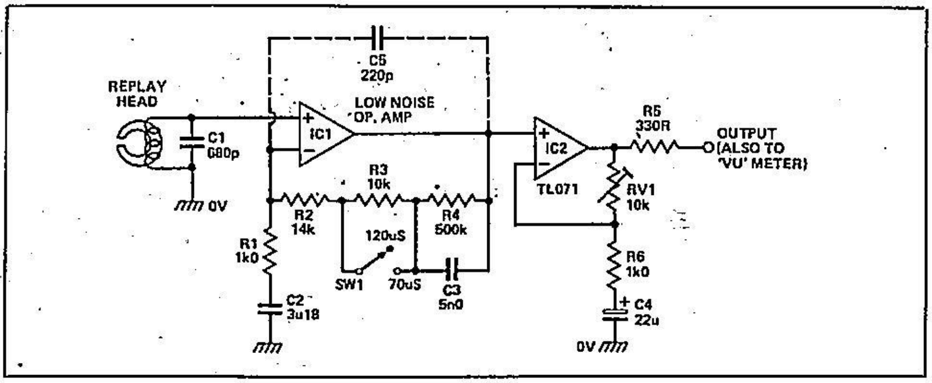

Fig. 13. A typical cassette replay amplifier giving the frequency response shown in Fig. 6.

cluding the Dolby processing — will show the types of circuit layout which will be needed in all these systems.

Replay Amplifier

The overriding consideration here is of low noise in the amplifier, since the input signal will only be about 0.5 mV, and a 60 dB S/N ratio will demand an effective input noise of 0.5 uV, from the amplifier and input circuitry. Fortunately, the effective bandwidth of the replay amplifier, because of its downward slope with frequency, is only 1 to 2 kHz. Nevertheless, this necessitates an effective input resistance of only some few thousand of ohms. We must be careful therefore, that we do not needlessly include input resistive components, to add to the 300-600 ohms of the head winding resistance. The required equivalent input noise resistance required by the desired S/N ratio does put most of the audio ICs out of consideration; however, there are a few, such as the Signetics/Mullard NE5533/5534, the Precision Monolithic/Raytheon OP27, and the Hitachi 12017, which would be satisfactory electrically. Of these, the latter has a non-standard base connection, which would make it awkward to substitute, whereas the ICs with the standard 741 type connections could be upgraded as better devices appear.

In commercial units, for reasons of economy, it is customary to use the same amplifier for both record and replay, with appropriate component changes accomplished by multiple switching. However, from the point of view of the amateur constructor, and certainly for the ease of explanation, it makes life easier to show the record and relay circuits as separate entities. I have shown a suitable circuit design, based on a low-noise op-amp, in Fig. 13.

In this circuit, the output of the replay head (through suitable switching if it is combined with the record head) is taken directly to the input of IC1. The gain-frequency characteristics of this stage are determined by the RC network in its negative feedback loop. Referring back to Fig. 6, we see that the LF gain is rolled off at 50 Hz (a 3180 uS time constant), at a gain of 500. From this we can infer that the total resistance in the feedback path, from output to -ve in, must be 500K, if R1 is 1k0. Also, the time constant of R1C2 must be 3180sS. If R1 is 1k0, then C2 must be 3180 nF or 3.18uF. This shows how simple the use of 'time constants' makes the task of working out circuit component values.

Now, we require the gain to decrease linearly from 50 Hz to 1.33 kHz (in the case of the 120uS equalization) or 2.27 kHz (for 70uS). This we can accomplish by means of C3 and R2 and R3, switched by S1. If C3 is 5n0F — this must have an impedance greather than 500 k at 50 Hz, but we can't afford to go too high (Z_{c50} for 5n0 is 636k) — then the 120uS time-constant will be given for a value of R2+R3 of 120/5 = 24k. Also, the 709uS time constant will require R2 on its own, to be 70/5 = 14k. So R2 = 14K and R3 = 10K.

IC2 is a simple output buffer stage, to give an adjustable gain of 1 to 11, depending on the setting of RV1. R5 gives some output isolation, and the value of C4 is chosen so that the LF response is adequate. Since 3.18uF gives a -3 dB point at 50 Hz, 22uF will give a -3 dB point at 7 Hz, which is low enough.

A small circuit refinement is the inclusion of C1 across the cassette head to tune the head, with its internal inductance, to some 15 to 18 kHz. The actual value will depend on the head inductance, and can be calculated from the formula f° = ½ LC. A value of 680-820 pF will be in the right order. This limits the wideband noise output from the head, and reduces the chance of noise being worsened by cross-modulation within the input IC amplifier.

C5 across the first amplifier stage performs a similar bandwidth limiting function. This may not be acceptable for the NE5533 or 5534, so regard it as an option.

