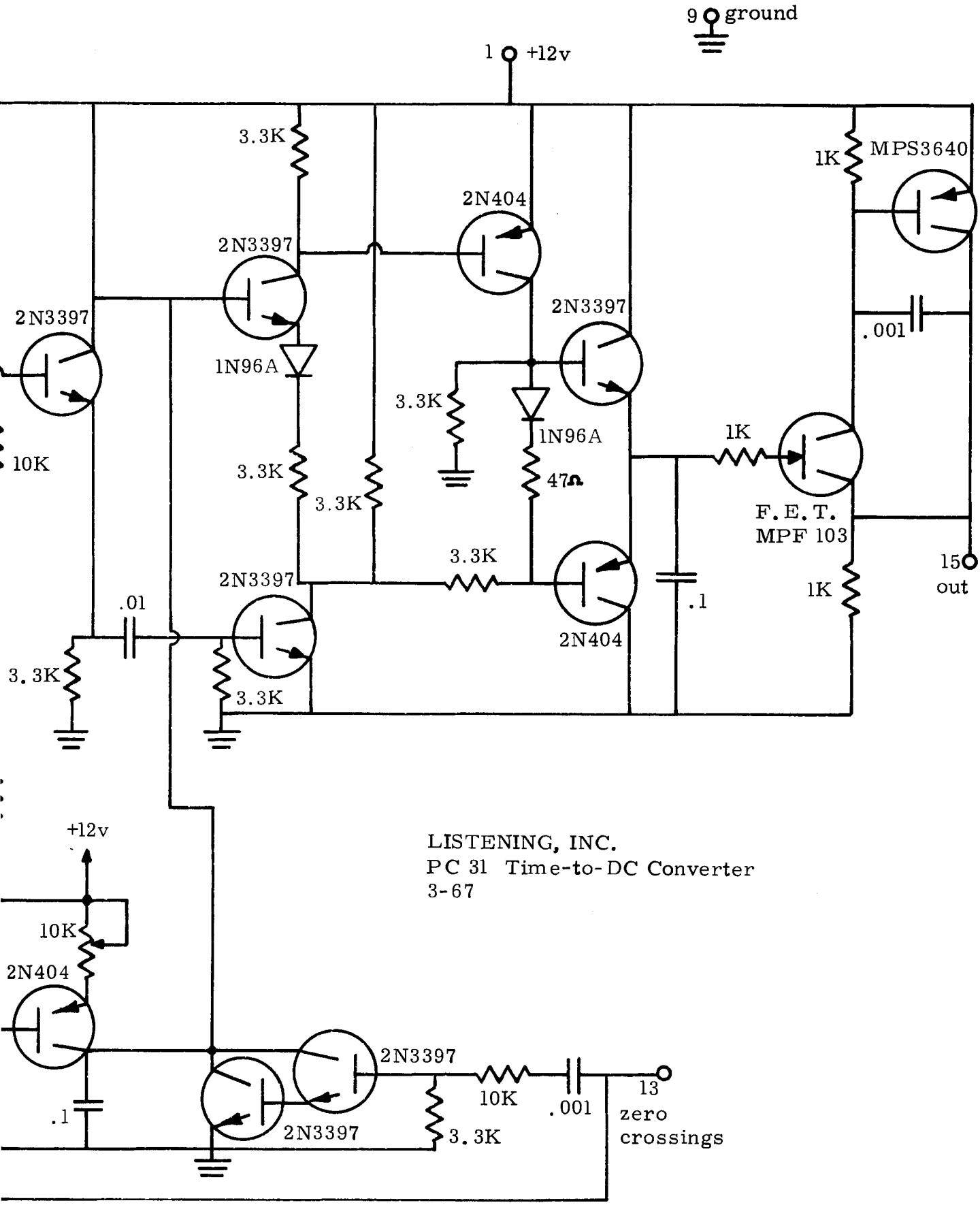
11. enabling pulse from vocal pulse detector

13. squared speech input

15. dc output




3.3K
3.3K
2N339
33K
33K
10K
10K
2N3397
2N3397
11 VPD
.001
1N96A
1N96A
3.3K
33K
3.3K
33K
33K
33K
.01
1K
10K
2N404
10K


9 ground
1 +12v
3.3K
2N404
2N3397
1K
MPS3640
2N3397
2N3397
.001
1N96A
3.3K
1N96A
10K
3.3K
47Ω
1K
3.3K
F.E.T.
MPF 103
15
out
3.3K
2N3397
2N404
.1
1K
.01
3.3K
3.3K
+12v
LISTENING, INC.
PC 31 Time-to-DC Converter
3-67
10K
2N404
2N3397
10K
.001
13
zero
crossings
.1
2N3397
3.3K

PC 34: Whistle Gate-on-logic

Whistle output is gated off except when there is a voice input to the translator. The presence of voice input is determined by the following logic applied to the detected vocal pulse epochs:

Whistle is gated on if and only if:

1. There have been at least two detected vocal pulses, separated by at least 4 msec.
2. The interval between successive vocal pulses does not exceed 15 msec.
3. There has been a vocal pulse within the past 15 msec.

Vocal pulse input from the vocal pulse detector is delayed 20 microseconds to allow sampling by the vocal pulse, then resetting. The first function is generated by resetting a voltage ramp with each delayed vocal pulse; the ramp voltage is sampled and held at each vocal pulse epoch. Thus a dc voltage is generated which is proportional to the interval between vocal pulses. The ascending ramp time constant is selected to put 4 msec=6 volts.

The second logic function is performed in the same manner; this circuit and the third function are on PC 36.

The three logic functions are applied to an AND gate which produces a high (positive) output when the whistle is to be gated on.

Pin connections:

1. + 12 volts

3. delayed vocal pulse to PC 36.

8. ground

11, 12, 13. AND gate inputs

15. gate output

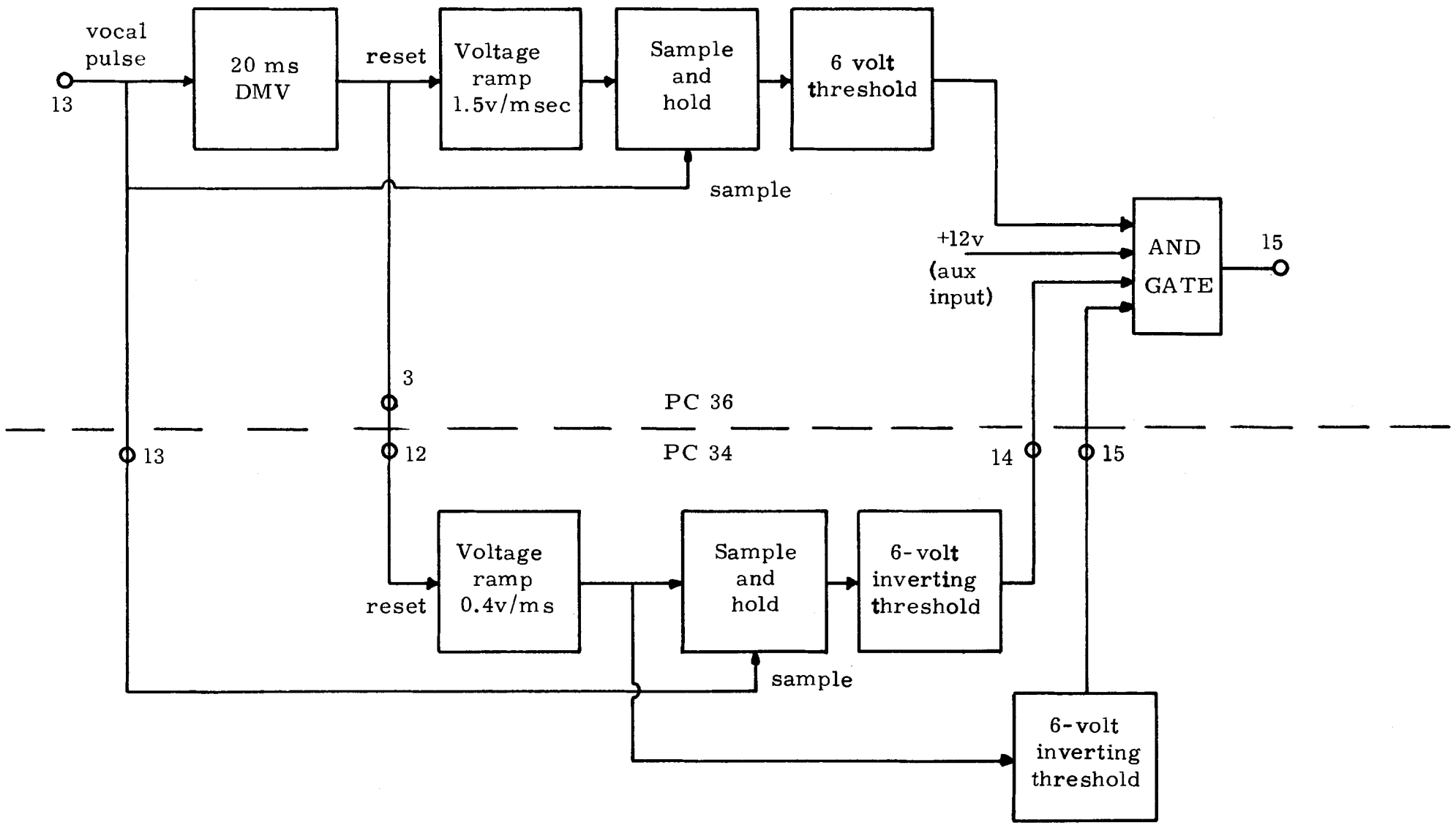
PC 36: Whistle Gate-off Logic

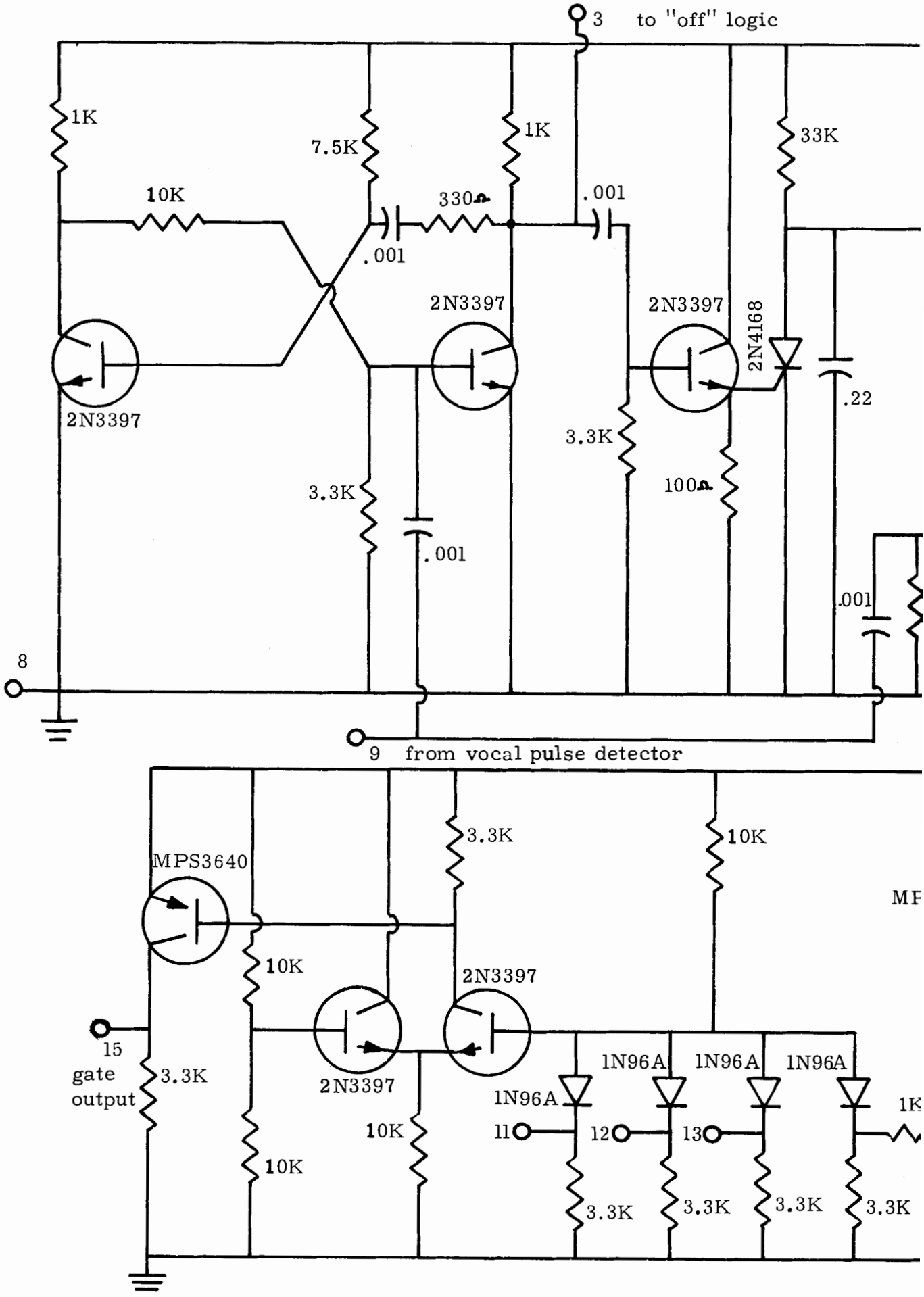
Refer to the description of PC 34. An ascending voltage ramp designed for 15 msec=6 volts is reset by each delayed vocal pulse. The ramp voltage is sampled by each vocal pulse, 20 usec before being reset, and held until the next vocal pulse. A voltage threshold detector gives a high output whenever the sample voltage is less than 6 volts.

