BY DOUG DeMAW, W1FB

DOUG'S DESK

CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORY

A Catalog of Practical Circuits—Part I

Among the many interesting letters I receive from readers are those which contain questions about basic, practical transistor circuits. Some who write want to know the correct values for resistors and capacitors, depending upon the frequency of operation, for bipolar transistors, FETs, and ICs. The best I can offer are workable ball-park values that guarantee good performance, but not necessarily peak performance.

Some years ago I wrote *The ARRL Electronics Data Book,* in which I added several pages of practical single-stage circuits with assigned component values. That portion of the book was popular among those who tinkered and built equipment, but who lacked design expertise and experience. Some of the circuits presented in the book could be combined to provide complex circuits, such as receivers and transmitters, or portions thereof. This short series of articles presents a collection of individual and combined circuits that may be photocopied and kept in a notebook for future use by those who are learning electronics, or by those experimenters who wish to build circuits. In subsequent columns I will present small-signal and power RF amplifiers, IF amplifiers, oscillators, VFOs, mixers, balanced modulators, AGC circuits, and more. Each installment will contain a description of the performance characteristics of the particular circuit.

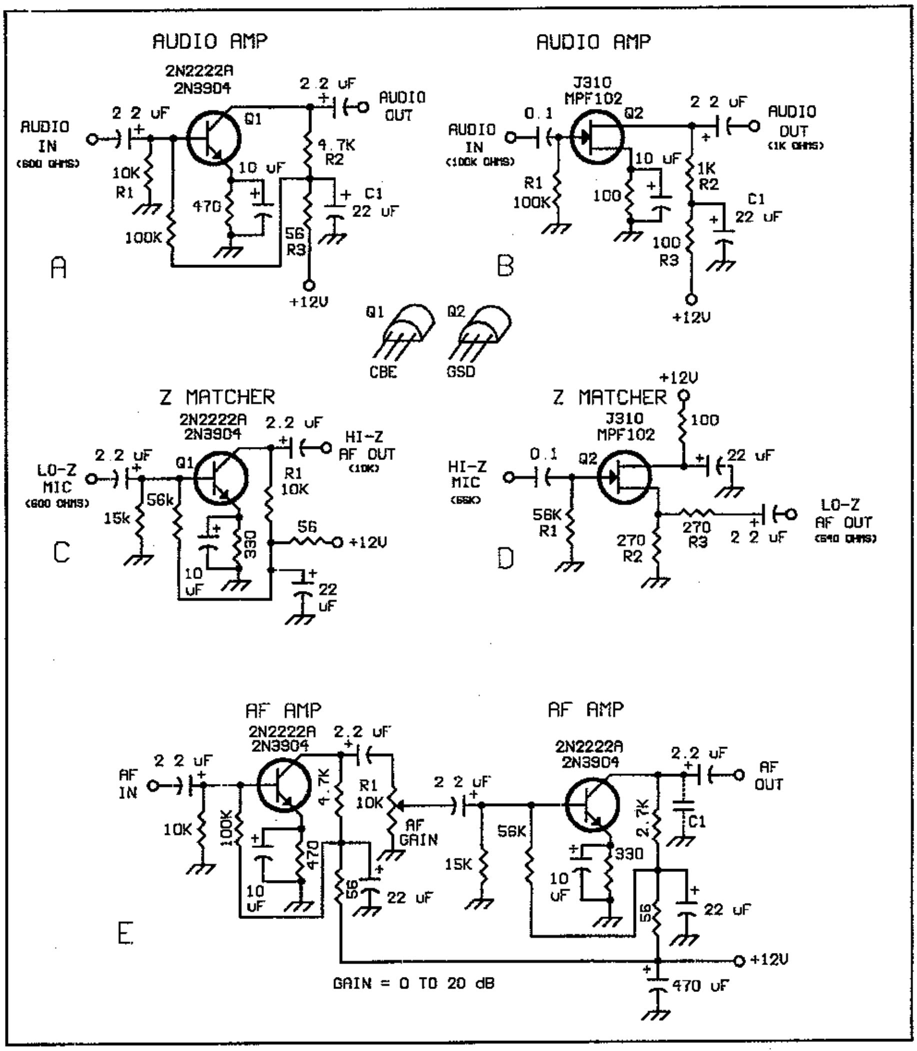

Fig. 1— Basic circuits for audio stages with assigned practical component values. Each circuit is discussed in the text. Capacitors without polarity marked are disc ceramic. Polarized capacitors are electrolytic or tantalum, 16 VDC or greater. Resistors are 1/4 watt carbon or carbon film.