Record Amplifier

This has to meet five design requirements. The output must be large enough to drive the cassette record head through the 47k swamp series resistance. A normal IC op-amp will do this quite well, with very low distortion, when operated from ± 12 or 15

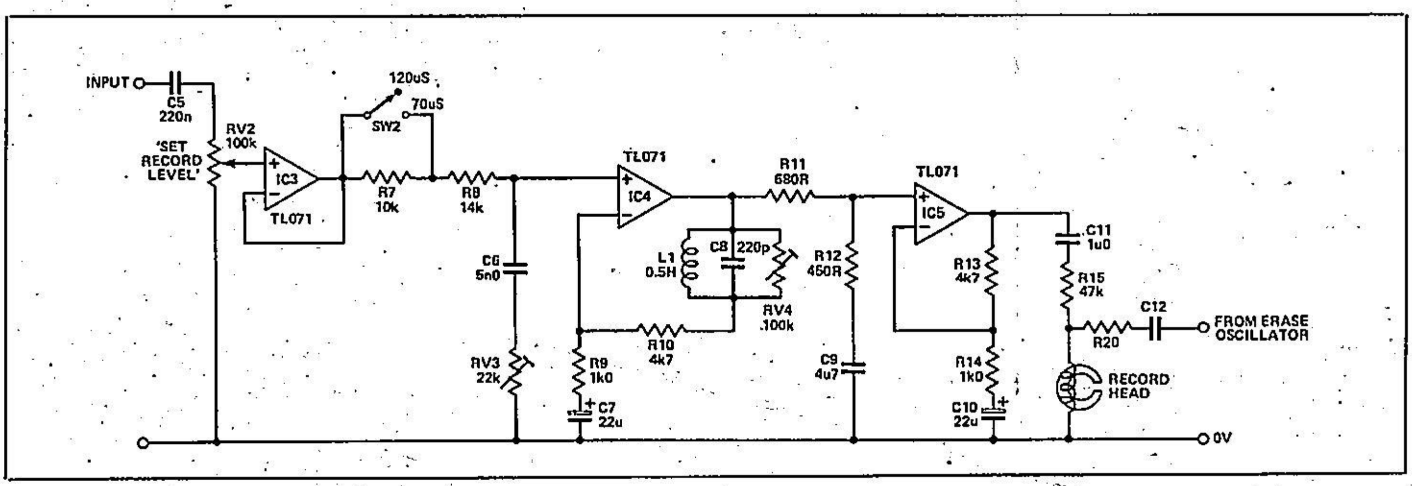

Fig. 14. A typical cassette record amplifier giving the frequency response shown in Fig. 12.

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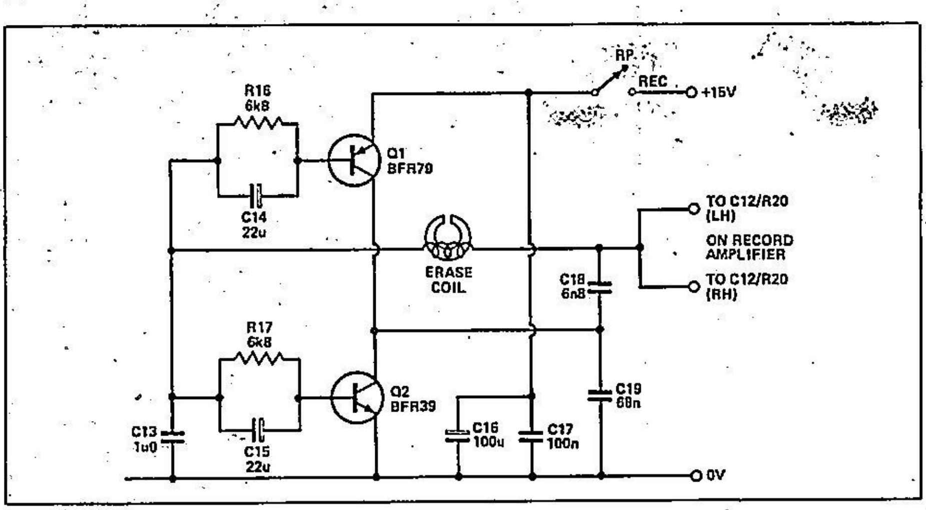

Fig. 15. A cassette recorder bias and erase oscillator.

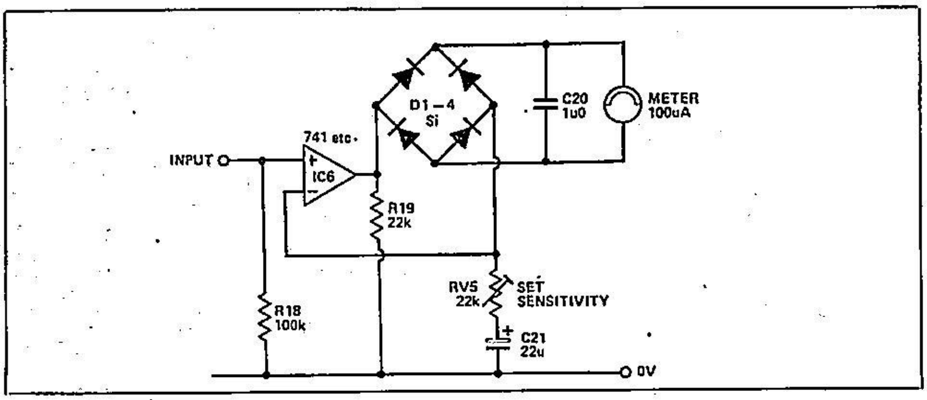

Fig. 16. A simple recording level meter circuit.

