New BJT Amplifier Design with High Gain and Low Power Dissipation

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Writer's comment: The Technical Report for my ENL 102E class was one of my favorite papers to write because it allowed me to demonstrate what I had learned in the class with a "real world" paper on a topic of my interest. Prior to taking this class, the majority of my writing was creative essays and history papers. This lack of technical writing experience showed when Dr. Henderson handed back my first assignment with more red ink on it than text! Technical writing, I soon discovered, was a different breed of composition. I quickly learned to apply Dr. Henderson's technique of SCC (Simplify, Clarify, and Correct) to any technical piece. As a result of this class, SCC always comes to mind when I am reading or writing technical pieces. As an added bonus, since my topic was BJT amplifiers, I was able write my paper and simultaneously study for an Electronic Circuits midterm that was on the same day the paper was due!

—Ridah Sabouni

Instructor's comment: Writing a successful engineering report requires execution of several skills simultaneously: encoding technical ideas into sentences that are concise, clear, & correct; organizing those sentences into sections that advance arguments with precision and accuracy; and engaging and convincing a critical audience. Ridah Sabouni's report is excellent in all of the preceding areas. The central purpose of this exemplary document, is to recommend a winning product, given three viable contenders. Mr. Sabouni passes judgment on the merits and flaws of each of these alternatives based on a set of judgment criteria, which he describes in his Introduction. This "up-front" frame of reference allows him to avoid ad hoc reasoning later on when he's offering his closing argument. The rhetorical mode he uses is *classical evaluation*. Indeed, this engineering report is a shining example of how well basic core tools of the liberal arts apply to discourse geared toward a high-tech audience.

—Brad Henderson, University Writing Program

Summary

In order to stay competitive in a highly evolving and dynamic marketplace, Delphi Computers will unveil a new consumer laptop design that will be ready for the public in the summer of 2006. Our consumer research department has found that any future laptops must offer a large array of multimedia features and long battery life to be successful.

Amplifiers are an integral part of any electronic device. Amplifiers provide the gain necessary to run multiple applications efficiently and smoothly. Amplifiers, however, use up a significant percentage of total power and battery consumption. As a result, the amplifiers required for the new laptop design must be high gain and low power, while not costing any more than present amplifiers.

Our present amplifiers need to be redesigned to meet the requirements of the new laptop design. These present amplifiers dissipate too much power while simultaneously not providing enough gain to allow for multiple multimedia accessories on the laptop.

We found a new common emitter – emitter follower BJT amplifier best met our target specifications involving high gain and low power dissipation. The power dissipation of the amplifier under room temperature conditions measured only 1.6 mW per amplifier with a corresponding gain of 22. These numbers are unmatched for amplifiers in our industry. We believe with this amplifier design, the new laptops' design specifications will meet and exceed consumer expectations. Furthermore, the new amplifier design can be applied to multiple Delphi computer divisions where a high gain, low power amplifier is needed.

I. Introduction

Delphi Computers will roll out a new line of laptop computers during the summer of 2006 that the company hopes will be industry leaders for years to come. These next- generation laptops need to be able to support a variety of multimedia features efficiently and have speeds comparable to the top desktops in the market. The current laptop design uses common emitter Bipolar Junction Transistors (BJTs) as the main signal amplifier in nearly all its computer circuit components. A next-generation laptop designs will require 100,000– 200,000 more amplifiers than the current laptop design.

The current laptop design using existing common emitter BJT amplifier technology is not adequate in three ways: First, transistor power consumption will increase by 50%, along with a corresponding 50 % heat dissipation increase. This added heat has a negative effect on the life and durability of the laptop. Second, the transistor amplification will not be enough to provide for multiple features such as DVD burner, digital camera, and multiple USB drives. Multiple multimedia features require high individual amplifier gain to provide a sufficient overall amplification. Third, battery lifetime is poor because of the large power consumption of the transistors and multimedia features. The current amplifier design must be changed, as long battery lifetime and a multitude of multimedia features are both essential to a successful product in the laptop market.