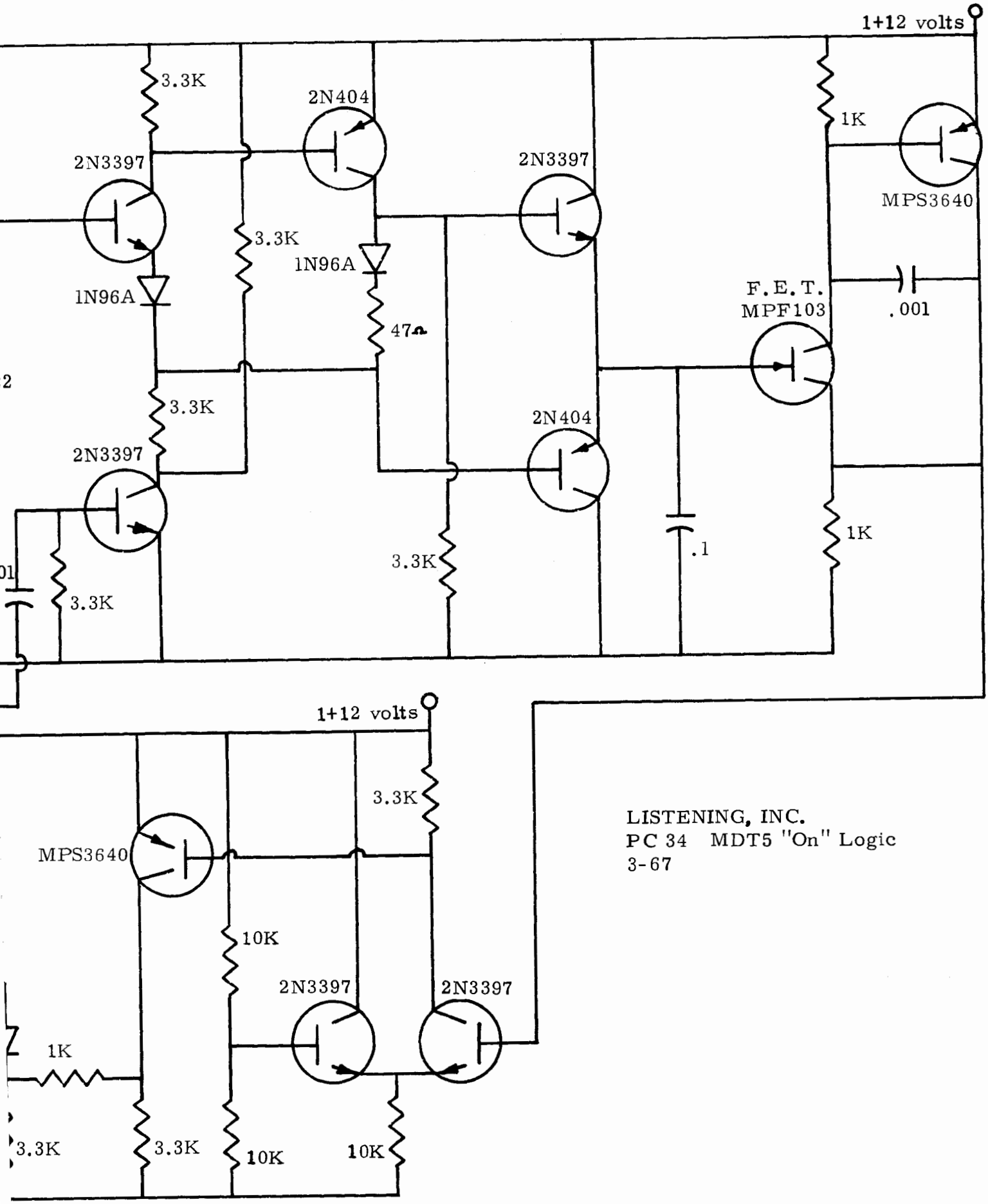
The same voltage ramp is fed directly to a 6-volt threshold detector whose output is high whenever the sample voltage is less than 6. This function is required because, if the vocal pulse train is suddenly arrested, there will be no further sampling of either the 4 msec or the 15 msec voltage ramps, and their logic functions would remain unchanged. The directly coupled threshold detector will, however, gate the whistle off if no vocal pulse is received within 15 msec.

Pin connections:

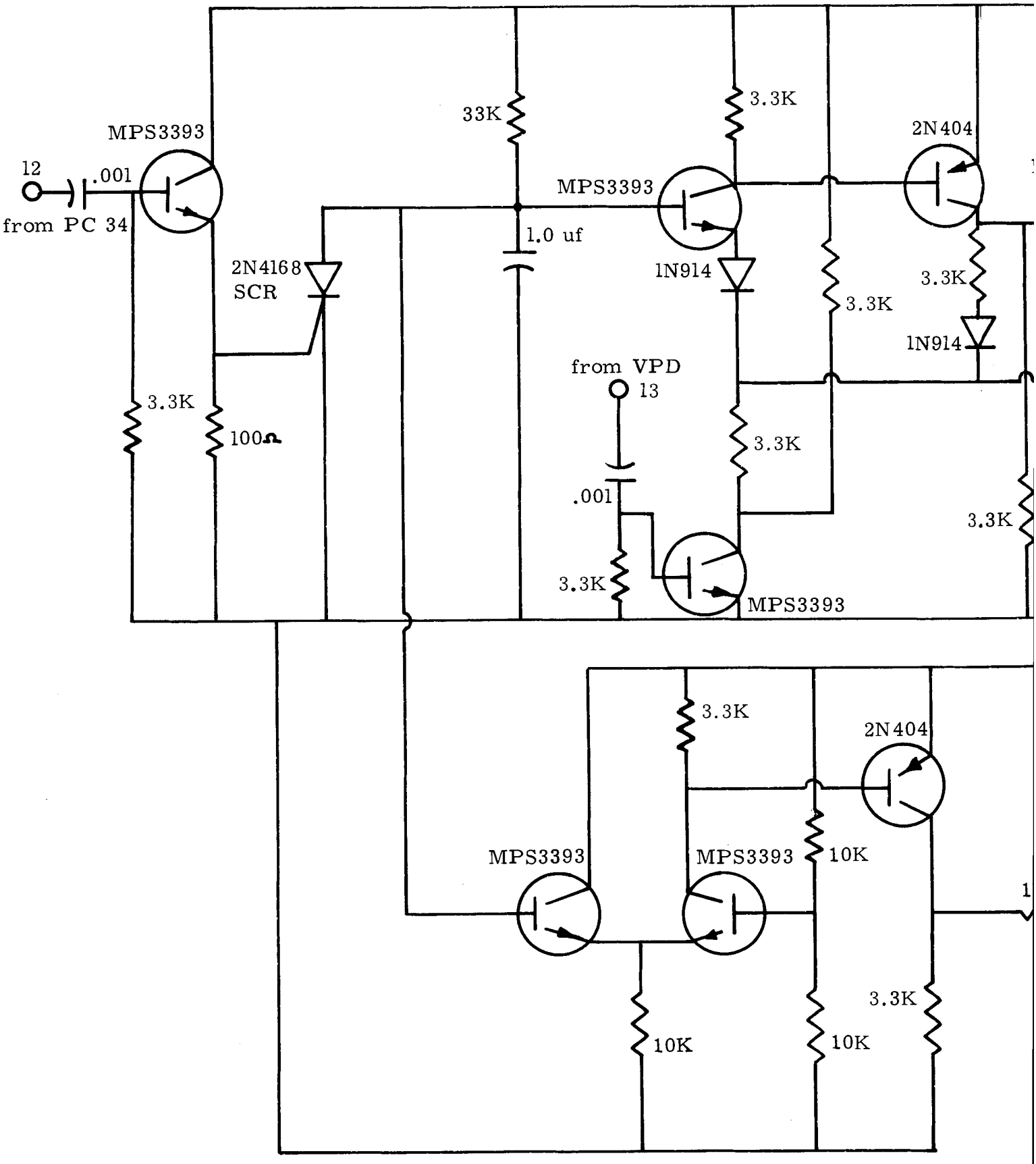
3. + 12 volts
10. ground
12. delayed vocal pulse input from PC 34
13. vocal pulse input
14. output, "interval-15 msec", to AND gate PC 34
15. output, "pulse within past 15 msec", to AND gate PC 34

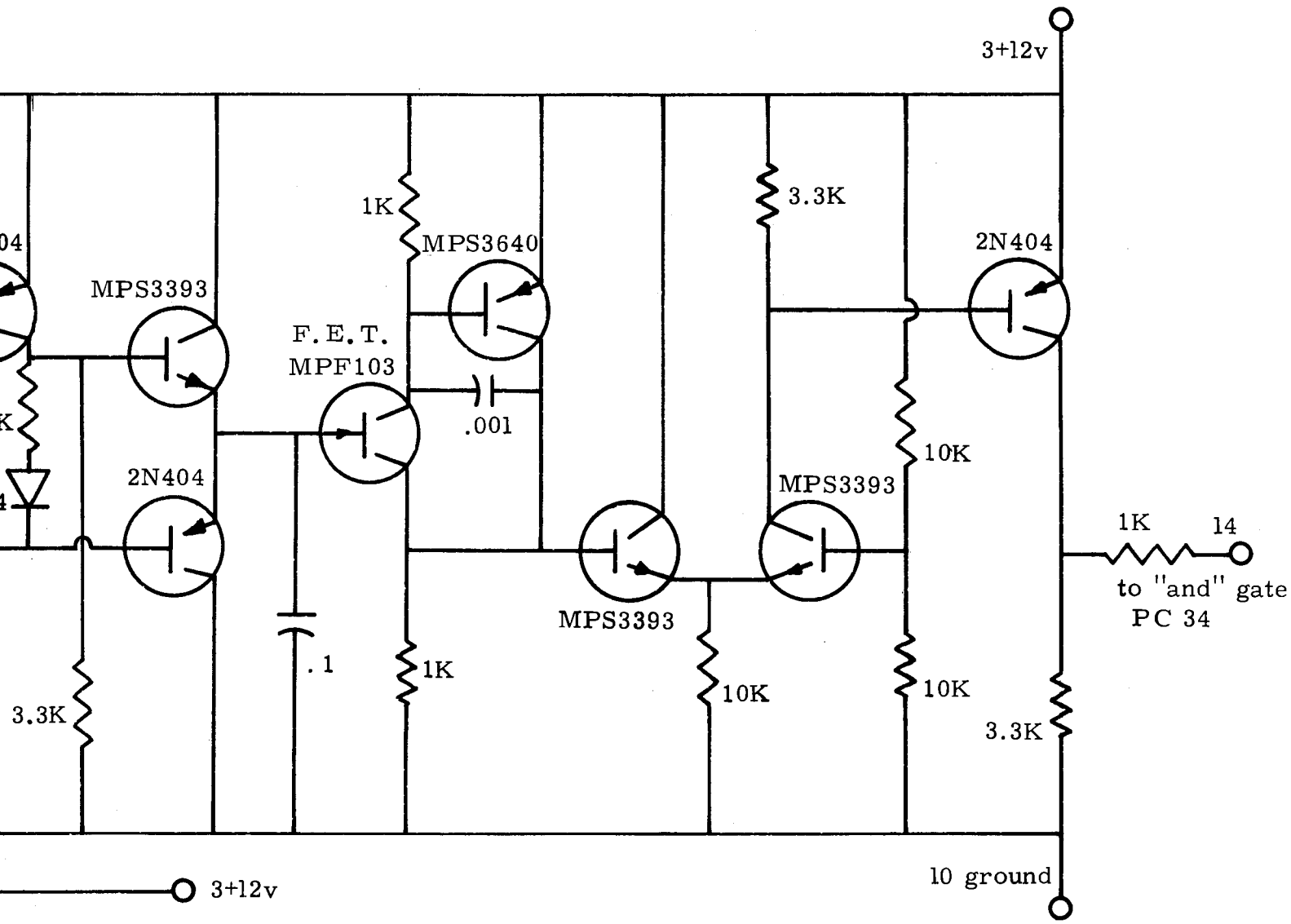

vocal pulse
13
20 ms DMV
reset
Voltage ramp 1.5v/msec
Sample and hold
6 volt threshold
sample
+12v (aux input)
AND GATE
15
3
PC 36
PC 34
13
12
14
15
reset
Voltage ramp 0.4v/ms
Sample and hold
6-volt inverting threshold
sample
6-volt inverting threshold


3 to "off" logic
1K
7.5K
1K
33K
10K
330Ω
.001
.001
2N3397
2N3397
2N4168
2N3397
.22
3.3K
100Ω
3.3K
.001
.001
8
9 from vocal pulse detector
MPS3640
3.3K
10K
10K
2N3397
15
gate
output
3.3K
2N3397
1N96A
1N96A
1N96A
1K
10K
11
12
13
10K
3.3K
3.3K
3.3K
3.3K

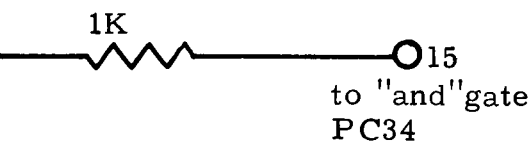


LISTENING, INC.
PC 34 MDT5 "On" Logic
3-67


MPS3393
12
.001
from PC 34
33K
3.3K
2N404
MPS3393
1.0 uf
2N4168
SCR
1N914
3.3K
3.3K
3.3K
1N914
from VPD
13
3.3K
100Ω
.001
3.3K
3.3K
MPS3393
3.3K
2N404
MPS3393
MPS3393
10K
10K
10K
3.3K



LISTENING, INC.
PC 36 MDT5 "Off" Logic
7-67



PC 39: Output Amplifiers

1. Whistle output to hydrophone

Zero to 1 volt p-p input controlled by the HYD adjustment on the rear apron is applied to the input of a driver stage which provides compensation of minus 6 db per octave in the 5 to 20 kHz whistle region. The complimentary emitter follower output feeds a driver transformer with center-tapped secondary to obtain push-pull drive for the output stage. Collector load in the output is the primary of a 1:14 audiotransformer which is a current source for hydrophone loads of .002 microfarads and up. Maximum current into a .002 ufd load is about 5mA at 5kHz. The overall voltage gain with a capacitive load has a slope of minus 12db per octave.