Some Useful Audio Circuits

Fig 1 represents the first of the circuit catalog series. Single-stage audio amplifiers using a bipolar transistor and an FET are seen at *A* and *B*. The input and output impedances listed in fig. 1 are approximate. Actually, the fig. 1(A) circuit input impedance (Z) may be as great as 1000 ohms, but is typically in the 600 ohm range. The stage output Z is determined somewhat by the value of R2, which is actually in parallel with the unloaded characteristic output impedance of Q1. Therefore, the true output Z is slightly less than 4.7K ohms in this example. C1 and R3 form a decoupling network that helps prevent audio energy from migrating along the +12 volt line to any succeeding stage that may be used. Unwanted audio current migration from stage to stage can cause audio self-oscillations (motorboating or squealing) as a result of unwanted feedback.

An FET audio amplifier is shown at *B* of fig. 1. It has a high input Z because the gate of an FET typically exhibits a Z of 1 megohm or greater. R1 sets the Z level by virtue of its selected value (100K ohms in this case). R2 establishes the output Z. Again, C1 and R3 comprise a decoupling network. The effective gain of each of these stages is between 10 and 15 dB.

Fig. 1(E) illustrates how two audio amplifier stages may be combined to obtain variable audio gain from zero to approximately 20 dB. The input stage has lower bias than the output stage. This is to reduce current within the first transistor, which in turn decreases the internal noise generated by the flow of junction current. This helps ensure quieter operation (reduced white noise). Potentiometer R1 sets the gain level. In the vacuum-tube radio days this potentiometer was known as the "volume control." Both fig. 1(E) stages are decoupled from one another by means of 56 ohm resistors and 22 µF capacitors.

C1 at *E* of fig. 1 is optional. It may be

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QRN Squasher Correction

An error in the PC board pattern for the W1FB MK-III QRN Squasher (July 1997 *CQ*, page 66) was introduced by FAR Circuits and not noticed until a reader called it to my attention. The problem is at Q2, where C3 and R4 are joined, then mistakenly routed to the Q2 collector. Cut the PC conductor at the pad where C3 and R4 are joined, thereby divorcing them from the Q2 collector. Add a short jumper wire from the C3/R4 pad to the Q2 base. Q2 will have no gain until this error is corrected. The fig. 1 schematic diagram is correct.

added to restrict the high-frequency response of the amplifier. Typical values for C1 range from 0.005 to 0.1 µF. The larger the capacitor value the more bassy the audio appears. The absence of "highs" causes this effect. Minimizing the high-frequency response is especially beneficial in receiver audio systems. This method minimizes high-frequency hiss (which can mask a weak signal) and greatly reduces the annoying effects of high-pitched heterodynes from nearby CW signals. An amplifier of this type may be used to drive an audio IC such as an LM386 for speaker operation. High-Z headphones of the 2000 ohm or greater type can be used with this circuit, as shown. However, if you wish to use 8 ohm earphones, it will be necessary to include a miniature audio transformer (1K to 8 ohms suitable) between the second transistor output port and the phones. A reasonable impedance match is necessary in order to ensure maximum audio power transfer.

Microphone Z Matchers

Fig. 1(C) and 1(D) show methods for using transistors to match unlike impedances. This may be necessary when interfacing a low-Z microphone with a high-Z audio circuit, or vice versa. Fig. 1(C) provides a reasonable Z match between a modern 600 ohm microphone and a high-Z microphone input stage, such as that of a tube type of transmitter. Most of these older transmitters were designed for microphones with a 50K ohm impedance.

