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DIGITAL RECORDING AMPLIFIERS FOR A MAGNETIC TAPE RECORDER

by

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SUMMARY

To enable digital data to be recorded using an Ampex AR200 analogue tape machine two types of plug-in digital amplifiers have been developed. Separate amplifiers are used for NRZ data and for RZ data.

CONTENTS

1. INTRODUCTION

An Ampex AR200 tape recorder, available at these laboratories, is used primarily in aircraft evaluation studies. It has been shown[1] that analogue recording is required for data involving large bandwidth and digital recording is required for data requiring measurement to high accuracy. To reduce the quantity of airborne measuring equipment required and to allow time correlation between data recorded using digital techniques and data recorded using analogue techniques, the same Ampex AR200 tape recorder is used for both analogue and digital recording.

Recording amplifiers have been developed to provide suitable current drive for the recording heads. These amplifiers plug directly into the Ampex AR200 electronics unit which will also accept direct, frequency modulation (*FM*) or pulse duration modulation (*PDM*) amplifiers supplied by the manufacturer.

This report is the second of a series describing equipment developed at these laboratories for use in airborne data acquisition and ground station data reduction applications.

For reasons detailed elsewhere[2] both non-return-to-zero-mark (*NRZM*) and return-to-zero (*RZ*) type digital recording are made available. The *NRZ* amplifier described here supersedes the one described by Fraser[1] which required the head winding to be raised to a nominal 11 volt DC above ground.

2. DIGITAL INPUT SIGNALS

The Ampex AR200 electronics unit is fitted with one BNC type input connector for each recording amplifier. All input signal grounds are connected together electrically via the metal front panel of the AR200 electronics unit. Incoming digital signals are derived from the airborne data processor[3]. Both the Ampex AR200 and the data processor are powered from a nominal 27·5 volt DC (aircraft DC supply in the case of airborne measurements). To reduce the generation of ground noise voltages the data processor ground is isolated from aircraft power ground via a DC to DC converter power supply, so that grounding of the digital inputs (one side of which is connected to the common of the airborne data processor) is usually performed at the inputs of the Ampex AR200 electronics unit.

The digital signals derived from the data processor may be either non-return-to-zero-mark (*NRZM*) or return-to-zero (*RZ*). Separate recording amplifiers which will be referred to respectively as *NRZ* and *RZ* digital amplifiers (discussed in Secs. 3 and 4) have been developed to handle input signals in either of these two forms. For the serial system[3] of digital recording, either two *NRZ* amplifiers or one *RZ* amplifier may be used, and for the parallel system[3] of digital recording, to be incorporated later, seven *NRZ* amplifiers will be required.

The two *NRZM* input signals for the serial system of digital recording represent the data signal and an odd lateral parity signal (may also be thought of as a non-return-to-zero-space [*NRZ-S*] signal as per *IRIG*[4]). Amplifier input signal waveforms for a sample of typical digital information are indicated in Fig. 1. Logic levels for these input signals are compatible with the SN5400 series of TTL (transistor-transistor-logic) integrated circuits. These voltage levels are designated V_H (high) and V_L (low) respectively and fall within the ranges specified below:

$$2{\cdot}4 \text{ volt} < V_H < 5{\cdot}5 \text{ volt}$$

$$0 \text{ volt} < V_L < 0{\cdot}4 \text{ volt}$$

The *RZ* input signal is of the form indicated in Fig. 1. It is similar to that mentioned by Weber[5] but differs from that mentioned by *IRIG*[4].

The bit repetition frequency f_B (Fig. 1) may be varied in binary steps in the data processor according to the information rates required but subject to the limits indicated in the following table.