2. Loudspeaker output

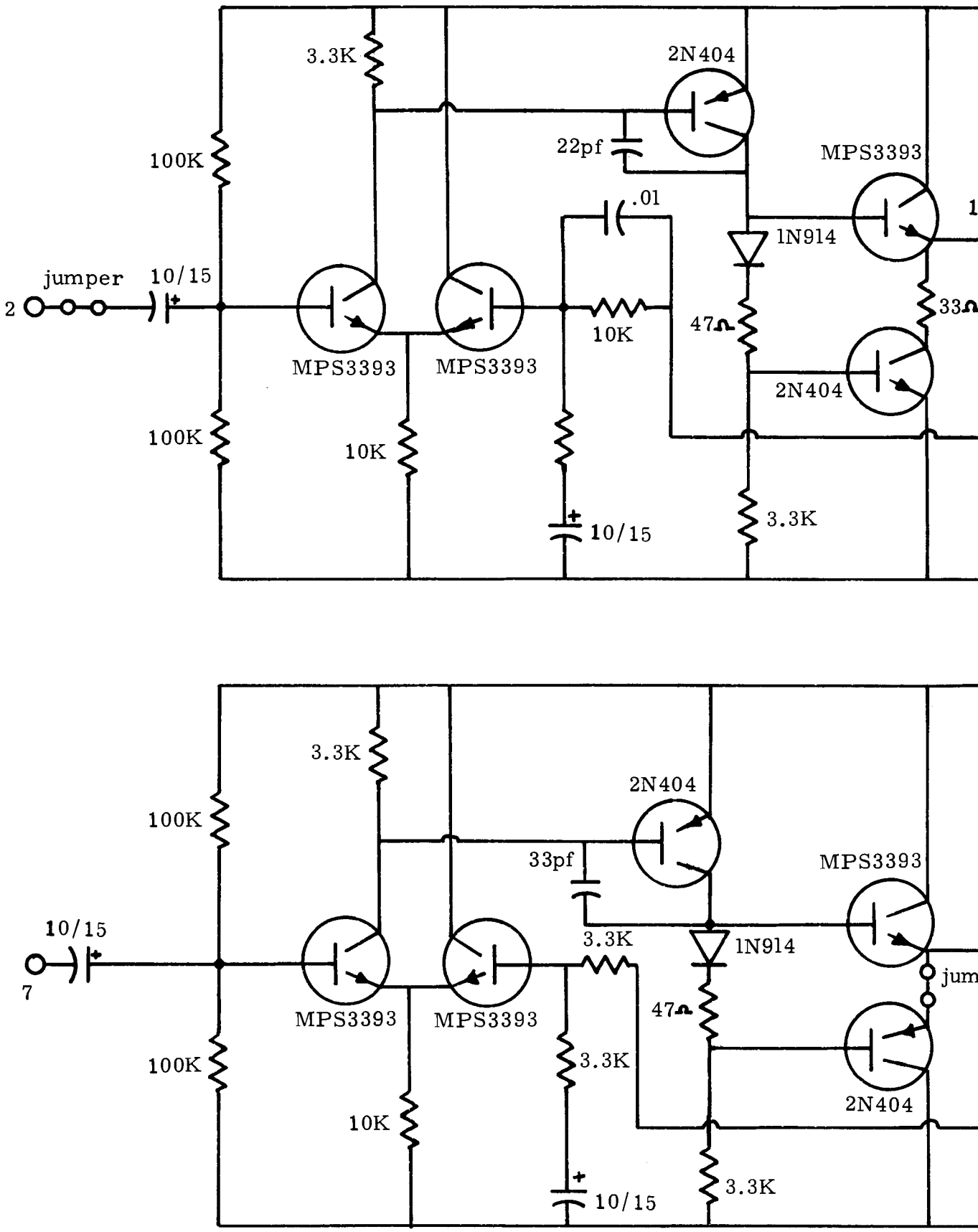
A cone-type tweeter of 16ohms impedance is driven by a complimentary emitter follower output stage similar to the driver stage in the hydrophone amplifier. Maximum power output is 250mw.

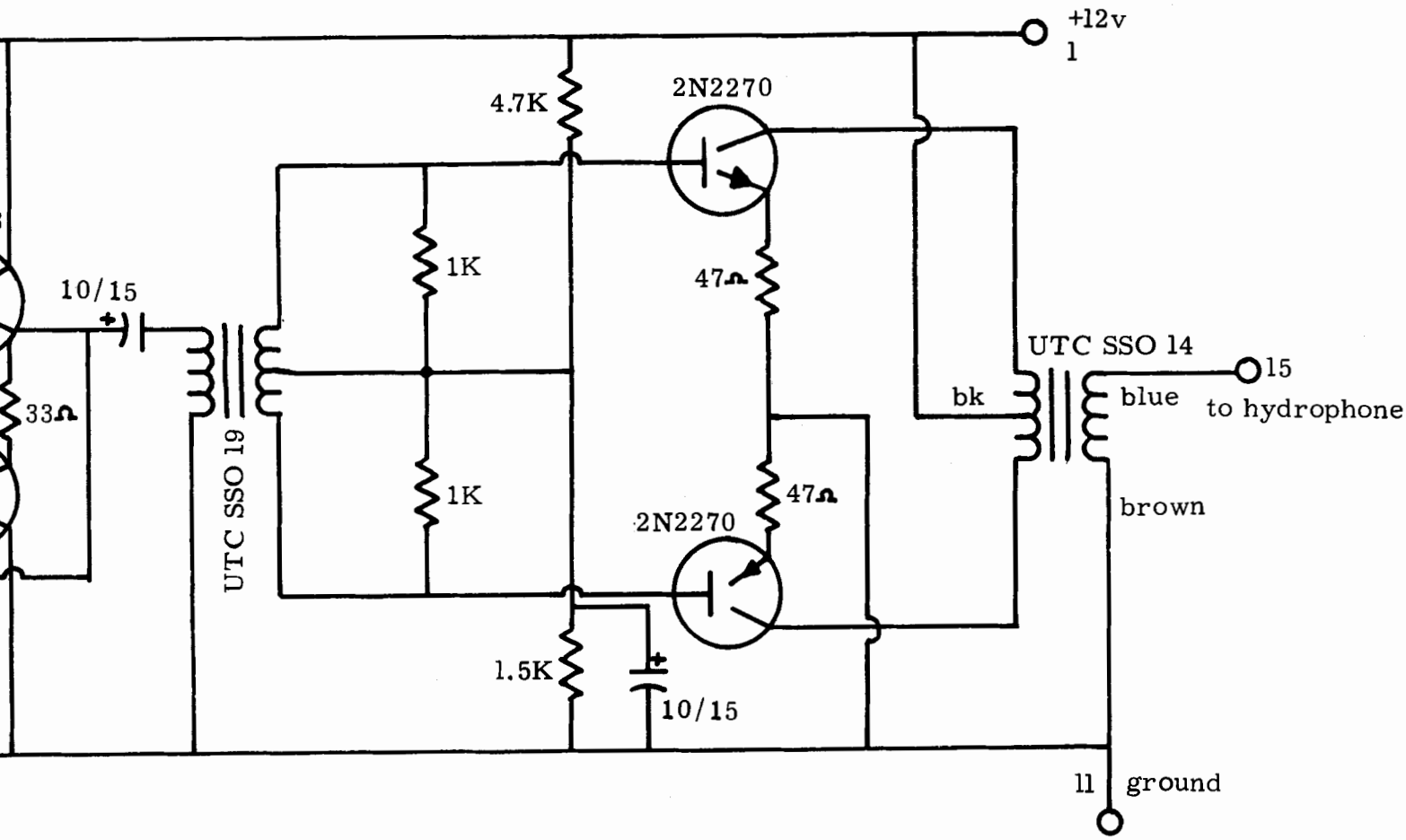
3. Vocal Pulse Output

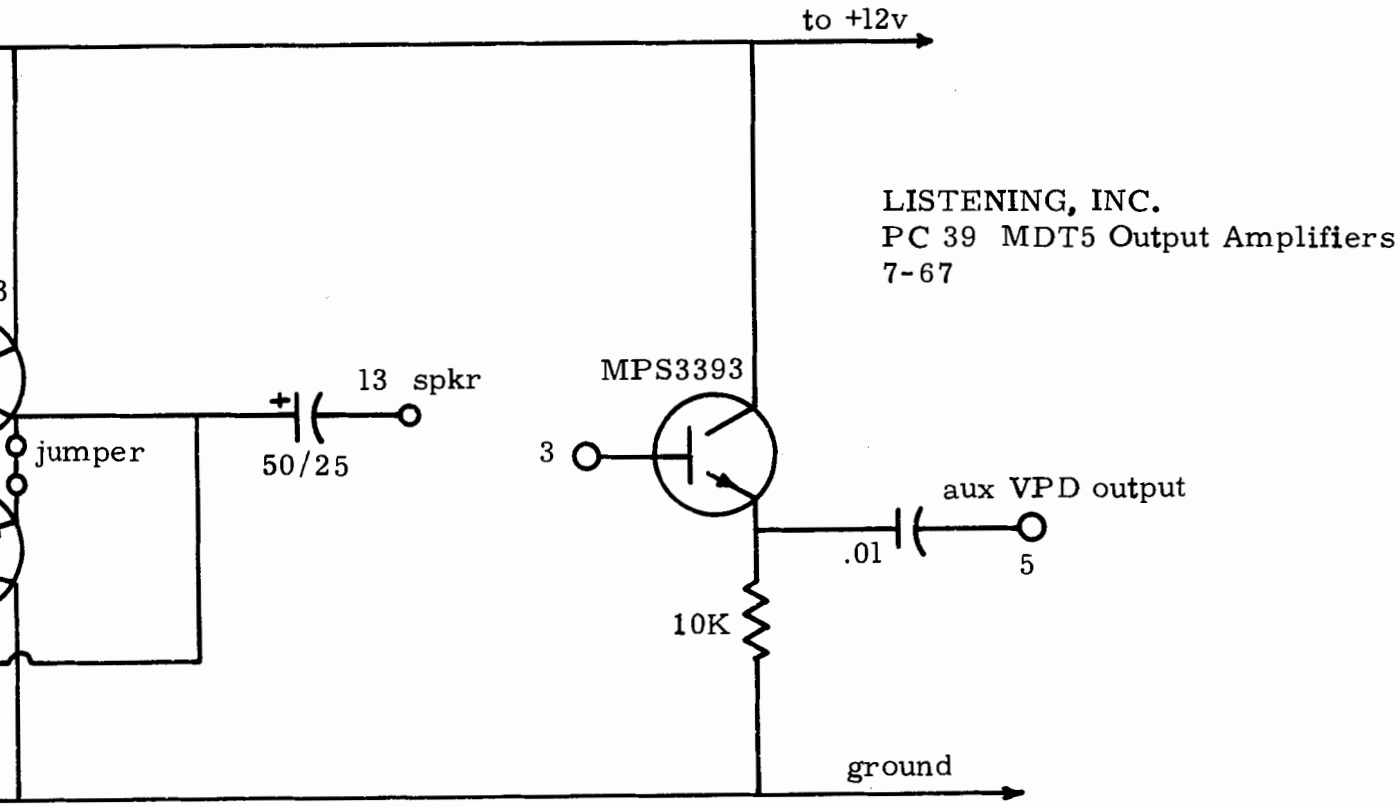
A simple capacitively coupled emitter follower stage provides a buffered vocal pulse reference output.

Pin connections:

1. + 12 volts
2. input to hydrophone amplifier
3. input to vocal pulse buffer
5. vocal pulse output to rear panel jack
7. input to loudspeaker amplifier
11. ground
13. output to loudspeaker
15. output to hydrophone


3.3K
2N404
22pf
MPS3393
100K
.01
1N914
jumper
10/15
2
MPS3393
MPS3393
10K
47Ω
33Ω
2N404
100K
10K
10/15
3.3K
3.3K
2N404
100K
33pf
MPS3393
10/15
3.3K
1N914
7
MPS3393
MPS3393
47Ω
100K
3.3K
10K
2N404
10/15
3.3K