An FET is used at fig. 1(D) to match a high-Z microphone to a modern low-Z transmitter microphone input circuit. A D-104 microphone is typical of the high-Z types that require a circuit of this variety. Some amateurs insert a 47K or 100K ohm resistor in series with the microphone audio lead where it enters the transmitter. This allows the microphone to be used with a 600 ohm input port. The "bandaid" helps to improve the overall audio response, but causes some loss of audio energy in the process. If no corrective measures are taken, the transmitted signal usually has high-pitched, unpleasant audio quality because of the mismatch.

Transistor Selection And Availability

One of the most common complaints I receive from readers is "I can't locate the parts for your circuit. Where can I get the transistors, relays, (or whatever)?" Countless electronics catalogs are available for the asking. Nearly any ordinary component can be found by browsing the catalogs. However, certain types of transistors and ICs are somewhat elusive for those who are not familiar with the process of scrounging parts.

Substitution of transistors is usually acceptable at audio frequencies. This is because noise figure (NF) and f_T (upper frequency limit where the device gain is one or unity) are not limiting factors for performance. The fig. 1 circuits specify 2N2222A or 2N3904 transistors because they are inexpensive and easy to obtain as surplus. However, a 2N2222, 2N4400, 2N4401, and a host of similar small-signal audio or RF NPN transistors may be used in the fig. 1 circuits without changing the parts values listed. Don't be afraid to experiment. The same rule may be applied in the case of JFETs. There are many types of JFETs other than the J310 and MPF102 devices specified in fig. 1. Some have 2N prefixes. In fact, a dual-gate MOSFET may be used as a JFET by tying gates 1 and 2 together and treating the device as a single-gate FET, as shown in fig. 1(B).

The NTE brand of transistors and ICs is perhaps the best source for devices that seem hard to find. Mouser Electronics (981 N. Main Street, Mansfield, TX 76063-4827 [for orders or a catalog call 800-346-6873]) markets NTE semiconductors. For example, the high-performance 2N4416 and Motorola MPF107 JFETs are available as NTE452 and NTE132, respectively. A 2N2222A is an NTE123A, a 2N3904 equates to NTE123AP, and an MPF102 is an NTE451. An NTE cross-reference manual is available from Mouser (no. 526-NTEDAD-3) for $4.95. The book is a worthwhile addition to any experimenter's library.

In Summary

This series is intended to impart information that is not generally available from any single source. Please send your suggestions to W1FB if there are catalog circuits you would like to have included in subsequent parts of this series.

73, Doug, W1FB

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DOUG'S DESK

CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORY

A Catalog of Practical Circuits—Part II

This, the last installment of "Doug's Desk," was submitted barely two weeks before Doug passed away. While his life and this new series were cut all too short, Doug left a rich legacy of writing, caring, and friendship —K2EEK

In Part I of this series we discussed a number of simple, basic audio circuits that could be saved in a notebook and used as reference material for those who like to build amateur equipment. Practical component values were assigned in each circuit to serve as "ball park" values. NTE equivalents were specified for each semiconductor used in the circuits. This month we continue with two audio power amplifiers and four small-signal RF amplifiers. NTE equivalents are listed in each circuit diagram for convenience of procurement. NTE devices are available from Mouser Electronics (958 N. Main St., Mansfield, TX 76063-4827 [800-346-6873]). See Part I for information about ordering an NTE cross-reference book from Mouser.

Audio Amplifiers for Speakers

Fig. 1(A) shows a popular audio amplifier used by experimenters. The National Semiconductor LM386 provides ample output power (roughly 300 mw) for most receiver applications. However, when driven with too much signal, it produces distorted audio output. I limit my use of this IC to receivers that are designed for low current consumption and portable work.

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A better audio chip for home-station use is specified in fig. 1(B). The LM388 produces up to 1.5 watts of output power. This is more than ample for comfortable room volume. Both circuits in fig. 1 are simple to build and easy to make operate. Should there be a tendency toward audio self-oscillation, it can usually be cured by connecting a 0.002 to 0.005 µF disc capacitor from the IC input terminal to ground. The larger the capacitor value the fewer the high-frequency audio components you will hear in the speaker. In fig. 1(A) the capacitor would go from pin 3 to ground, near U1. In fig. 1(B) the capacitor would be bridged from pin 8 to ground.