TAPE SPEED (inch per second)	MAXIMUM BIT REPETITION FREQUENCY (bits per second)
60	20480
30	10240
15	5120
$7\frac{1}{2}$	2560
$3\frac{3}{4}$	1280
$1\frac{7}{8}$	640

Limits on bit rate are determined primarily by the resolution of the magnetic tape recording and reproducing processes. Some preliminary examination of error rates indicates that the figures mentioned in the above table may be doubled. However the amplifiers described in this text are quite capable of operating at rates up to 40960 bits per second.

The duration of the *RZ* pulses (Fig. 1) has been made independent of the bit rate employed or the tape speed used and is set to 5 microsecond by the data processor.

3. NRZ DIGITAL RECORDING AMPLIFIER

In *NRZ* type recording the state of magnetization of the tape (either positive saturation or negative saturation) is consecutively reversed as "ones" are recorded. Hence recording head currents switching between levels to produce positive and negative tape saturation are required from the *NRZ* amplifier. The required recording head current waveform has a form similar to that for the *NRZ* input signal (Fig. 1). The function of the *NRZ* amplifier is therefore to provide a head current which will saturate the tape in one sense when the input is at level V_H (Fig. 1) and a current to provide saturation in the opposite sense when the input is at level V_L.

Frequently digital recorders employ recording head windings which are centre tapped. By connecting the centre tap to a supply rail and by switching current from one half winding to the other half winding, flux reversal is achieved. The appropriate driving signals in that case can be readily provided from a single supply by connecting alternate outputs of a flip-flop to each half winding. In contrast the analogue recording heads for the Ampex AR200 utilize single windings and hence current reversal must be provided. Since saturation flux may have to be maintained in one direction for a considerable period of time DC coupling to the head winding is essential.

Supplies of $+22V$ and $-20V$ are available at the plug-in recording card sockets of the AR200 electronics unit. Of these the $+22V$ supply has better regulation and lower ripple. To allow reversal of the recording head current positive and negative supply rails are required (unless the head winding is raised to some DC potential with respect to ground as described by Fraser[1]). Supply rails of $+15V$ and $-15V$ are derived from the $+22V$ input supply and the $-20V$ input supply respectively using series regulators in conjunction with the *NRZ* digital recording amplifier drawn in Fig. 2. (Further component details are given in the Appendix.) Short circuit output current from each supply is limited via *R*2 and *R*8 to about 60 milliamp. Booster transistors Q1 and Q4 enable the required output current (about 40 milliamp maximum from either supply) to be provided. Simultaneous adjustment of both output supply voltages (nominally $\pm 15V$) is provided by *R*4. Appropriate selection of *R*7 enables the output voltages to be made equal. Additional input filtering by way of C4 is required for the negative supply regulator.

In the *NRZ* amplifier Q5 and Q6 act as switches (being either fully "on" or fully "off"), Q7 acts as an emitter follower being always on, and Q8 and Q9 act as switches also. At the bit rates involved, allowing the transistors to saturate does not slow down the switching to any significant extent. When the input is high (at voltage V_H where $2{\cdot}4\text{v} < V_H < 5{\cdot}5\text{v}$) Q5 and Q9 will be on

whereas Q6 and Q8 will be off. Conversely when the input is low (at voltage V_L where $0v < V_L < 0{\cdot}4v$) Q6 and Q8 will be on whereas Q5 and Q9 will be off.

Head current provided, in each sense, by the output transistors Q8 and Q9 is 30 milliamp approximately, which is about the maximum level of current provided by the frequency modulation (*FM*) recording amplifiers. Current flows into the head winding "hot" terminal when the input is low and out of the head winding "hot" terminal when the input is high. Resistor R23 is connected in series with the head winding and is used for monitoring head current signals using the Ampex AR200 Test Set.

A photograph of the completed *NRZ* recording amplifier is given in Fig. 4(a).