LISTENING, INC.
PC 39 MDT5 Output Amplifiers
7-67

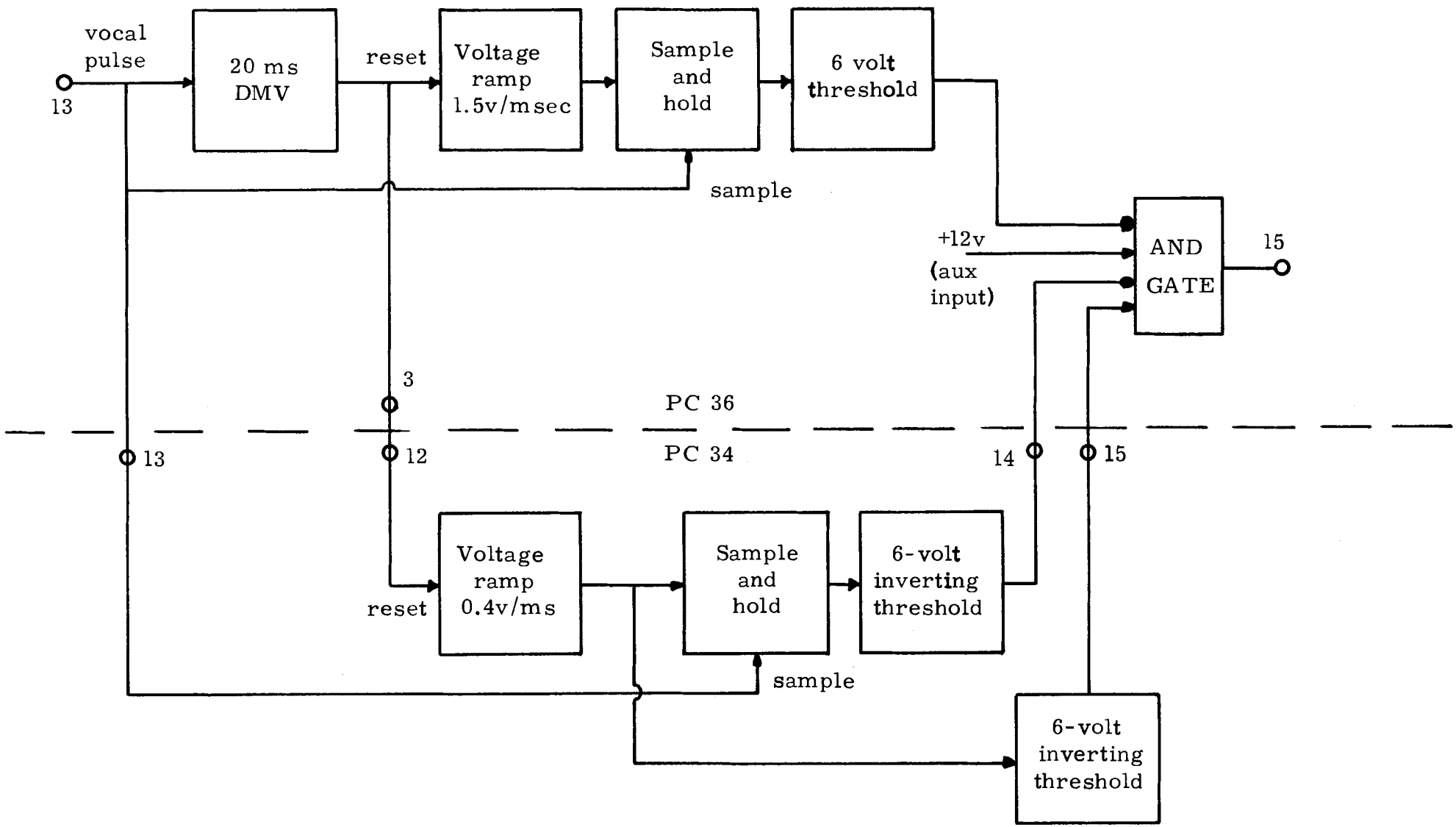
PC 38: Count Rate Meter

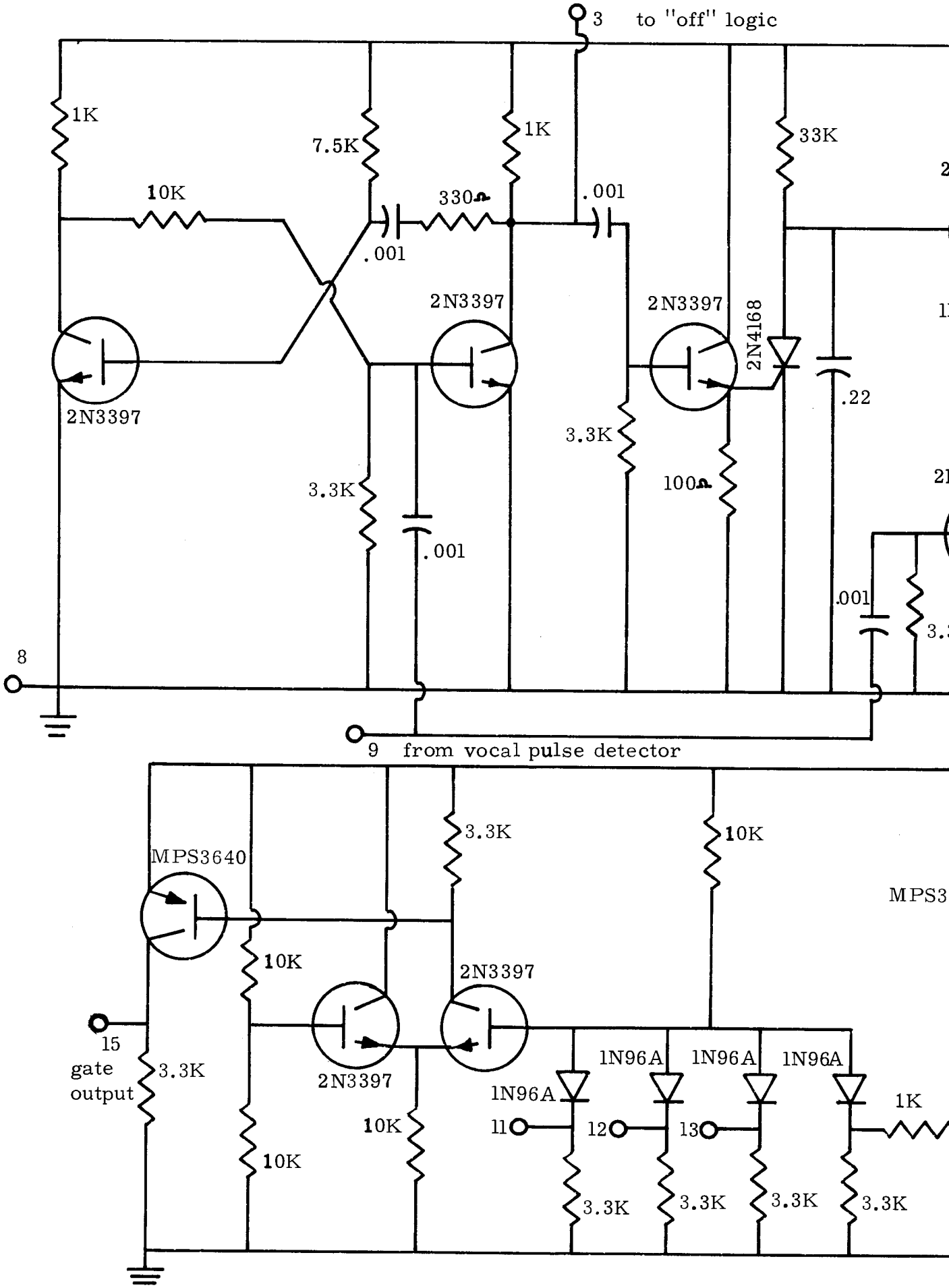
The whistle signal from the output of the FET signal gate is fed to an emitter follower buffer. The output of this buffer is brought out through pin 11 and is available at a rear panel jack.

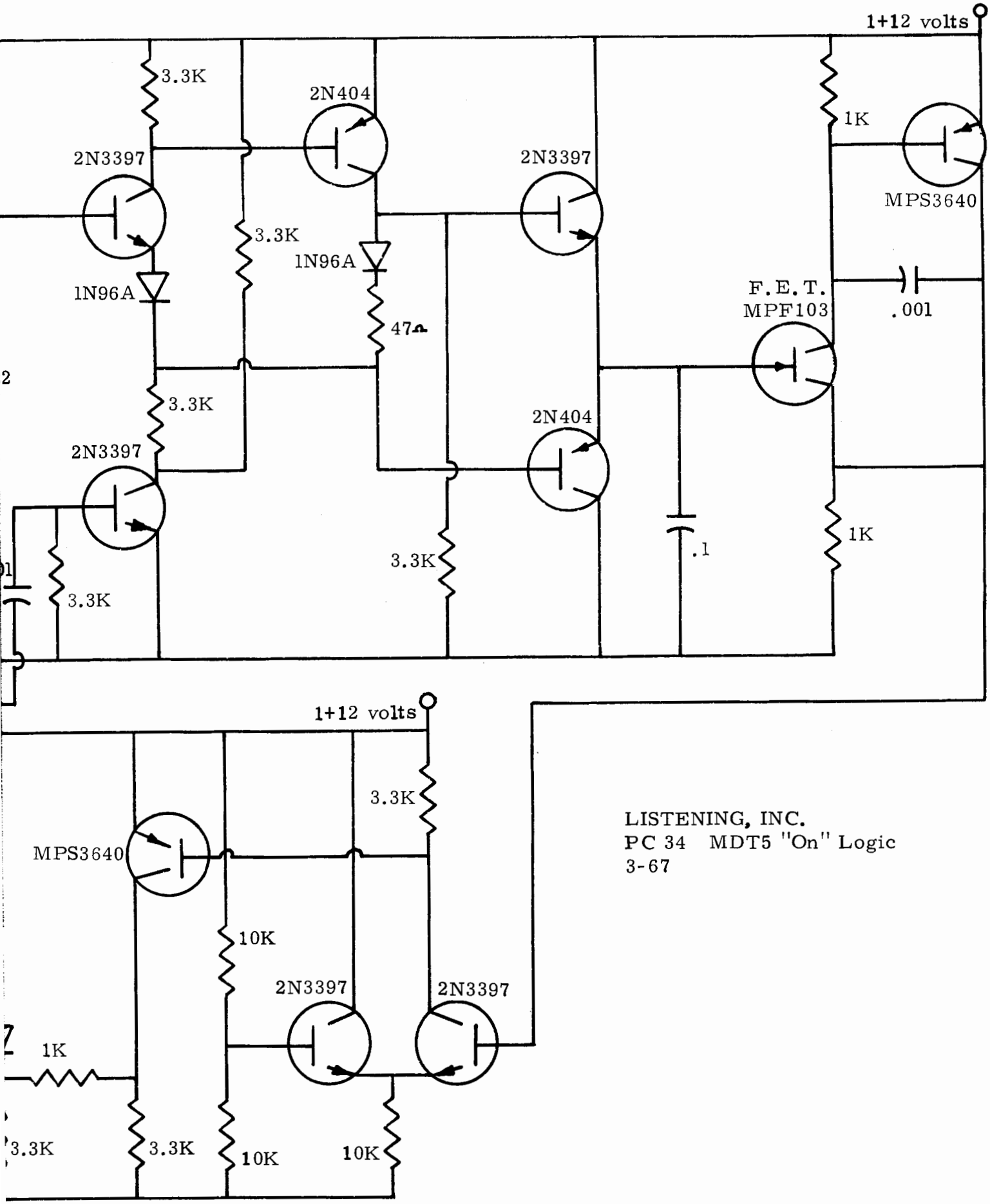
The buffered whistle is then applied to a squaring amplifier; the output of which triggers a 15 msec delay multivibrator. The pulses drive an adjustable current source using a PNP silicon transistor. Calibration is effected by adjusting the potentiometer mounted on the pc card. The current pulses are integrated by a .33uf capacitor, from which two outputs are available: one to drive the 200uA panel meter via a 10k ohm resistor, and the other via a direct coupled, unbiased emitter follower. The emitter-base diode gap of this transistor suppresses the first 5 kHz of the frequency range.

Pin connections:

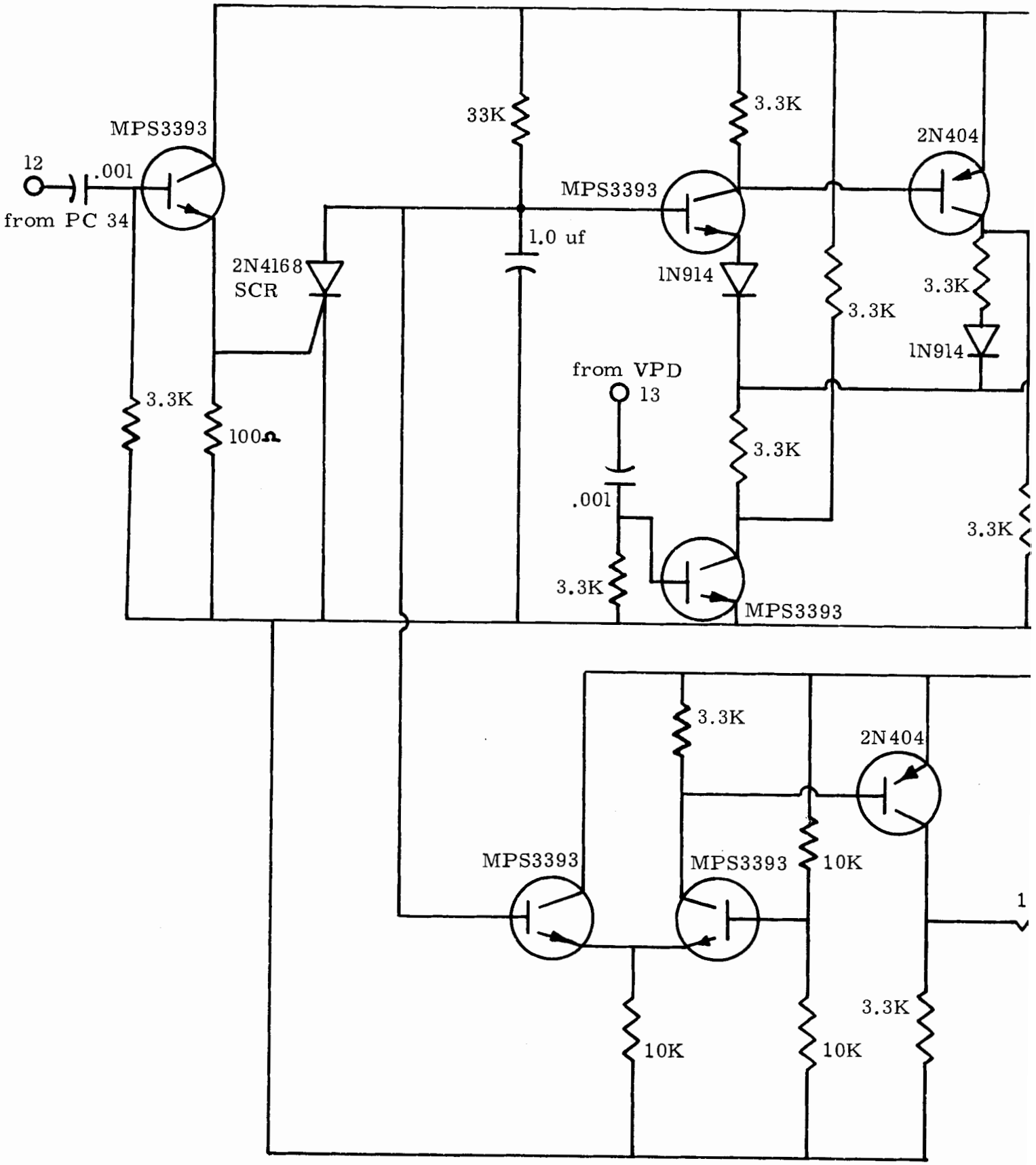
1. +12 volts
6. whistle input
11. buffered whistle output
13. ground
14. dc output to panel meter
15. zero-suppressed auxiliary output to rear panel jack

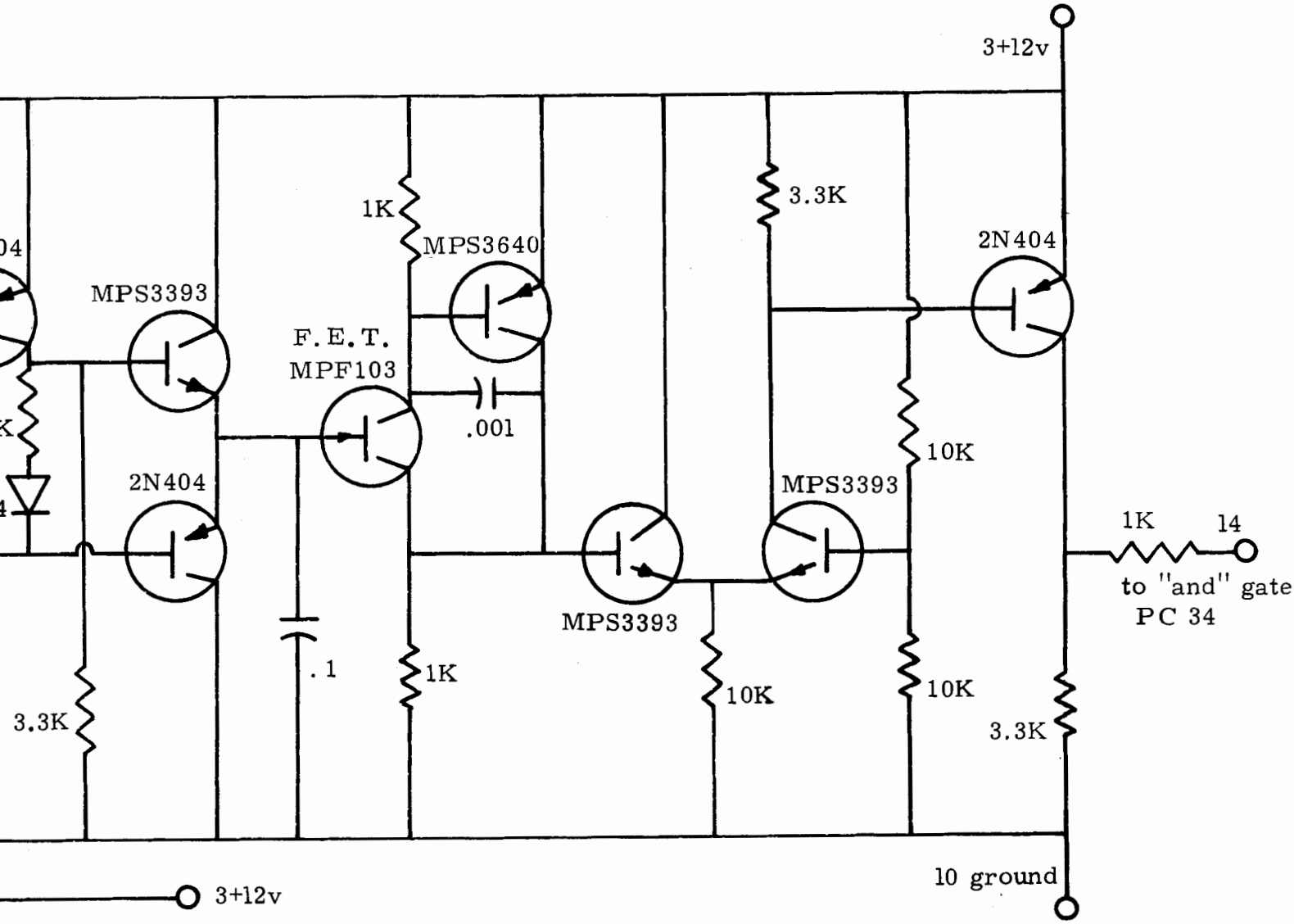

vocal pulse
13
20 ms DMV
reset
Voltage ramp 1.5v/msec
Sample and hold
6 volt threshold
sample
+12v (aux input)
AND GATE
15
3
PC 36
PC 34
13
12
14
15
Voltage ramp 0.4v/ms
reset
Sample and hold
6-volt inverting threshold
sample
6-volt inverting threshold