Delphi's new line of laptops should use a new design of amplifiers with a three-fold target performance:

1. The overall voltage gain of the amplifier at the signal frequency of 100 kHz must be between 18 – 22. This is a significant increase from the current gain of 10.

2. The cost per amplifier should be no more than the current amplifier cost of $1 per million amplifiers.

3. The power dissipation should be no higher than 2 milli-Watts (mW) at room temperature (25°C) ± 10 °C. Anything lower than 2 mW would put Delphi Computers at a significant advantage over the marketplace today.

This development helps the entire Delphi Computer Company, since the resulting design can be modified to applications in the Delphi desktop division, printer division, and the newly formed Delphi TV division. The advantages of a low power, high gain BJT amplifier are applicable to the entire Delphi business.

II. Product Improvement

There are three viable solutions that meet the target performance of the new amplifier design:

1. We can modify the current common emitter BJT amplifier's parameters. (See Figure 1, Appendix A)

2. We can introduce a common base BJT into the design, creating a common emitter – common base amplifier. (See Figure 2, Appendix A)

3. We can introduce an emitter follower (common collector) BJT into the design, creating a common emitter-emitter follower amplifier. (See Figure 3, Appendix A)

We can improve the current common emitter BJT amplifier design to meet the target amplifier performance. This can be done by varying the resistor values in the amplifier (See Figure 1, Appendix A) to produce an alternate biasing scheme for the BJT. A stand-alone common emitter amplifier produces a high current gain and a high voltage gain.

The common base stage will act as a current buffer in the amplifier design. This second stage produces a high voltage gain and acts as a buffer to any current gain. The advantage of introducing any kind of buffer into the product is a high increase in reliability. While this amplifier uses more components than a simpler common emitter amplifier, industrial manufacturing procedures today ensure a fairly equivalent cost and amplifier size.

The emitter-follower will act as a voltage buffer in the amplifier design. This second stage produces a high current gain and acts a buffer to any voltage gain. Again, the voltage buffer will produce a more reliable product. This amplifier, when manufactured using modern techniques, is also at an equivalent cost and size to the present amplifier used.

III. Evaluation Procedure

To evaluate the performance of each amplifier, we organized a variety of tests using the PSPICE circuit simulation program. This simulation program automatically calculates the total power dissipation for each amplifier, as well as the gain and the optimum resistor values we would want to use. Once we found the best possible specifications for each amplifier, each amplifier circuit was built and tested using highly sensitive voltmeters and ammeters. We built the amplifiers into circuits to ensure they would function according to the simulation results under real conditions.

IV.Results

Table 1: Voltage Gain with 100 kHz signal Frequency

Design	Voltage Gain
Common Emitter	18
Common Emitter – Common Base	20
Common Emitter – Emitter Follower	22

Table 2: Amplifier Cost per 1 million

Design	Cost per Million Amplifiers ($)
Common Emitter	0.9
Common Emitter – Common Base	1.0
Common Emitter – Emitter Follower	1.0

Table 3: Power Dissipation

Design	Power Dissipation (mW) at 15°C	Power Dissipation (mW) at 25°C	Power Dissipation (mW) at 35°C
Common Emitter	1.5	2.0	3.0
Common Emitter – Common Base	1.8	1.9	2.0
Common Emitter – Emitter Follower	1.4	1.6	1.9

V. Conclusions & Recommendations

We met the three target performances by the common emitter – common base design and the common emitter – emitter follower design. The common emitter design met the target performances only at room temperature—at 10 °C above room temperature, the power dissipation rose to an unacceptable 3 mW.

The common emitter amplifier cost the least, at only $0.9 per million amplifiers. However, the other two designs were within the target price as expected; both the common emitter – common base and the common emitter – emitter follower cost $1 per million.