4. RZ DIGITAL RECORDING AMPLIFIER

The head current signal from the *RZ* digital recording amplifier (Fig. 3) requires three levels to produce positive saturation, zero magnetization, and negative saturation of the tape. Normally the tape is unmagnetized (hence erasure of previously recorded data is required before *RZ* data is recorded). When a "one" is recorded a short pulse of current saturates the tape in one sense and when a "zero" is recorded a pulse of current saturates the tape in the opposite sense. The *RZ* recording amplifier produces a three-level recording current signal similar in waveform to that of the input signal (Fig. 1).

Identical regulators to those used for the *NRZ* amplifier are used for the *RZ* amplifier. The amplifier used here is the same as that used for the output stage of the *NRZ* amplifier.

In this case both output transistors Q8 and Q9 must be held "off" when the input signal is at level V_O (where $V_O = +0{\cdot}6v$ as indicated in Fig. 1). Diode *CR*1 ensures that Q8 remains "off" under these conditions.

Use of constant and relatively short duration pulses independent of the tape speed employed is justified[2] as the recorded wavelength approximates a recording head gap width at all tape speeds (provided the distance moved by the tape over the duration of the head current pulses is small compared with the gap width).

A photograph of the completed *RZ* recording amplifier is given in Fig. 4(b).

5. CONCLUSION

Plug-in digital recording amplifiers have been developed for recording digital data with the Ampex AR200 airborne analogue tape machine. Separate amplifiers are used for signals in *NRZ* and *RZ* format respectively as provided by an airborne data processor.

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MELBOURNE, Victoria, 3001.

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1. Fraser, K. F.	A Data Acquisition System Suitable For Airborne Applications A.R.L. Mech. Eng. Report 126, July 1969
2. Fraser, K. F.	Reduction Requirements For Data Acquired By Airborne Data Logger A.R.L. Mech. Eng. Report 130, March 1971
3.	Airborne Data Processor Paper to be published at A.R.L.
4. Telemetry Working Group of the Inter-Range Instrumentation Group	Telemetry Standards IRIG Document No. 106-69
5. Weber, P. J.	The Tape Recorder as an Instrumentation Device Ampex Corporation Publication 1963

APPENDIX

COMPONENT LISTS

Components used on the amplifier printed circuits have been given an identification label (or legend) consisting of a letter prefix followed by a number. The letter prefix identifies the class of component as indicated in the following table:

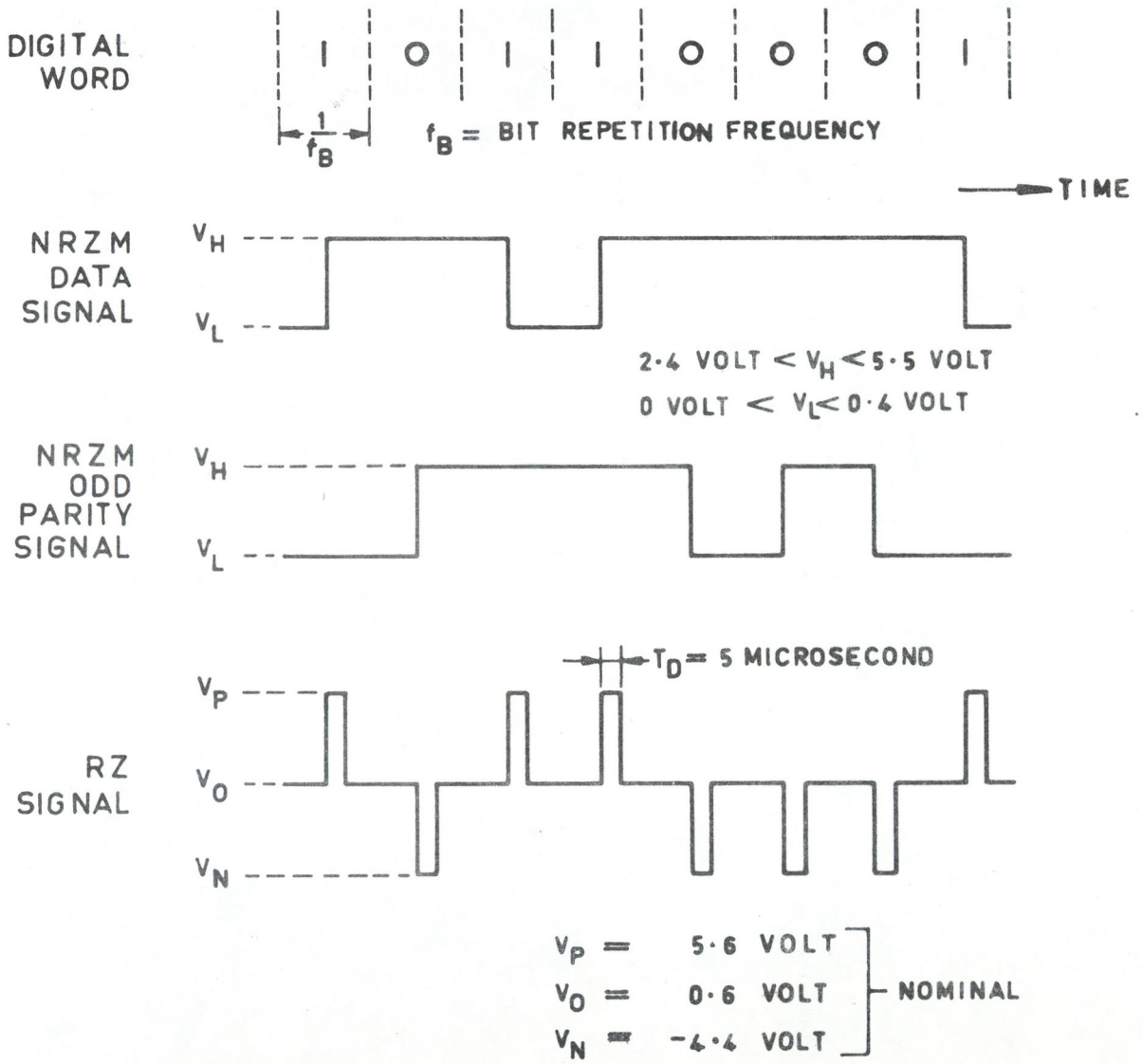
CLASS OF COMPONENT	LETTER PREFIX
Resistor	R
Capacitor	C
Diode	CR
Transistor or Integrated Circuit	Q

The following table list the components used in the digital recording amplifiers. Resistance and capacitance values given in this table (and also marked on the circuit diagrams) are respectively in ohm and picofarad ($K = 10^3$ and $M = 10^6$). Thus a capacitance value designated $100K$ means $0 \cdot 1$ microfarad and a capacitance value designated $4 \cdot 7M$ means $4 \cdot 7$ microfarad.

Components For NRZ and RZ Recording Amplifiers (FL-01-04-01)