3 to "off" logic
1K
7.5K
1K
33K
10K
330Ω
.001
.001
2N3397
2N3397
2N4168
2N3397
.22
3.3K
100Ω
3.3K
.001
.001
8
9 from vocal pulse detector
MPS3640
3.3K
10K
MPS3
10K
2N3397
15
gate
output
3.3K
2N3397
1N96A
1N96A
1N96A
1N96A
1K
10K
11
12
13
10K
3.3K
3.3K
3.3K
3.3K

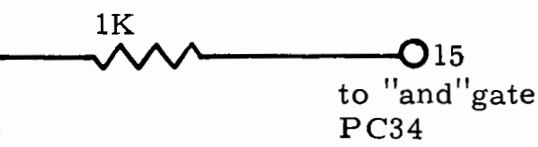


LISTENING, INC.
PC 34 MDT5 "On" Logic
3-67


12
.001
from PC 34
MPS3393
33K
3.3K
MPS3393
2N404
1.0 uf
2N4168
SCR
1N914
3.3K
3.3K
1N914
from VPD
13
3.3K
100Ω
3.3K
.001
3.3K
3.3K
MPS3393
3.3K
2N404
MPS3393
MPS3393
10K
10K
10K
3.3K



LISTENING, INC.
PC 36 MDT5 "Off" Logic
7-67



PC 39: Output Amplifiers

1. Whistle output to hydrophone

Zero to 1 volt p-p input controlled by the HYD adjustment on the rear apron is applied to the input of a driver stage which provides compensation of minus 6 db per octave in the 5 to 20 kHz whistle region. The complimentary emitter follower output feeds a driver transformer with center-tapped secondary to obtain push-pull drive for the output stage. Collector load in the output is the primary of a 1:14 audiotransformer which is a current source for hydrophone loads of .002 microfarads and up. Maximum current into a .002 ufd load is about 5mA at 5kHz. The overall voltage gain with a capacitive load has a slope of minus 12db per octave.

2. Loudspeaker output

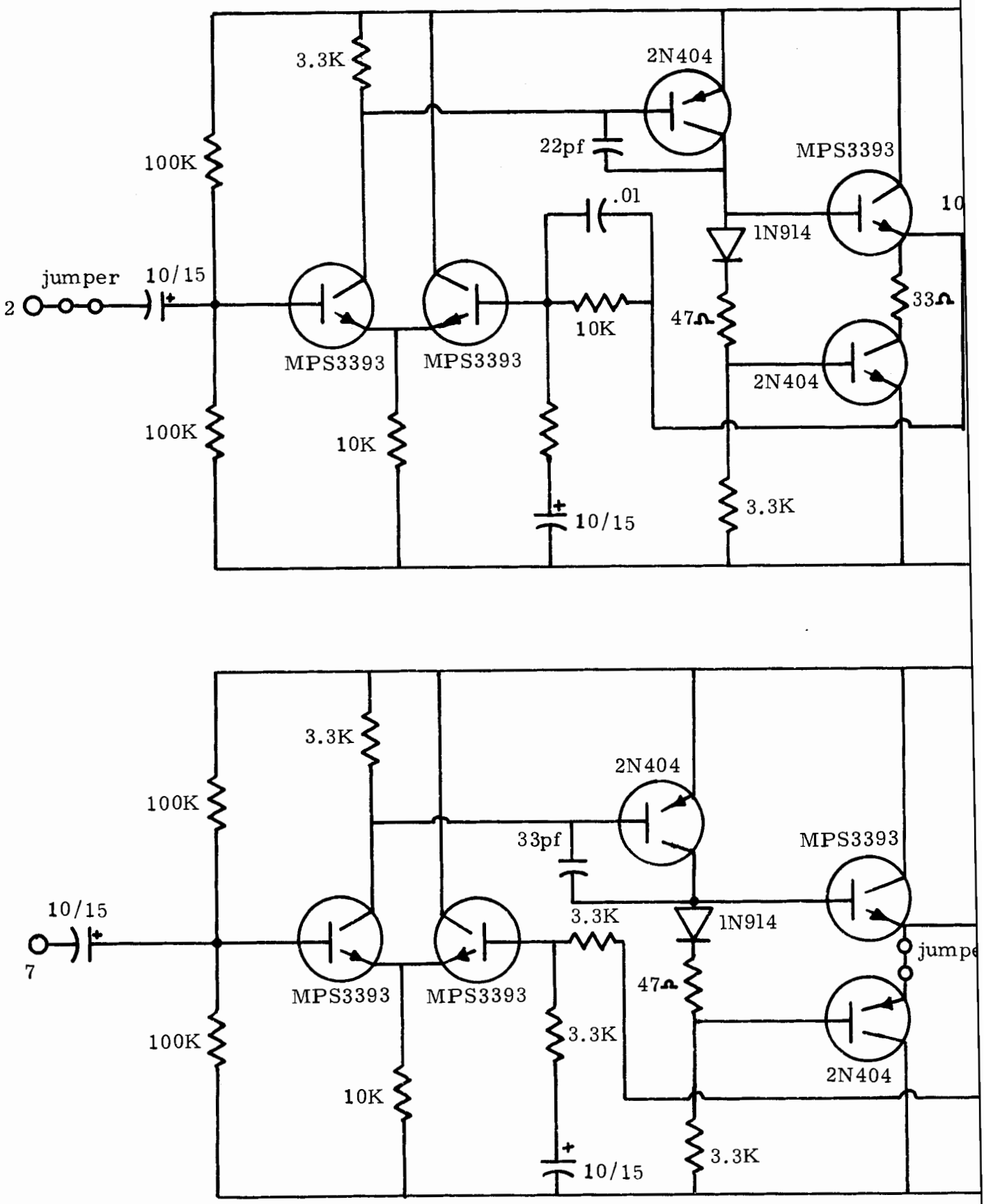
A cone-type tweeter of 16ohms impedance is driven by a complimentary emitter follower output stage similar to the driver stage in the hydrophone amplifier. Maximum power output is 250mw.

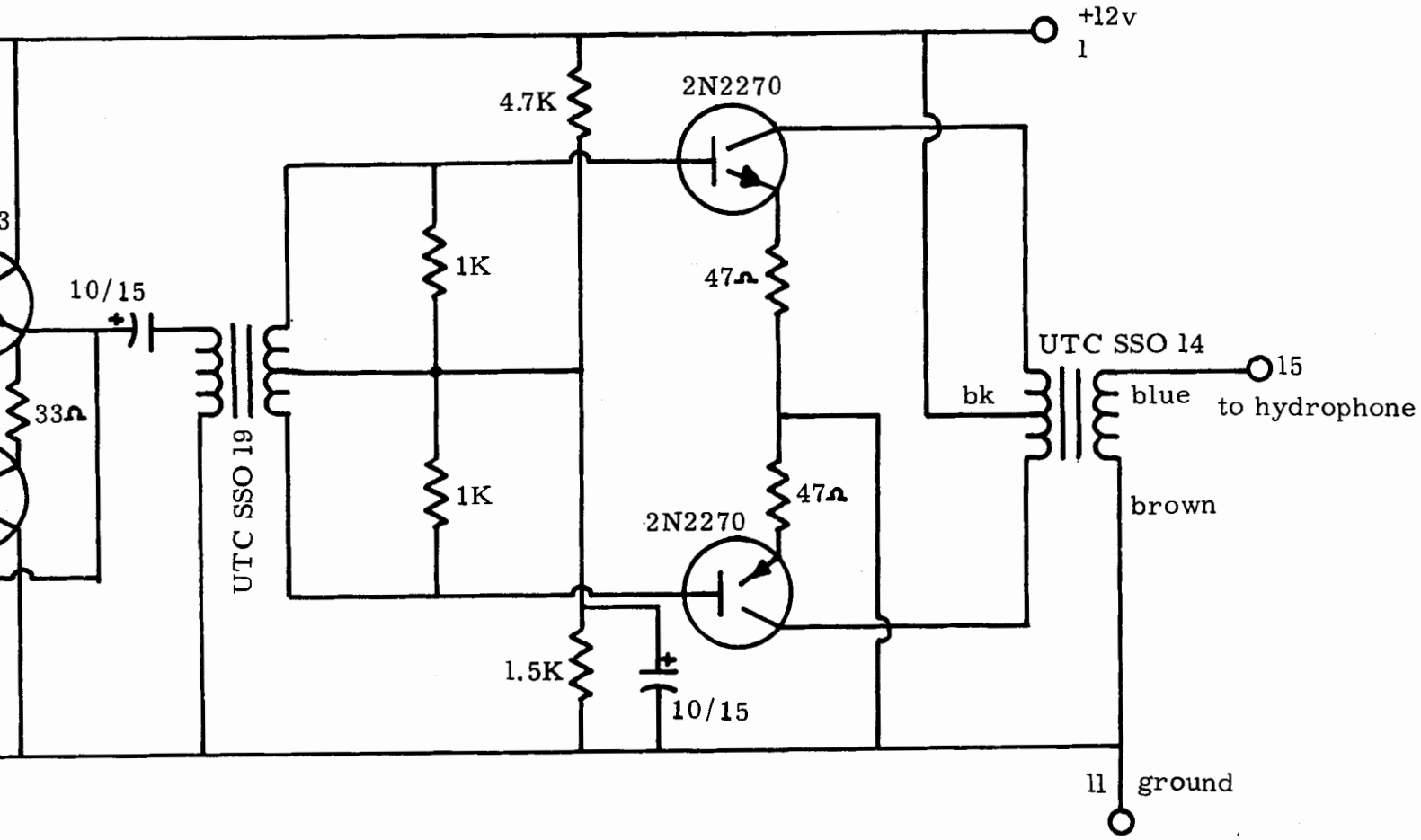
3. Vocal Pulse Output

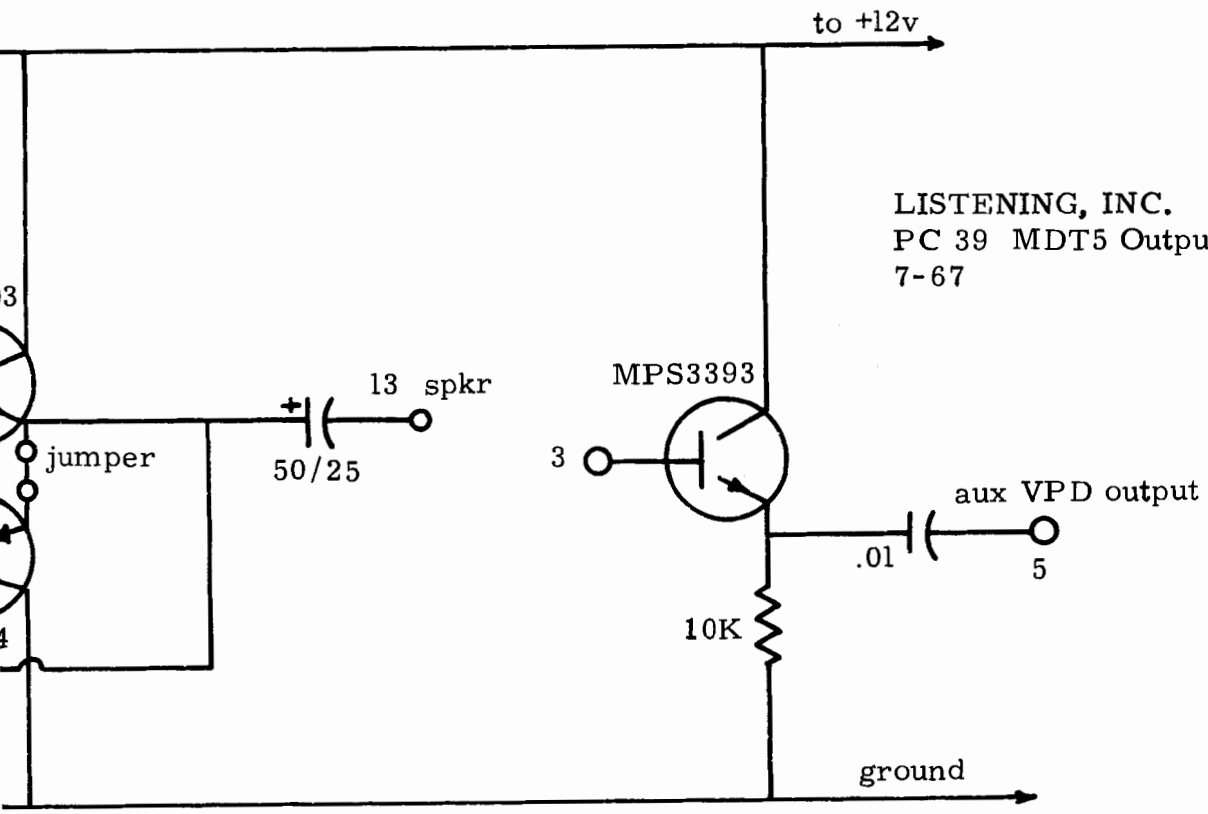
A simple capacitively coupled emitter follower stage provides a buffered vocal pulse reference output.

