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*A look at the driver stages of the new super Class A amplifiers that achieve high output white maintaining a near-zero level of distortion.*

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IN THE MARCH ISSUE, WE EXAMINED THE design of the new Super Class-A amplifier output stage developed by JVC. The Super-A design is intended to provide nearly the full efficiency of a Class-B amplifier circuit with no notch-distortion or switching distortion.

In discussing power amplifiers, it is usual to emphasize the design of the output stage since it is that stage that actually delivers power to the speakers. However, there are a number of amplifier characteristics that are determined by earlier stages, such as the driver or voltage-amplifier stages. Those characteristics include frequency response, gain, thermal drift, slew-rate, etc. The driver stage may also have a great bearing on the distortion characteristics of the entire amplifier.

## Driver-stage distortion

In developing a driver circuit for their new Super Class-A amplifier, JVC's engineers examined first the three types of distortion that can be found in a common-emitter amplifier circuit. Figure 1 shows the input/output characteristics of a common-emitter amplifier circuit that is driven with constant current. Those characteristics are commonly called the $V_{CE}$-$I_C$ characteristics. Note that in this diagram each curve rises to the right. That means the even with a constant input-signal current, the collector-current ($I_C$) increases as the collector-to-emitter voltage ($V_{CE}$) increases. It follows that the gain of the stage varies as $V_{CE}$ varies. That variation of gain normally amounts to around 10% in the pre-driver stage, since variations of $V_{CE}$ roughly coincide with those of the power supply voltage. JVC calls that type of distortion the $V_{CE}$ distortion is illustrated (in exaggerated form) in Fig. 2.

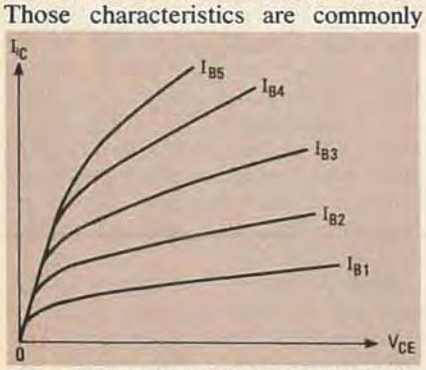


**FIG. 1—INPUT/OUTPUT CHARACTERISTICS for a common-emitter stage. Collector current versus collector-to-emitter voltage is shown for a number of fixed values of base current.**

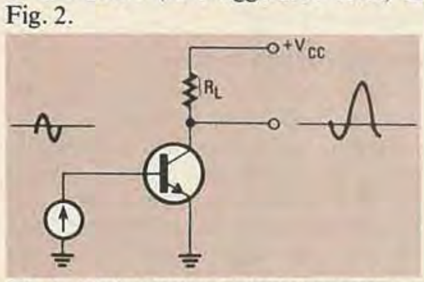


**FIG. 2—SINGLE-STAGE COMMON-EMITTER amplifier. Variations in collector current as the collector-to-emitter voltage changes causes distortion.**

A second form of distortion that occurs in common-emitter amplifier circuits arises because of the capacitance between the collector and base of the common-emitter transistor stage. Commonly called $C_{ob}$, that capacitance varies with the collector-to-base voltage ($V_{CB}$) in such a manner that it increases as $V_{CB}$ decreases. In the common-emitter amplifier circuit, the $C_{ob}$ variation of capacitance $C_{ob}$ results in distortion, the nature of which is illustrated in exaggerated form in Fig. 3. In the course of the development of the Super-A Class circuit, JVC called that type of distortion $\Delta$ $C_{ob}$ distortion.

The third and final form of distortion associated with a common-emitter circuit is known as $\Delta$ $V_{BE}$ distortion. The input/output characteristics of a common-emitter cirucit is shown in Fig. 4. Note the relationship between input voltage and output current. It is logarithmic. Therefore, if input and output are compared in terms of *voltage*, a high level of distortion is present. Figure 5 shows the general nature of that distortion, again in exaggerated form for the sake of clarity.

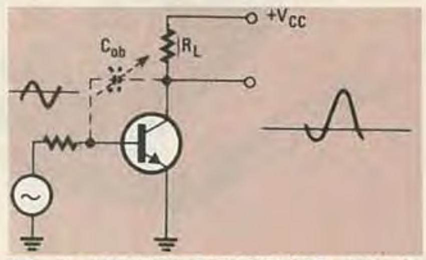


**FIG. 3—JUNCTION CAPACITANCE within the transistor also causes distortion. That capacitance, called $C_{ob}$, varies in accordance with the collector-to-base voltage.**

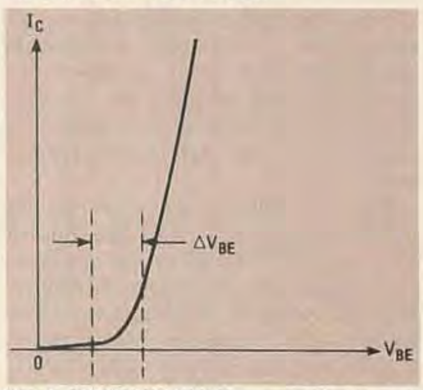


**FIG. 4—INPUT VOLTAGE versus output current for a common-emitter stage. Operation in the nonlinear portion of curve causes distortion of the output signal.**

Several approaches are possible for reducing the $\Delta$ $V_{BE}$ distortion. The use of constant-current drive or the connection of a current feedback resistor to the emitter might be one possible approach. Another approach might be to attempt to cancel the $\Delta$ $V_{CE}$distortion and the $\Delta$ $V_{BE}$ distortion with each other by

# SUPER CLASS A Amplifiers

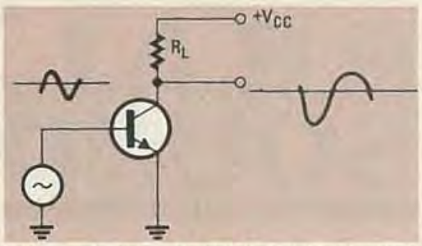


FIG. 5—DISTORTED OUTPUT WAVEFORM is caused by nonlinear operation of common-emitter transistor stage.

choosing an appropriate driving impedance, since those distortions are essentially mirror-images of each other.