LEGEND	VALUE	DESCRIPTION
R1	22	Resistor, fixed, metal film, 0·25 watt, Type RL20
R2	6·8	Resistor, fixed, wire-wound, 1 watt, Welwyn W21 Series
R3	16K	Resistor, fixed, metal film, 0·1 watt, Type RL07
R4	1K	Resistor, variable, wire-wound, Bourns 224P
R5	2K	As for R3
R6	22	As for R1
R7	SELECTED VALUE	As for R3, select for equal positive and negative supply voltages
R8	10	As for R2
R9	1·8K	As for R3
R10	1·8K	As for R3
R11	47K	As for R3
R12	11K	As for R3
R13	1K	As for R3
R14	1K	As for R3
R15	1K	As for R3
R16	1K	As for R3
R17	2·2K	As for R3
R18	330	As for R3
R19	820	As for R3
R20	820	As for R2
R21	470	As for R2
R22	470	As for R2
R23	10	As for R3 or R1
C1	100K	Capacitor, fixed, pacer filmite, 80VW, Sprague Type E-192
C2	100	Capacitor, fixed, ceramic, Vitramon Type VK33
C3	4·7M	Capacitor, fixed, electrolytic, tantalum, 50VW, Airtronic Type ATR
C4	150M	Capacitor, fixed, electrolytic, tantalum, 30VW, Sprague Type 109D