Pin connections:

1. + 12 volts
2. input to hydrophone amplifier
3. input to vocal pulse buffer
5. vocal pulse output to rear panel jack
7. input to loudspeaker amplifier
11. ground
13. output to loudspeaker
15. output to hydrophone


3.3K
2N404
100K
22pf
MPS3393
.01
jumper
10/15
2
1N914
33Ω
47Ω
10K
MPS3393
MPS3393
2N404
100K
10K
10/15
3.3K
3.3K
2N404
100K
33pf
MPS3393
10/15
3.3K
1N914
7
MPS3393
MPS3393
47Ω
100K
3.3K
10K
2N404
10/15
3.3K





LISTENING, INC.
PC 39 MDT5 Output Amplifiers
7-67

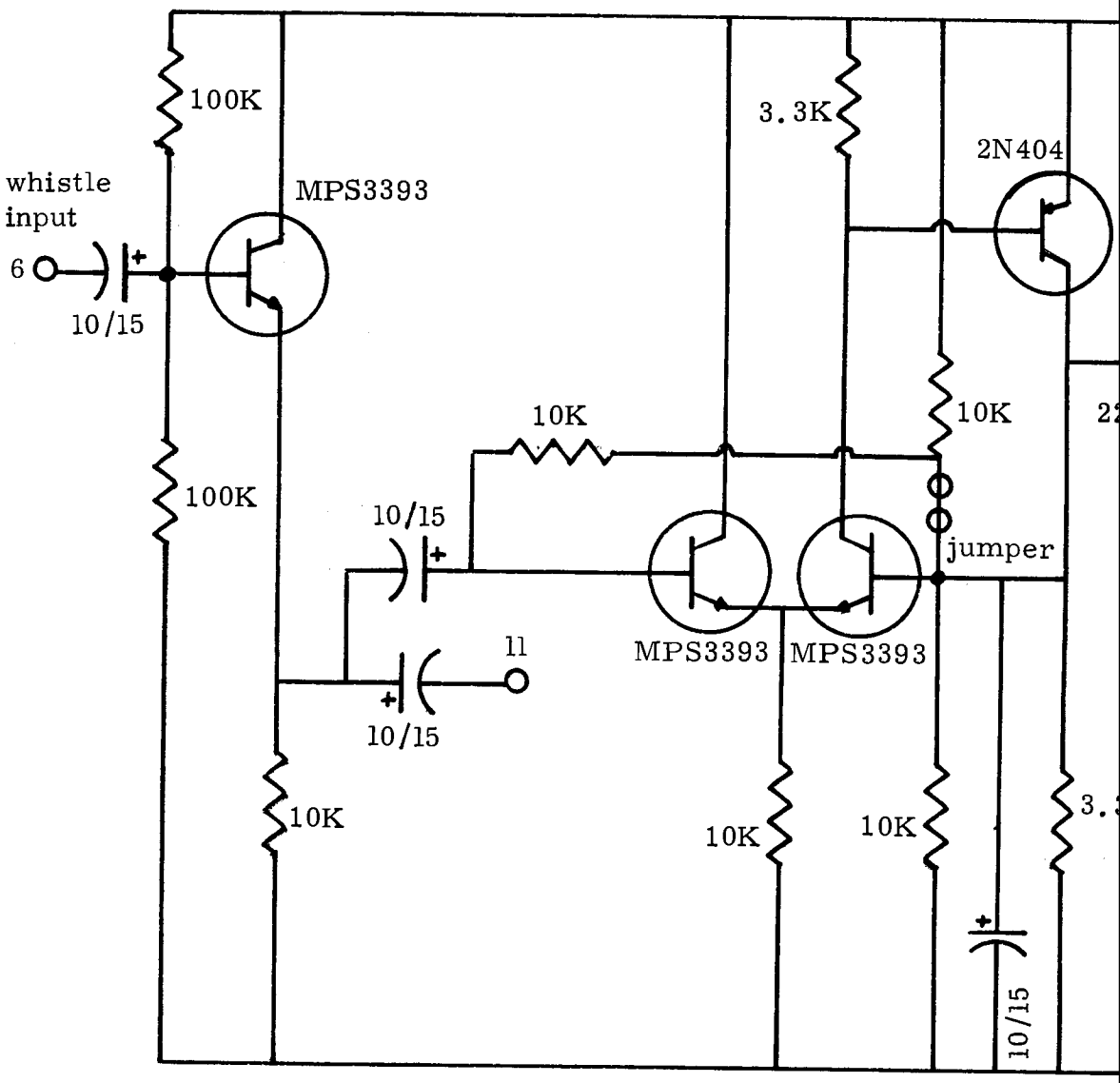
PC 38: Count Rate Meter

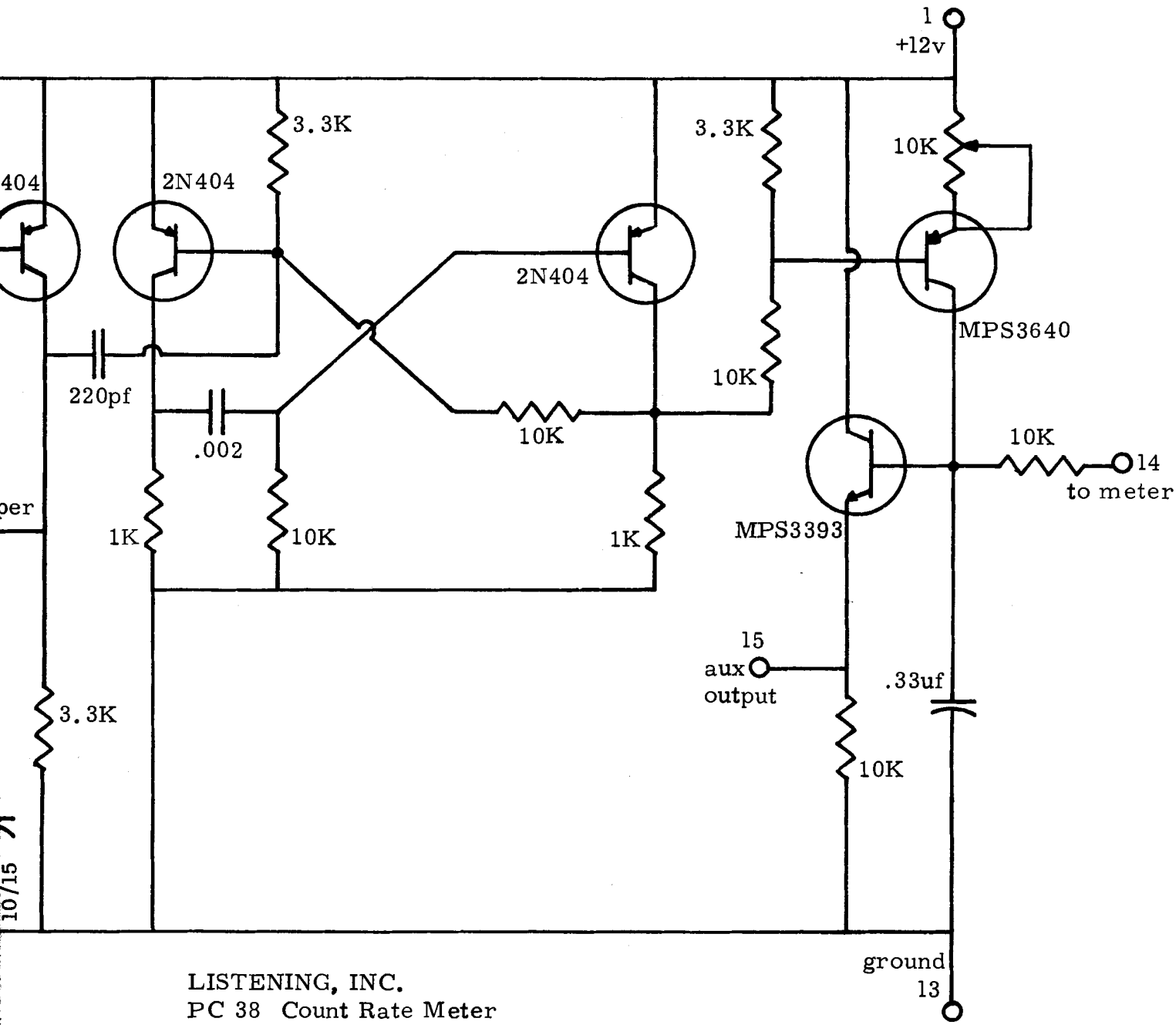
The whistle signal from the output of the FET signal gate is fed to an emitter follower buffer. The output of this buffer is brought out through pin 11 and is available at a rear panel jack.

The buffered whistle is then applied to a squaring amplifier; the output of which triggers a 15 msec delay multivibrator. The pulses drive an adjustable current source using a PNP silicon transistor. Calibration is effected by adjusting the potentiometer mounted on the pc card. The current pulses are integrated by a .33uf capacitor, from which two outputs are available: one to drive the 200uA panel meter via a 10k ohm resistor, and the other via a direct coupled, unbiased emitter follower. The emitter-base diode gap of this transistor suppresses the first 5 kHz of the frequency range.

Pin connections:

1. + 12 volts
6. whistle input
11. buffered whistle output
13. ground
14. dc output to panel meter
15. zero-suppressed auxiliary output to rear panel jack


100K
3.3K
2N404
whistle
input
MPS3393
6
10/15
10K
10K
100K
10/15
jumper
11
MPS3393
MPS3393
10/15
10K
10K
10K
10/15



LISTENING, INC.
PC 38 Count Rate Meter
7-67

PC 16: Voltage Controlled Oscillator

The drain-to-source resistance of a field-effect transistor with zero average drain-to-source voltage varies approximately as $R = \frac{Ro}{1-Vg/V}$ in which Ro is typically a few hundred ohms, V is the pinch-off voltage of the transistor, and Vg is the gate voltage. Thus linear functions of 1/R are linear functions of Vg.

One application of this relation is in the Wien bridge oscillator, for which the oscillation frequency is 1/2 RC. In the circuit of PC 16, if the field-effect transistors Q1 and Q2 are matched within 10% for I_{dss}, the curve of frequency vs. control voltage is linear within 1% over at least a decate (See characteristic curve below.).

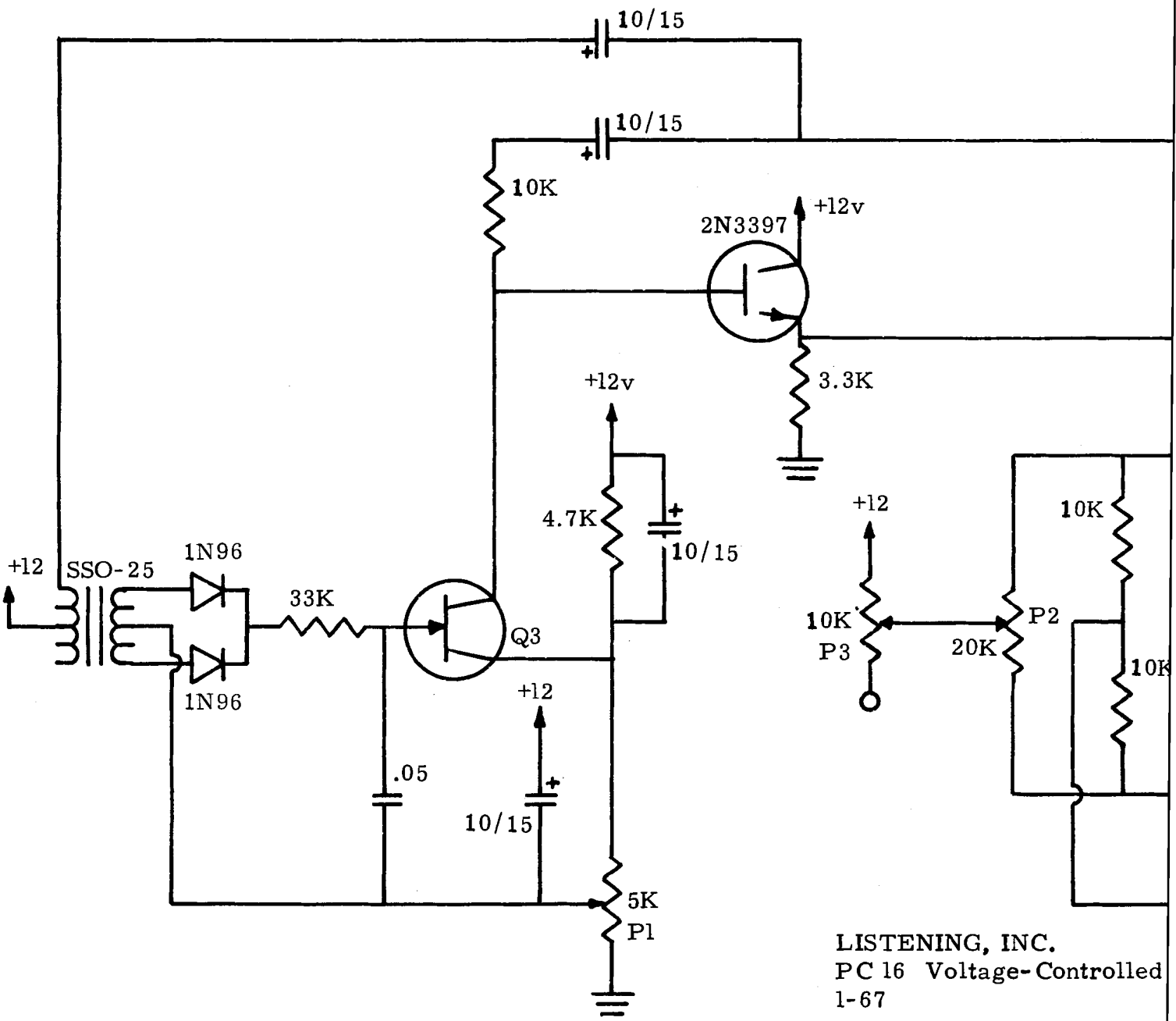
Referring to the schematic, an additional FET is used as an AGC element. The voltage across Q1 and Q2 is 50 mv. peak-to-peak, which holds the distortion to less than 1%. At this low voltage, the usual resistive bridge arms and high-gain differential amplifier generate excessive noise; hence, an actual Wien bridge connection is not used. Instead, the "half Wien Bridge" Q1-Q2-C-C is used as a low-Q tuned circuit, and the Q3 regulates the loop gain to sustain oscillation.