While both the common emitter – common base and the common emitter – emitter follower met the target specifications, the results show a clear power dissipation advantage from the common emitter – emitter follower. The common emitter – emitter follower dissipated 1.4, 1.6, and 1.9 mW of power at 15 °C, 25 °C and 35 °C respectively, compared with

a power dissipation of 1.8, 1.9, and 2.0 under the same conditions for the common emitter – common base design. The low power dissipation under all tested conditions makes the common emitter – emitter follower a significant improvement in heat dissipation.

We recommend implementation of the common emitter – emitter follower BJT amplifier in the next generation Delphi laptops. The low power consumption with simultaneous high gain will give Delphi a huge edge against the laptop competition in these categories. This will allow Delphi to offer an array of multimedia services unprecedented in the laptop industry. Furthermore, the power consumption of this amplifier is so low that we believe it would be a great fit for Delphi TVs and Delphi desktops as well. This amplifier design may well give the edge needed to establish Delphi TVs as a major player with a significant share of the TV market.

VI. Appendix A

Figure 1: Common Emitter BJT Amplifier

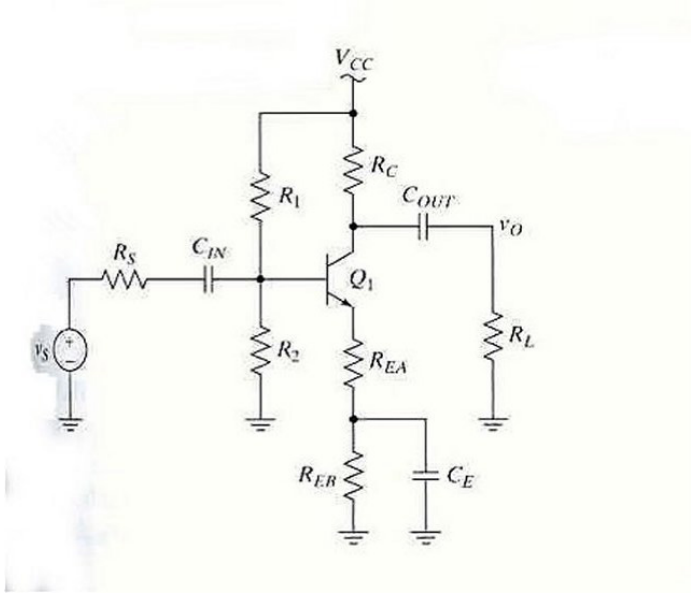

Figure 2: Common Emiter – Common Base BJT Amplifier

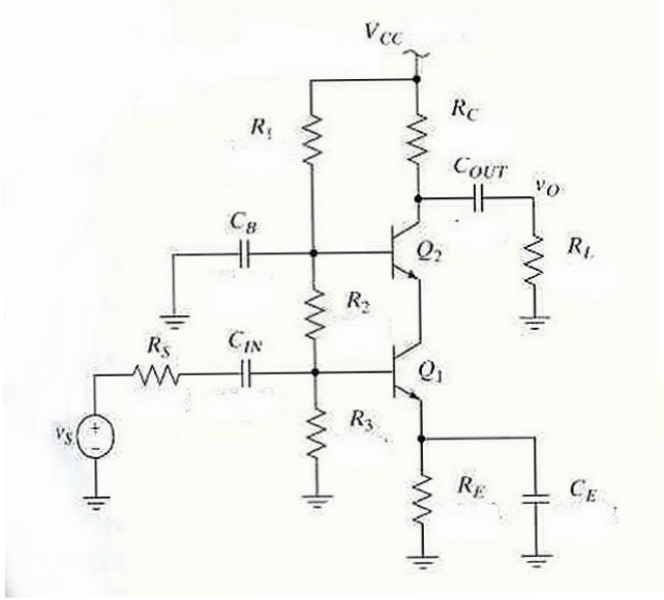

Figure 3: Common Emitter – Emitter Follower BJT Amplifier