Practical RF Amplifiers

Four small signal RF amplifiers are seen in fig. 2. One of the simplest ones is shown at (A). The grounded-gate JFET is very stable and generally needs no special attention to keep it that way. The tradeoff associated with grounded- or common-gate operation is reduced gain. The fig. 1(A) circuit yields roughly 10 dB of gain. The secondary of T1 and the primary of T2 (largest windings) are wound to provide resonance at the chosen operating frequency with C1 and C2 at mid-range capacitance. For the lower part of the HF band it may be necessary to add C3 and C4 (fig. 2[B]) to ensure resonance without the transformer windings being awkward to place on the cores (less inductance needed). All four circuits in fig. 2 are designed for a 50 ohm input and output impedance. In order to realize this condition you should use 10 percent of the main winding turns for the smaller winding. Experimenting with the exact number of smaller winding turns (adding or subtracting) will optimize the circuit for maximum gain. The source impedance of the grounded-gate JFET amplifier in fig. 2(A) is 200 ohms. This is determined by $10^6/g_m$ where g_m is in micromhos. The same rule applies for source follower FETs. Thus, if the transconductance of a JFET is 5000 µmhos (pardon me for not using micro Siemens!), the source impedance is 200 ohms for a grounded-gate or source-follower RF amplifier.

The tap on T1 is made at approximately one eighth of the total winding turns. Place the tap nearest the grounded end of the T1 secondary. Although the tuned circuits in fig. 2 are shown with toroid cores, they may be air wound at the high end of the HF spectrum, and at VHF. Amidon Associates No. 2 cores are fine for use from 1.8 to 10 MHz. Use No. 6 cores from 10 to 50 MHz.

Although an MPF102 can be used at Q1 of fig. 2(A), the 2N4416 will provide better performance in terms of gain, noise figure, and pinch-off characteristics. An MPF102 should be okay for the lower end of the HF spectrum, except for the most demanding circuit performance.

More RF Amplifiers

Bipolar junction transistors (BJTs) are used as RF small-signal amplifiers in many circuits. Fig. 2(B) shows a typical circuit that uses a BJT. The base of Q1 is tapped down on the secondary of T1 to provide an impedance match. The base impedance in this circuit is on the order of