V supplies. It has to provide a means for adjusting the record signal level. It has to provide a modicum of bass lift, say +3 dB at 50 Hz and +6 dB at 30 Hz, to compensate for the specified roll-off in the replay curve. It has to provide the specified de-emphasis at 70uS or 120 uS as required, and finally, it has to generate a peak, of +15 dB or so, at 15 kHz, to offset the head losses.

A circuit which will meet these requirements, and give a high quality performance, is shown in Fig. 14. In this, IC3 is a simple unity gain buffer amplifier, which has a low output impedance but yet allows a high impedance input to the record level control. R9, R10, C6 and S2 generate the 70 and 120uS de-emphasis characteristics. Since we have calculated suitable values for these for the replay amp., we can use these again. R11 is a trimmer resistor which we can use to assist in getting an optimally flat overall frequency response, by lessening the extent of this de-emphasis. IC4 is a gain stage with a low-frequency gain of 5.7. However, the LCR network formed by L1, C8 and RV4 is tuned to resonate at 15 kHz; this makes the gain increase at this frequency to an extent which is governed by the Q of the circuit, which can be adjusted by RV4 (for the tuned circuit, f_0 = ½ LC).

R11, R12 and C9 generate the boost at 50 Hz (3180 *us*, the time constant of C9R11) and the levelling off at 30 Hz (5300 *us*, the time constant of C9 (R11+R12)). IC5 is another straight gain stage, with a gain of 5.7, and this drives the record head through C11 and R19.

Overall, the gain of this amplifier is 30 at 1 kHz, which allows a 5 V RMS output from IC5 for a 170 mV input. Bias is applied to the head directly from the bias oscillator circuit.

Bias and Erase Oscillator

In reel-to-reel recorders, and in the rather more up-market cassette decks, a separate transformer would be used, both as the coil in the LC erase oscillator, and as a transformer coupling from a secondary winding to drive the erase coils and HF bias circuitry. However, in cassette recorders, provided it is not proposed to use 'metal' tape (for which very high erase voltages across the erase head are needed to achieve the required 60 dB erasure of previously recorded signals), it is quite satisfactory to use the erase head itself as the coil in the oscillator circuit, and up to 25 V RMS can be generated by the oscillator circuit shown in Fig. 15. A small proportion of this is then bled off through an RC network to bias the record head.

The actual RMS bias voltage across the head for optimum recording characteristics must be determined by experience for the record head and tape being used, but it will probably lie somewhere between 5.5 and 10 V RMS, as measured by a wide-bandwith AC milli-voltmeter. Understandably, from Figs. 10 and 11, there is no such thing as a 'correct' bias voltage setting. All that one can do is to try to choose a voltage at which all of the conflicting tape characteristics are partially satisfied, in your own judgment. As simple a solution as any is to design the record and replay amps so that they give a reasonably good frequency response, and then trim the 'bias' voltage so that the overall frequency response is as level as possible. Obviously, if one has good instruments and a lot of time to experiment, a better compromise value could be found.

In Conclusion

These then are the basics of tape recording, and the circuits shown above, when used with a suitable cassette mechanism, an adquate power supply (derived for example from a pair of + and - output 12 or 15 V IC stabilizers and a decent quality pair of supply line bypass capacitors) and some form of recording level indicator which could well be a simple one-IC AC millivoltmeter of the form shown in Fig. 16, could be used to make a quite high performance DIY cassette recorder. However, being realistic, I do not really believe that anyone would want to build a cassette recorder — unless of course, they had most of the parts already at hand — when they could buy one, ready built, and with all the trimmings, for about two thirds of the wholesale price of the components.

Nevertheless, it is useful to know what kind of circuitry is employed in tape recorders, and what the problems and limitations are, so that one might rebuild or modify existing unsatisfactory equipment, or simply know where the strengths and weaknesses of the method lie. Also, because every tape or cassette recorder represents the end product of a very large number of design compromises, which affect distortion, modulation noise, overload characteristics, flatness of response and background noise level, as well as the straightforward HF bandwidth, cassette and reel to reel tape recorders differ in sound quality, one from another, very much more than, say, audio amplifiers or tuners do. Evaluation of the effect of these many compromises is truly an appropriate field for the 'subjective' listener.

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