C5	100K	Capacitor, fixed, pacer filmite, 80VW, Sprague Type E-192
C6	4·7M	Capacitor, fixed, electrolytic, tantalum, 50VW, Airtronic Type ATR
C7	SELECTED VALUE	As for C2, select (if required) to prevent oscillation
CR1		Diode, silicon, Type 0A202
CR2		Diode, silicon, Type 0A202
Q1		Transistor, silicon, Type 2N3502
Q2		Integrated circuit, positive voltage regulator, Type LM105,
Q3		Integrated circuit, negative voltage regulator, Type LM104,
Q4		Transistor, silicon, Type 2N3502
Q5		Transistor, silicon, Type AY6101
Q6		Transistor, silicon, Type AY6102
Q7		Transistor, silicon, Type AY6102
Q8		Transistor, silicon, Type AY6101
Q9		Transistor, silicon, Type AY6102

Mating printed circuit connectors for these amplifiers in the Ampex AR200 electronics unit are Cannon Type PBAD 30-2AE-2G.



INPUT SIGNALS TO DIGITAL RECORDING AMPLIFIERS

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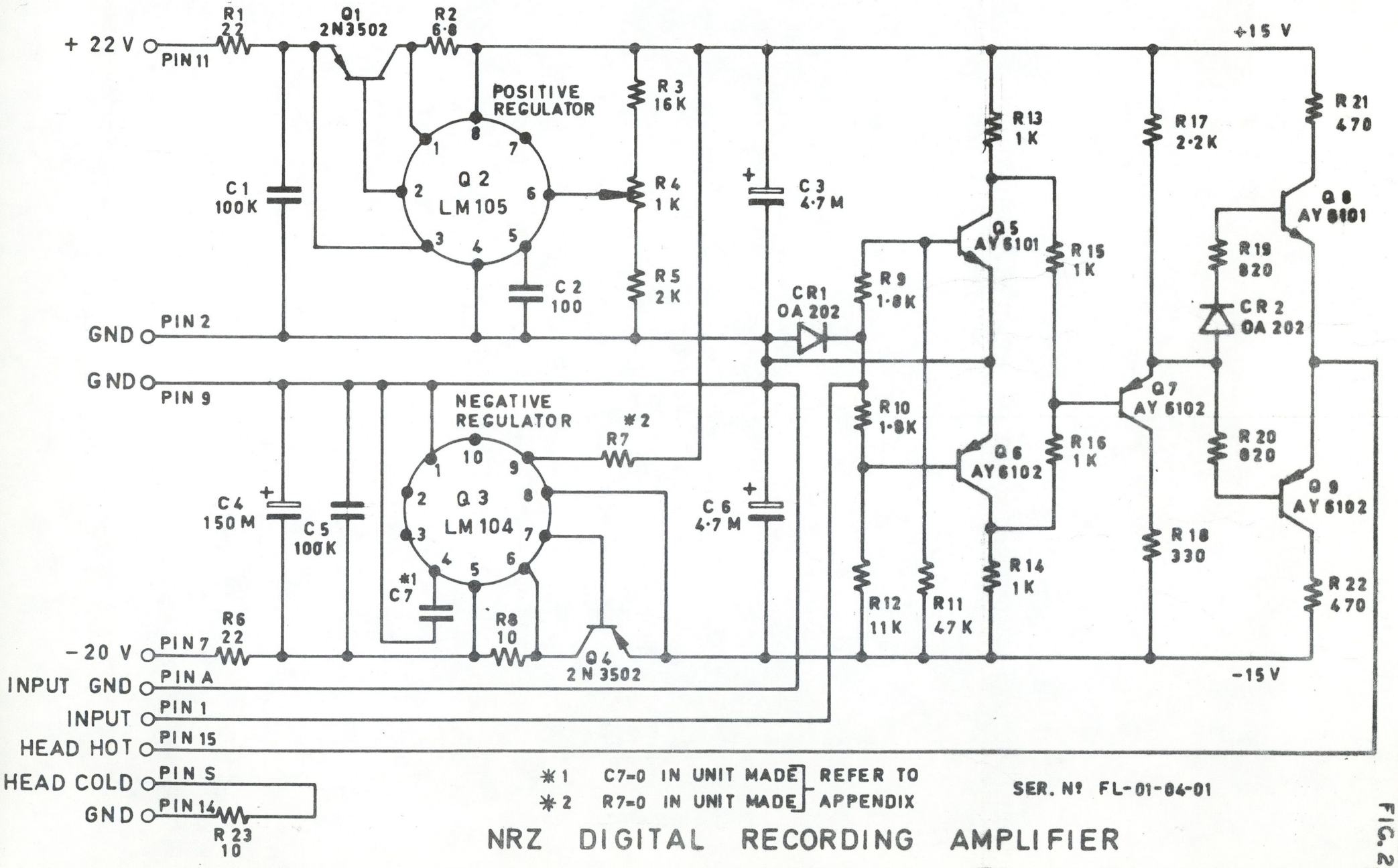
FIG.1