P2 is a linearity control which should be adjusted for minimum variation in signal voltage over the frequency range of the oscillator. This ensures that the resistances of Q1 and Q2 are tracking closely. In the circuit as shown, and with Q1 and Q2 mismatched by 10%, the output voltage variation is $\pm$ 0.1 db over a 10-1 frequency range. P3 varies the control scale factor (kHz per volt); zero control voltage gives maximum frequency. Output voltage is set to 1.5 volts peak-to-peak using P1.

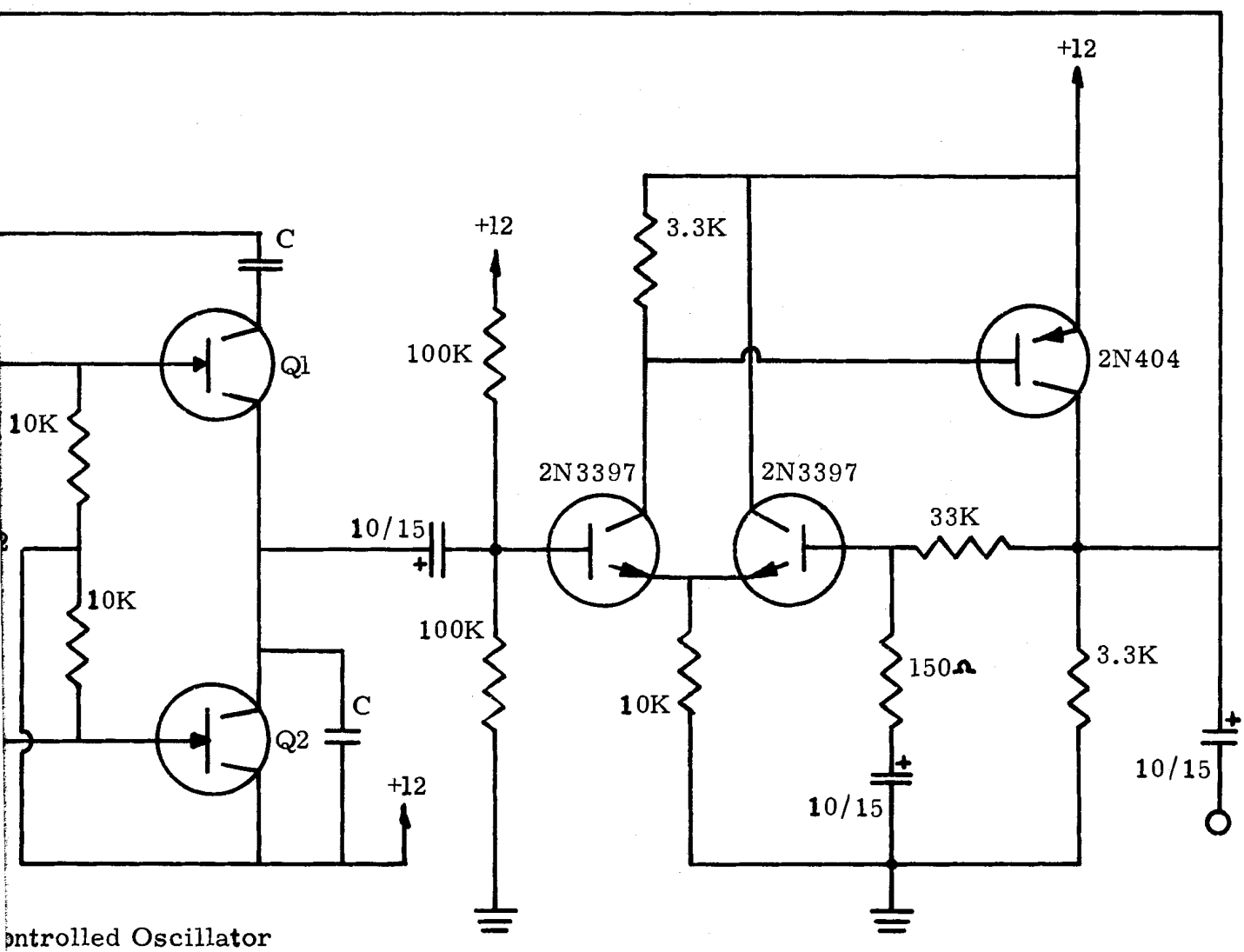
P2 is located closest to the connector end of the circuit board, P3 is in the middle, and P1 is farthest from the connector.

Pin connections:

1. + 12 volts
6. output
14. ground
15. control voltage



LISTENING, INC.
PC 16 Voltage-Controlled
1-67



ontrolled Oscillator

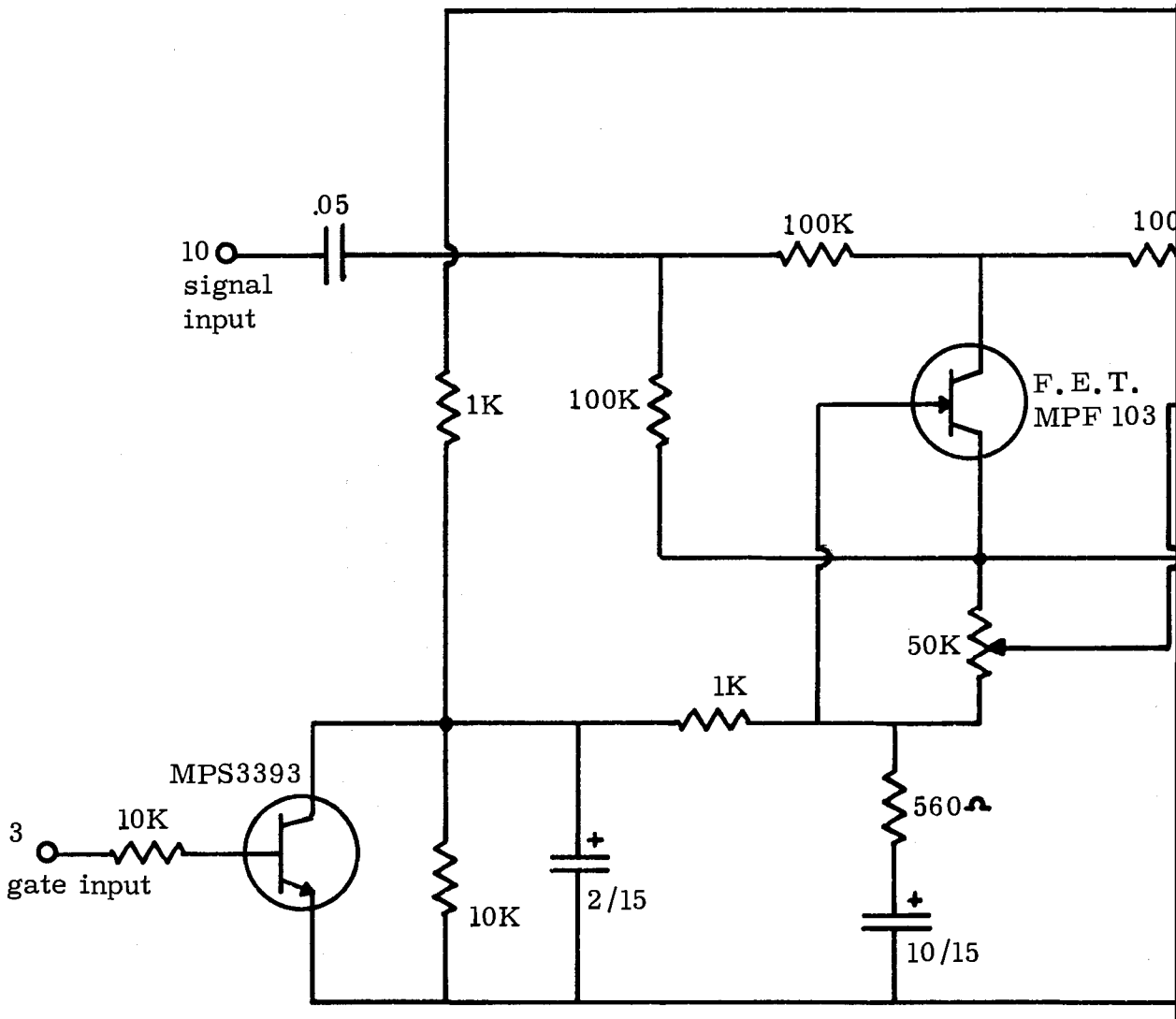
PC 40: Field-effect signal gate

The purpose of this circuit is to provide a smooth low-distortion leading and trailing envelope to the whistle output, with rise and fall times of 5 to 10 milliseconds and an on/off signal ratio of 90 db or greater. An input signal, not exceeding 100mv peak-to-peak, is applied to a pair of cascaded shunt attenuators employing field-effect transistors operated with no d.c. drain-to-source voltage. The gates of the FET's are driven by a switching transistor via an RC shaping network designed according to the figure below. The potentiometer is adjusted to balance the two FET characteristics for best envelope shape.

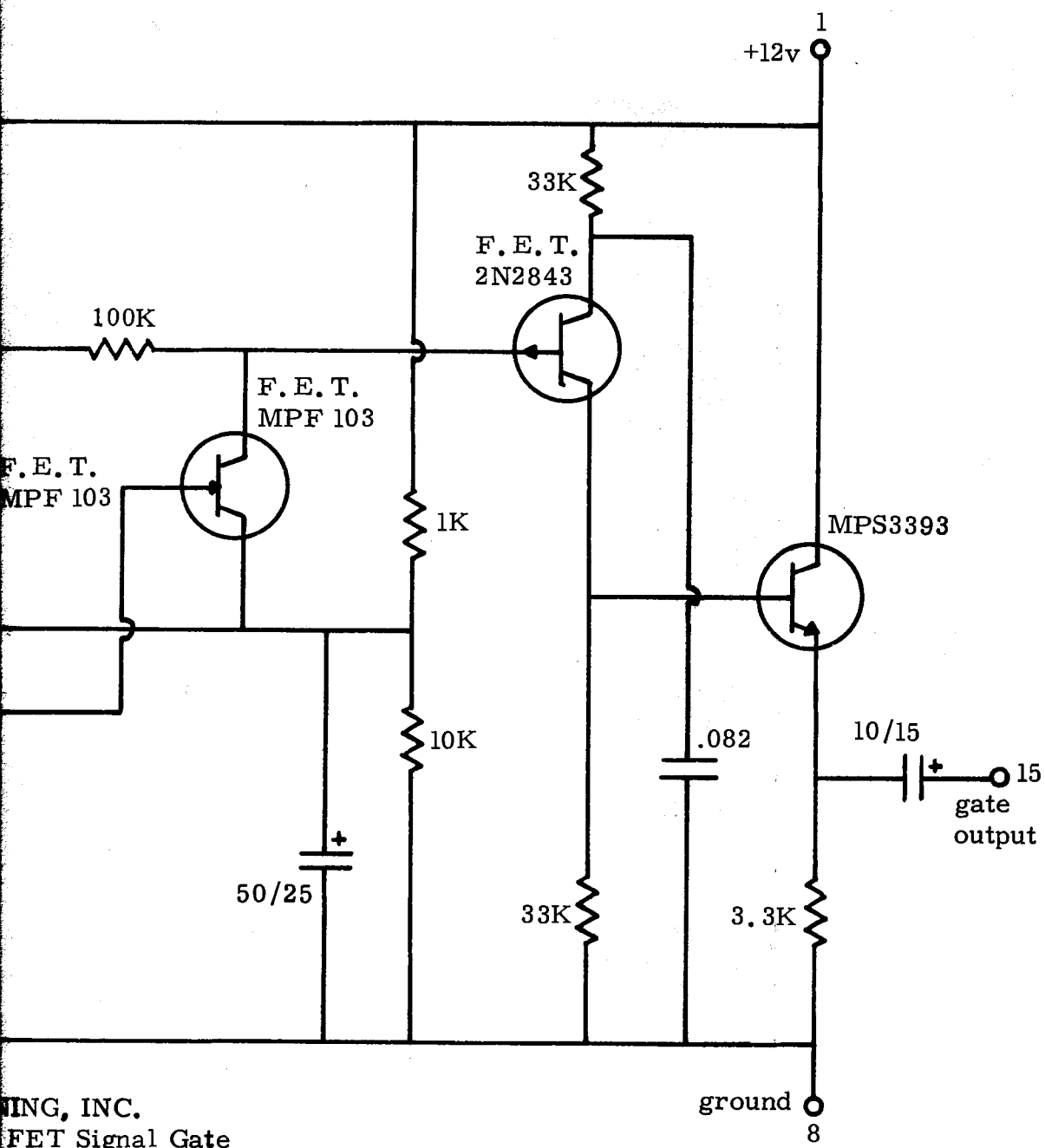
The attenuator output is delivered to an FET amplifier stage with a gain of approximately 25, and then to an emitter follower output stage.