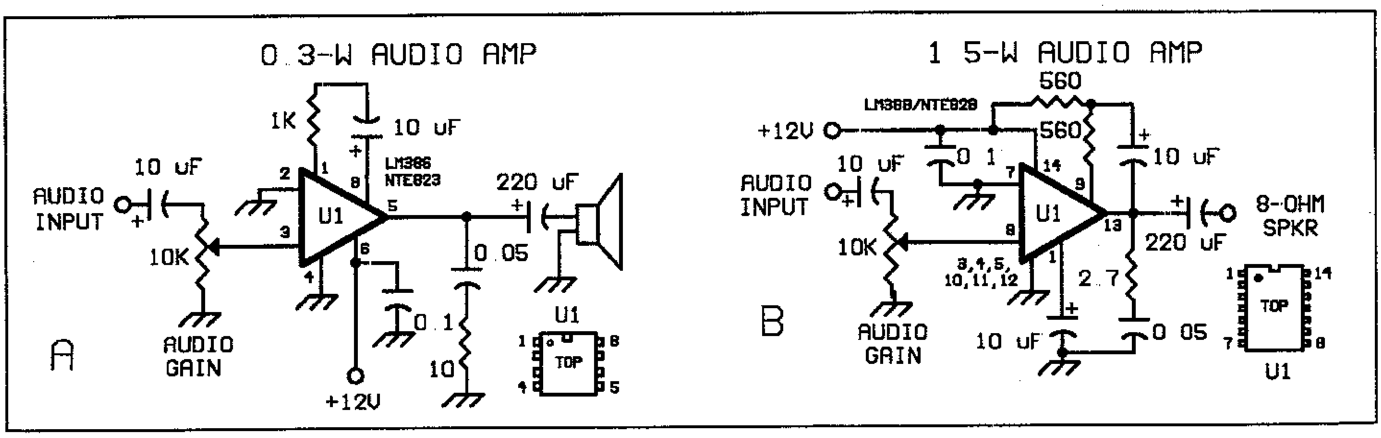

Fig. 1– Practical IC audio amplifiers for operating a speaker. Decimal value capacitors are disc ceramic. Polarized capacitors are electrolytic or tantalum. Resistors are 1/4 watt carbon.