*1 C7=0 IN UNIT MADE
*2 R7=0 IN UNIT MADE
REFER TO APPENDIX

SER. Nº FL-01-04-01

NRZ DIGITAL RECORDING AMPLIFIER

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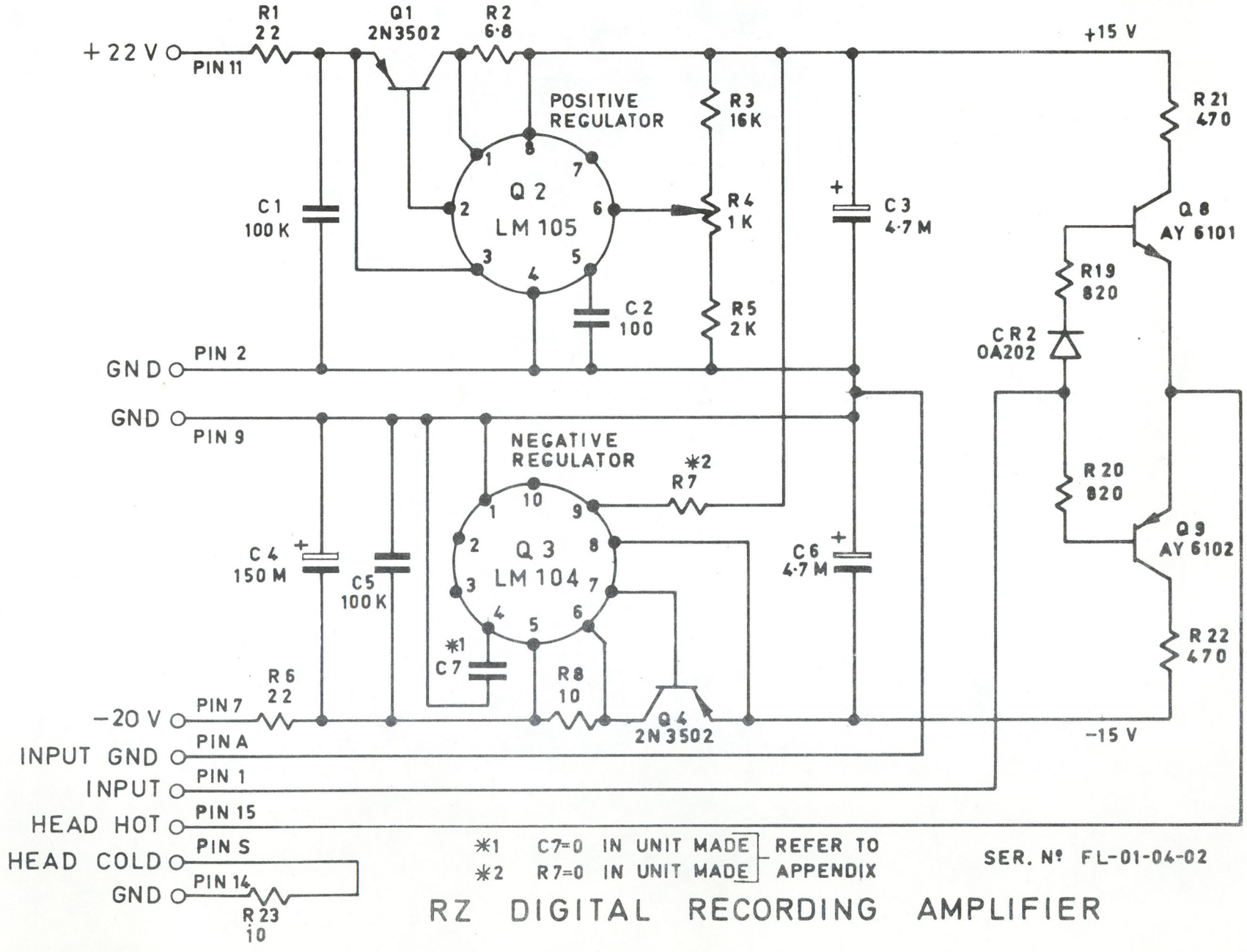
FIG. 2