Pin connections:

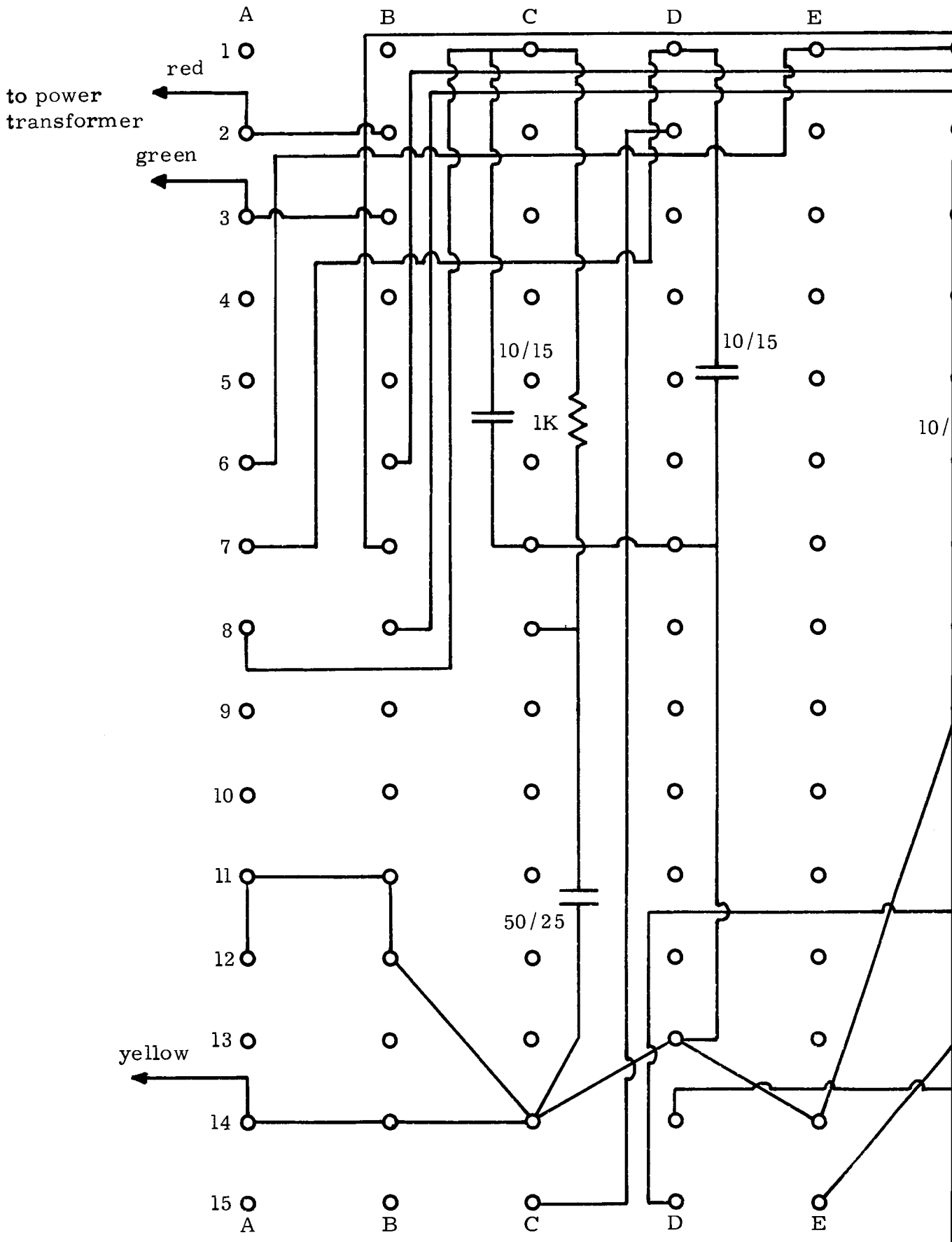
1. + 12 volts
3. gate input, 100mv p-p
8. ground
10. whistle signal input
15. gated whistle signal output, 1 volt p-p

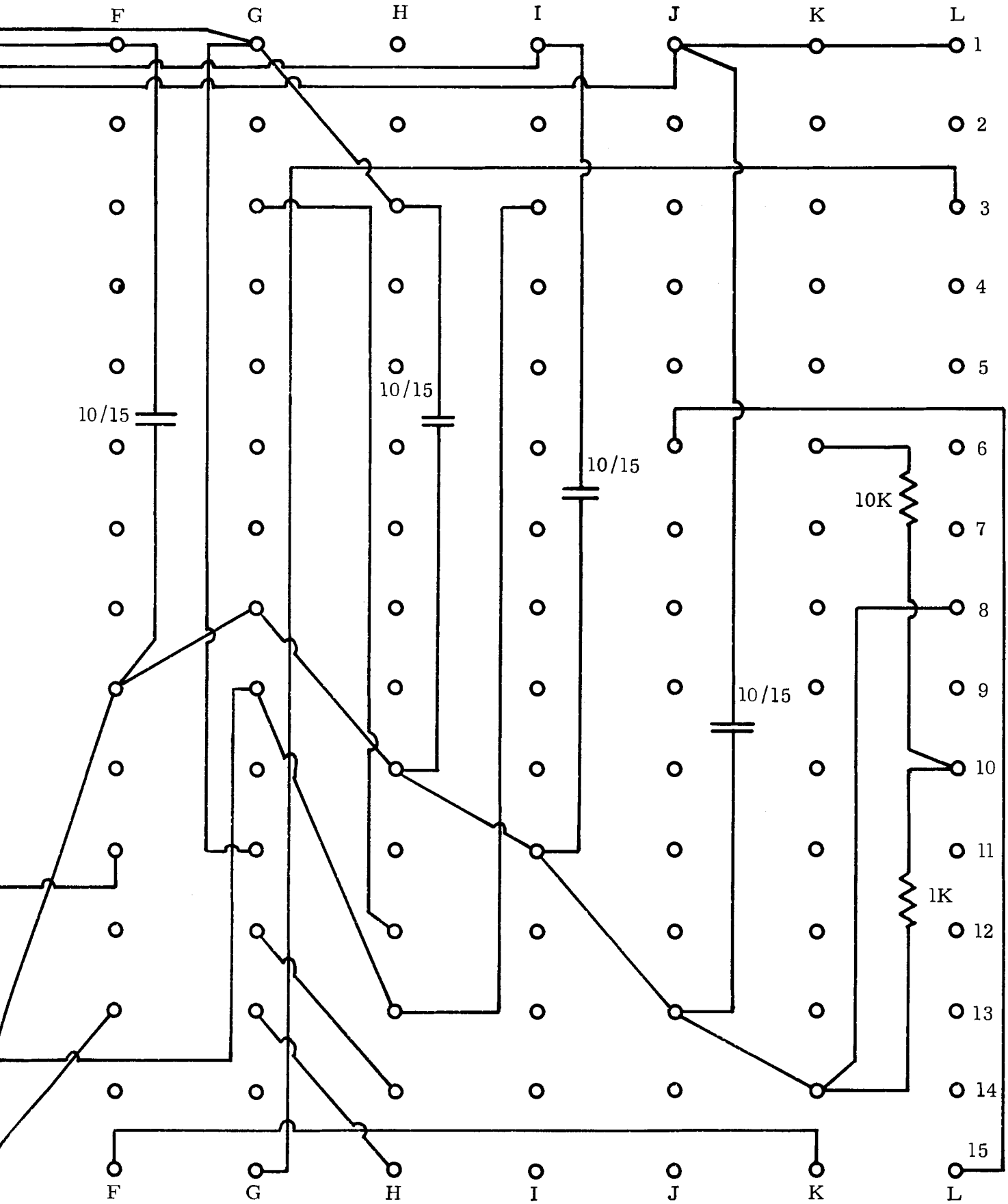


LISTENING, INC
PC 40 FET Sign
7-67

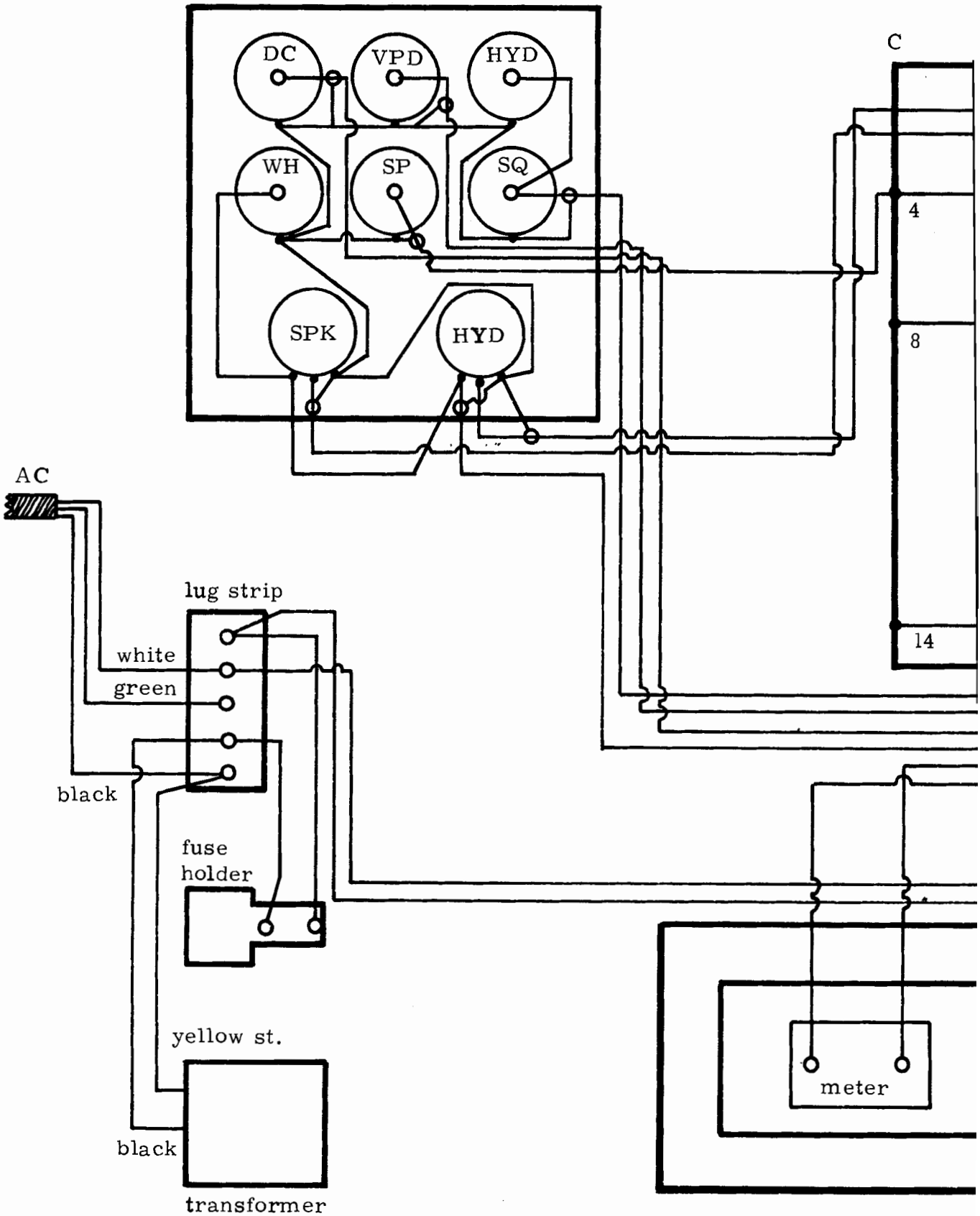


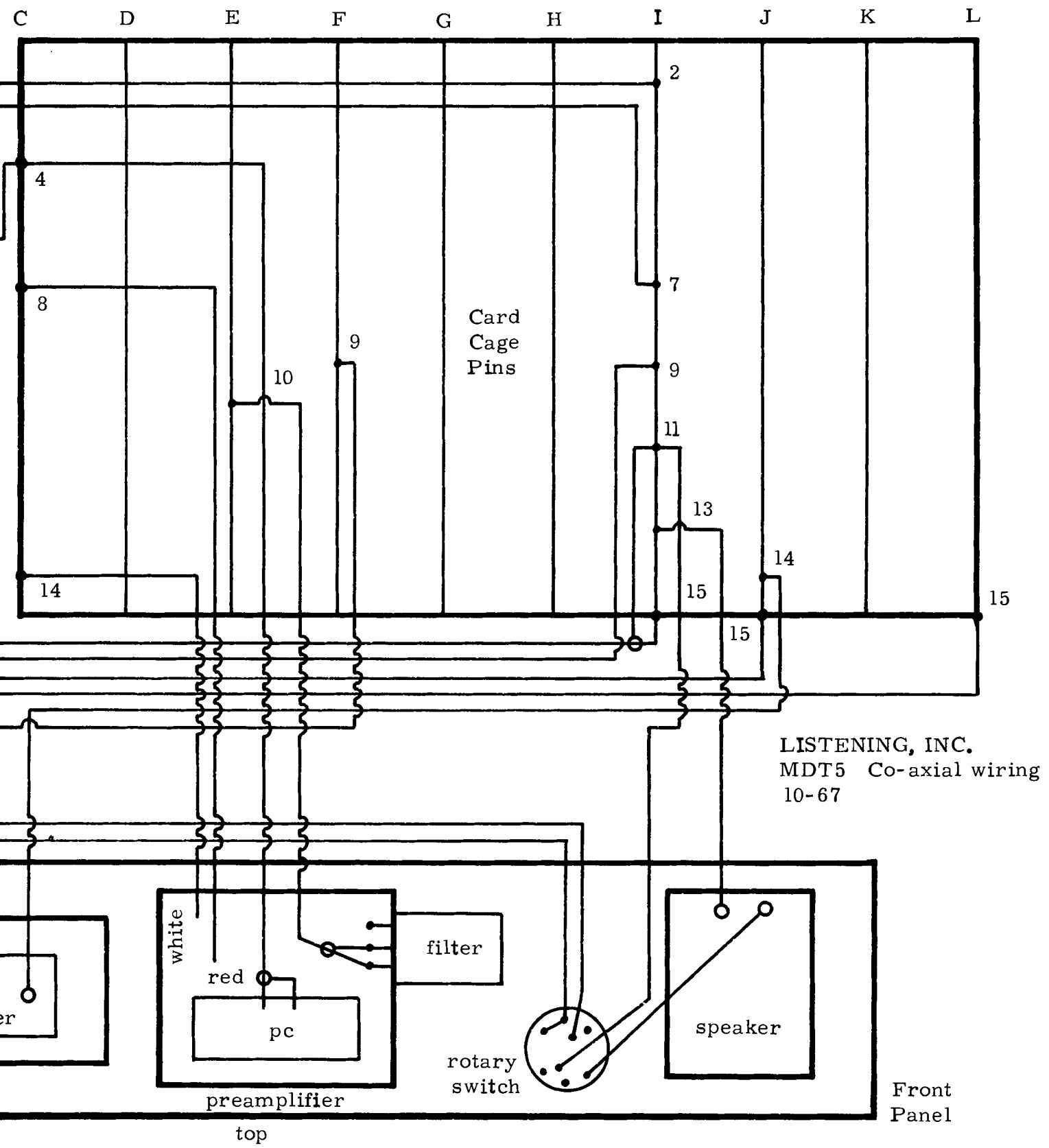
ING, INC.
FET Signal Gate


A
B
C
D
E
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
red
to power
transformer
green
yellow
10/15
1K
10/15
50/25
10/



LISTENING, INC.
MDT Card Cage Connector Wiring
9-67


DC
VPD
HYD
WH
SP
SQ
SPK
HYD
C
4
8
14
AC
lug strip
white
green
black
fuse
holder
yellow st.
black
transformer
meter


C
D
E
F
G
H
I
J
K
L
2
4
7
8
9
9
10
11
13
14
14
15
15
15
Card
Cage
Pins
LISTENING, INC.
MDT5 Co-axial wiring
10-67
white
red
filter
pc
preamplifier
top
rotary
switch
speaker
Front
Panel