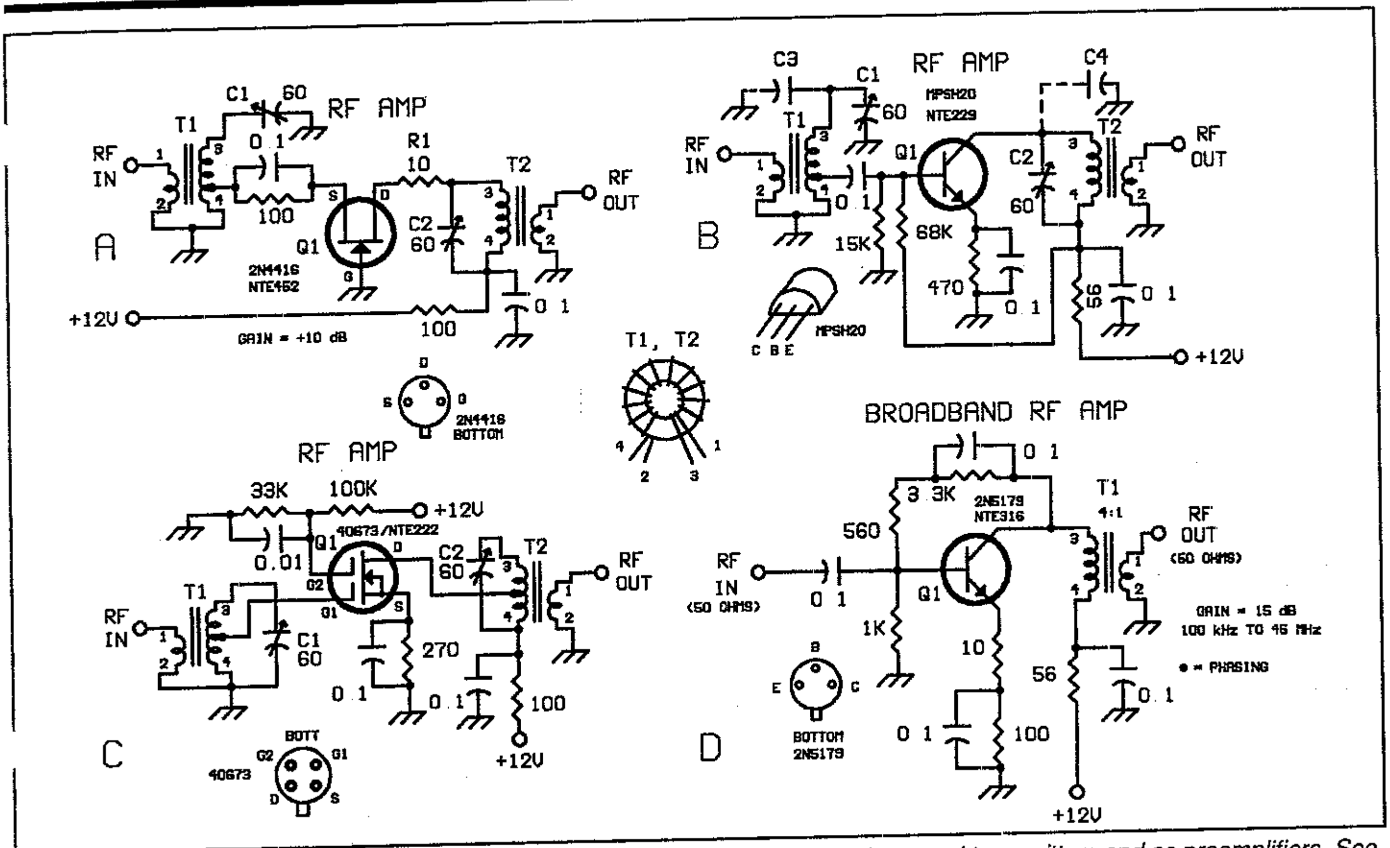

Fig. 2– Practical examples of small-signal RF amplifiers suitable for use in receivers and transmitters and as preamplifiers. See text for circuit explanations. Fixed value capacitors are disc ceramic. Variable capacitors are ceramic or plastic trimmers. Resistors are 1/4 watt carbon. NTE equivalents are given for the transistors specified.

600 ohms. The T1 tap is made near the grounded end of the secondary at one fourth the total secondary turns. Thus, if the secondary has 12 turns of wire, the tap is made 3 turns above the grounded end of the secondary winding.

The Motorola MPSH20 transistor specified for Q1 at fig. 2(B) is suitable through UHF. It has a low noise figure. However, for operation below 14 MHz it is okay to use devices such as the 2N3904, 2N2222A, and 2N4401. The noise factor below 14 MHz is usually determined by antenna noise rather than noise generated within the transistor. A 2N5179 is a good transistor for operation through VHF. The smaller windings on T1 and T2 are 10 percent of the number of turns used for the larger windings. C3 and C4 are additions that may be needed for operation at the low end of the HF range, as discussed earlier.

Fig. 2(C) shows how to use a dual gate MOSFET as an RF amplifier. The user must exercise caution when handling the 40673 or other MOSFETs (such as the 3N211) to prevent static charges from puncturing the gate insulation. MOSFETs are fragile in this respect. I usually twist all four transistor leads together until I am ready to install the device. It goes into the circuit only after all of the related components are in place.

Taps are used on T1 and T2 in the fig. 2(C) circuit. This is not for impedance matching. In fact, it causes an intentional mismatch. Q1 is tapped down on the tuned circuits in order to prevent unwanted self-oscillation. The taps are made at relatively low-impedance points of the tuned circuits. This helps prevent instability. A good starting point when placing the taps is midway down the larger windings of the tuned circuits. Experimentation with the taps may show that they can be made closer to the upper ends of the windings without encountering instability. The higher the tap points the greater the amplifier gain. Q1, as shown, has a gain of approximately 15 dB.

The RF amplifiers we thus far have discussed are called "narrow-band amplifiers." There are situations that require a broadband response where there are no tuned circuits to adjust. The circuit at (D) of fig. 2 is an example of a small-signal broadband amplifier. It has a reasonably flat (constant) frequency response from 100 kHz to 45 MHz. It is unconditionally stable. The input impedance is 50 ohms because of the biasing and the degeneration caused by the 10 ohm emitter resistor. The Q1 output impedance is 200 ohms. Therefore, T1 is used to provide a 4:1 step down to 50 ohms. T1 has 14 primary turns of No. 28 enamel wire on an Amidon FT-37-43 ferrite toroid. The secondary has 7 turns of No. 28 enamel wire. A 2N5179 CATV transistor is specified for Q1. However, for operation from 100 kHz to 28 MHz it is practical to use a 2N3904 or 2N2222A transistor in this circuit. I found when using a 2N2222A that maximum gain occurred when the 10 ohm emitter resistor was changed to 15 ohms. Modeling this circuit with NOVA software confirmed the 15 ohm value, respective to maximum gain.

In Summary

The circuits presented in Part II may be saved in a notebook as "recipes" for experimenters. It is important to remember that all RF circuits must have short, direct leads in order to discourage instability and loss of gain. Keep the pigtails of capacitors and resistors as short as practicable when assembling a project. Determining the proper number of transformer turns for a specified inductance and operating frequency is covered in *The ARRL Handbook* and *The ARRL Electronics Data Book*. I have tried to combine basic theory with the practical examples given in this article.

73, Doug, W1FB

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