RZ DIGITAL RECORDING AMPLIFIER

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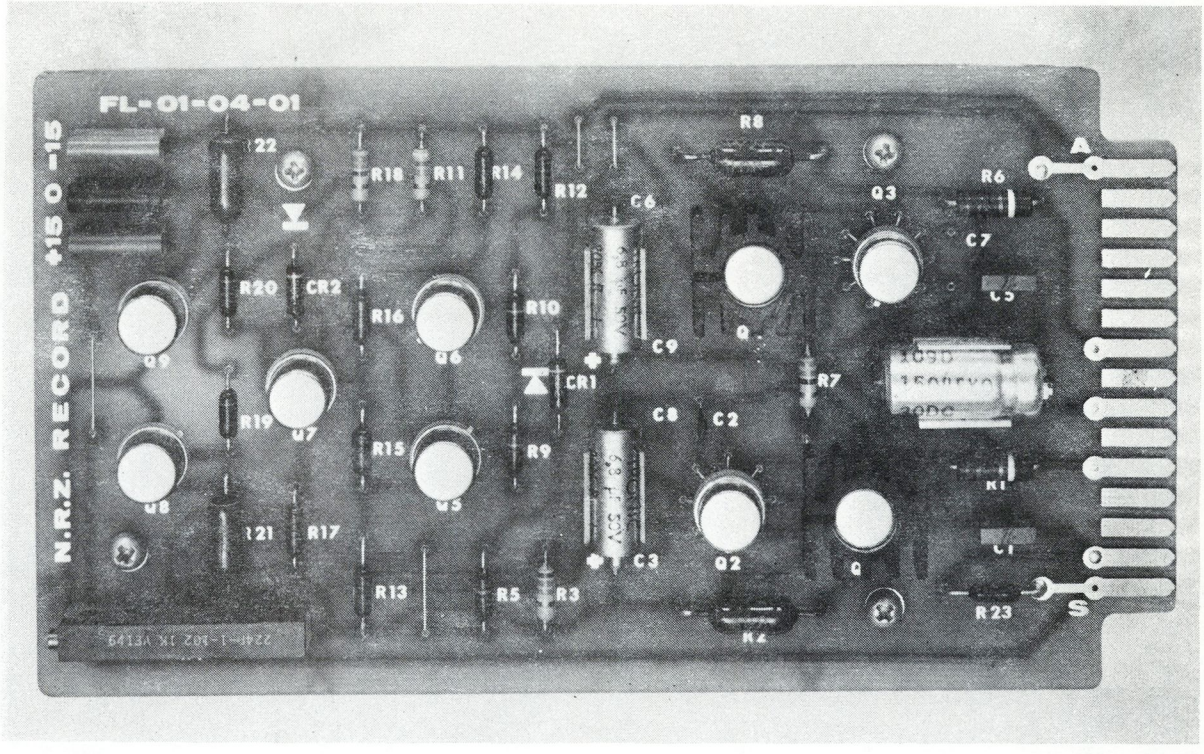
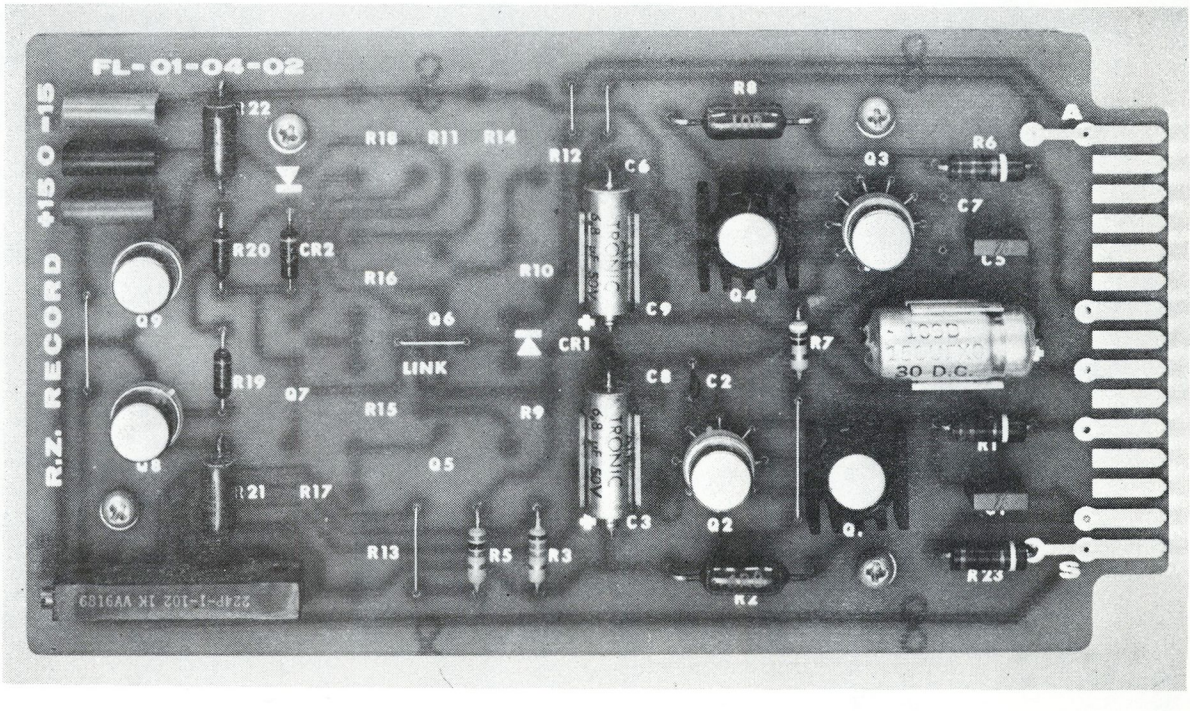
FIG. 3



(a) PHOTOGRAPH OF NRZ DIGITAL RECORDING AMPLIFIER



(b) PHOTOGRAPH OF RZ DIGITAL RECORDING AMPLIFIER