Figure 6 shows a typical input/output characteristic of a common-base amplifier circuit. It shows the collector current ($I_C$) vs. the collector-to-base voltage ($V_{CB}$) for a number of fixed values of emitter current ($I_C$). In this circuit, variations of $I_C$ caused by variations of $V_{CB}$ are almost non-existent. It should be noted, of course, that *current* gain of the circuit is 0 dB (gain equals 1.0). However, the very fact that gain is not influenced by variations of $V_{CB}$ is made use of in the familiar cascode amplifier circuit.

Cascode amplifier circuits are often used in high-frequency applications such as RF amplifiers because of their excellent frequency response resulting from the absence of the effects of capacitor $C_{ob}$. So, in that sense, there is nothing particularly new or different about them. However, when analyzed from the viewpoint of distortion and considered for their application in audio equipment, they have proven to be superior as a low-distortion amplifier circuit. The basic circuit of a cascode amplifier is illustrated in Fig. 7.

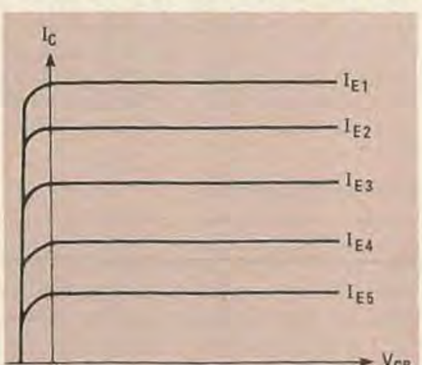


FIG. 6—INPUT/OUTPUT CHARACTERISTICS for a common-base amplifier stage. Collector current versus collector-to-base voltage is shown for a number of fixed values of emitter current.

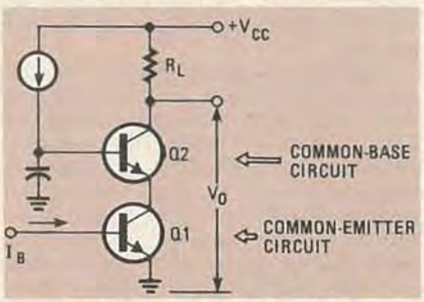


FIG. 7—SUPER CLASS-A DRIVER STAGE consists of cascoded common-emitter and common-base amplifier stages. Combination drastically reduces distortion.

That type of amplifier circuit provides excellent linearity through a combination of the common-emitter and common-base circuits, since the forms of distortion created by each of those circuits are effectively cancelled by each other. In the cascode circuit, input-signal current $I_B$ is first amplified $\beta$ times through the common-emitter transistor Q1 which has a large current gain. The signal is then applied to the emitter of the common-base transistor Q2, where it is amplified $\alpha$ times. Therefore, the output voltage across $R_L$ is equal to:

$$V_O = \alpha \beta R_L L_B$$

Note that the input signal is considered to be in the form of a current ($I_B$) and not in the form of a voltage. In actual applications, a signal-source impedance on the order of kilohms will suffice. That combination suppresses $\Delta V_{BE}$ distortion. Then, since an almost constant voltage is present at the emitter of the common-base circuit Q2, the $V_{CE}$ of Q1 takes on a constant value regardless of the presence of the input signal. Therefore there is no variation of gain and $C_{ob}$ due to the variation of $V_{CE}$ or $V_{CB}$. The variation of gain due to any variation of $I_C$ is negligible. Furthermore, the gain of Q2 can be considered to be 1.0 because of the characteristics of a common base circuit. As a result, nonlinear components disappear almost completely from the output-voltage $V_O$. Thus, the driver stage of JVC's Super-A circuit takes complete advantage of the properties of cascode operation and, according to JVC, reduces the distortion figure in the voltage and driver stages of an amplifier by one complete order of magnitude compared with conventional amplifiers.

Needless to say, there are many forms of distortion other than those that have been compensated for both in the driver and power stages of JVC's new Super-A Class amplifier products. Nevertheless, both in the driver and power stages, the most common drawbacks of semiconductors have been compensated for through the use of these new circuit approaches. As a result, the distortion (or, more properly, the harmonic distortion) of the Super-A circuit is far lower than the practical lower limit at which ordinary harmonic distortion meters function. The distortion level, in fact, lies far lower than the noise level of the amplifier. Typically, the harmonic distortion level of JVC's new A-X9 integrated amplifier measured by means of a spectrum analyzer for a test signal at 1 kHz and an output of 105 watts (the amplifier is rated at 100 watts from 20 Hz to 20 kHz, 8-ohm loads) was an inifinitesmal 0.0005%, according to JVC. **R-E**