[redacted]

Project 1
Report

9/17/2013

Project 1: CE Amplifier

Introduction:

The purpose of this project was to design a Common emitter amplifier Circuit. The transistor had to be npn, not from the lab, and avilable from newark.com. The criteria to be met included that the circuit must be bias stable, must have AC gain stability and an emitter bypass capacitor, must have an undistorted output, must have suitable coupling capacitors that meet my assigned lower cut off frequency of 60Hz.

Experiment:

To begin the design, I looked through the available transistors on newark.com, and chose the 2N5551 npn transistor for my amplifier. After comparing it with some other transistors it seemed to have values that would match most closely to my input voltage (See datasheet and Table 3). 5V were chosen for the ease of calculations.

Next, I chose $I_c = 1mA$ for simplicity of design

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effect (Keep R_L High to match input impedance so no voltage gain lost)

For the AC analysis, (Figure 2) I calculated r_π (calculation 8) gm (calculation 9), and A_v (calculation 10). Next, I needed to find the values of the coupling capacitors and bypass capacitor. To calculate C_E, I rearranged the equation to calculate frequency (calculation 11), where f was my lower cutoff frequency of 60Hz. Since C_E was to be the dominating capacitor, it was recessary to choose a frequency much lower than 60Hz to ensure that the coupling capacitors would not interfere with C_E. I chose a frequency of 0.6Hz for C_{C_1} and 0.006Hz for C_{C_2}. This ensured values that were available in the lab, and that the capacitors would not dominate the circuit (calculations 12-13).

After building and testing the circuit, I measured the current and voltage values to compare (Table 1). Recalculating gave Beta = 162.75438, which was used along with other measured values for another set of calculations.

Next, the upper and lower cutoff frequencies were measured using the oscilliscope (figures 3 and 4). The midband gain was in that range (figure 5). The gain was calculated to be $1.91V / 0.0294V = 64.966$. After getting these values, the parameters C_μ, C_M, and C_π were calculated to see how the calculated upper cutoff frequency compares to the measured upper cutoff frequency (Calculations 14-18). To do this SPICE parameters (Table 3) were used to find C_π, C_μ, and C_M. After calculating f_H to be 3.5844 MHz, it was much larger than the measured 410kHz. Since R_s was the only estimated value, it must be skewing the data somehow. Using an Excel Spreadsheet, R_s was increased until the gain was lowered and the cutoff frequency was lowered to very close to my measured cutoff frequency. That value was 525 Ω. Using a 523 Ω resistor connected in series between the circuits and frequency generator, the upper and lower cutoff frequencies were measured again. (Figures 6-7). My new upper cutoff frequency was 352 kHz and the new lower cutoff frequency was 47.4 Hz. The voltage and current parameters were measured again to compare (Table 2). The gain was reduced to $1.94V/38.1mV = 50.9186$, which is still relatively good. β incresed to 187,596, which is ok becau the 2 βs calculated wer within 15 of eachother.

Next, the BJT SPICE parameters were calculated again for comparison (calculations 19–22) This incresed C_M by 1.0639 times.

Conclusion

It is possible to control both the gain and the midband with an amplifier circuit. I was able to use a chosen lower cutoff frequency and calculate the values of both bypass and coupling capacitors to cause this cutoff. Controlling the high end cutoff was trickier, but I was able to adjust R_s to an appropriate number that did not change my original value very much. When recalculating the C_π, C_μ, and C_M parameters, I did not get the expected cutoff frequency. This is probably due to an error in calculation, because the upper cutoff frequency increased. The fault was not in the Circuit itself, because my measured values were very similar when comparing Tables 1 and 2. It would be interesting to see if there is a formula to find Rs given a cutoff frequency instead of trying to adjust it. Increasing Rs definitely helped, but there should be a better way to find that value apart from trial and error. Rs also adjusted the lower cutoff frequency as well. Internal resistance can be a big issue in cases like this.

Calculations

Dc

1)

3)

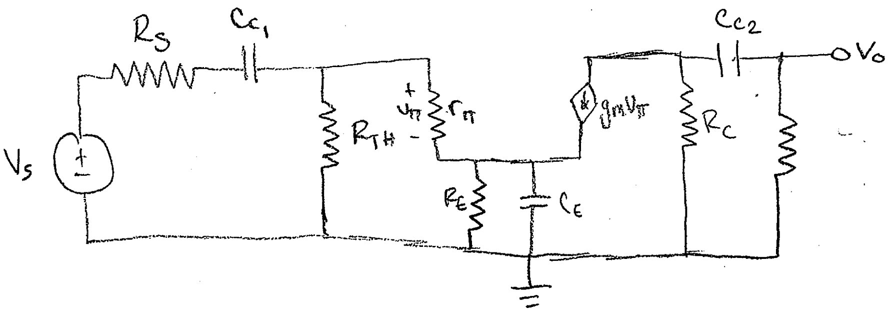
4)

5)

7)

[redacted]

AC Analysis:



[redacted]

Capacitor Calculations:

- C_E

[redacted]

τ_A

τ_B

3722 Hz

11) $C_E =$

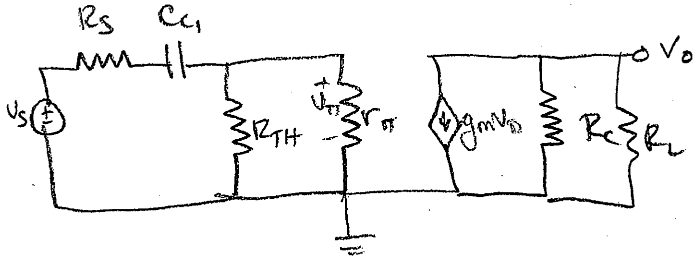
hing less for

C_{C_1} and C_{C_2}

Capacitor Calculations (cont.):

■ C_{C_1}

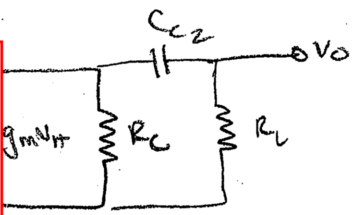
Chose $f_{c_1} = 0.6Hz$



$$\tau_{S_1} = (R_S + R_{TH} // r_\pi) C_{C_1}$$

12) $C_{C_1} =$ [redacted] $= \boxed{169uF}$

■ C_{C_2} [redacted]



13) C

$2\pi f_{c_2}(R_C + R_L)$

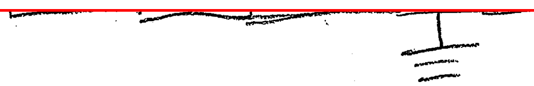
C_π, C_μ, C_M using SPCE Parameters

14) C [redacted]

15) C

16) C_M $\boxed{\text{pF}}$

17)



$\tau_p = (C_\pi // C_M)(R_{TH} // R_S // r_\pi) = 4.44021\times10^{-8}\,s$

18) $f_H = \frac{1}{2\pi\,\tau_p} = \boxed{3.5844\ \text{MHz}}$

· Recalcula [redacted]

Figures and Tables

Figure 1: DC Common Emitter Circuit

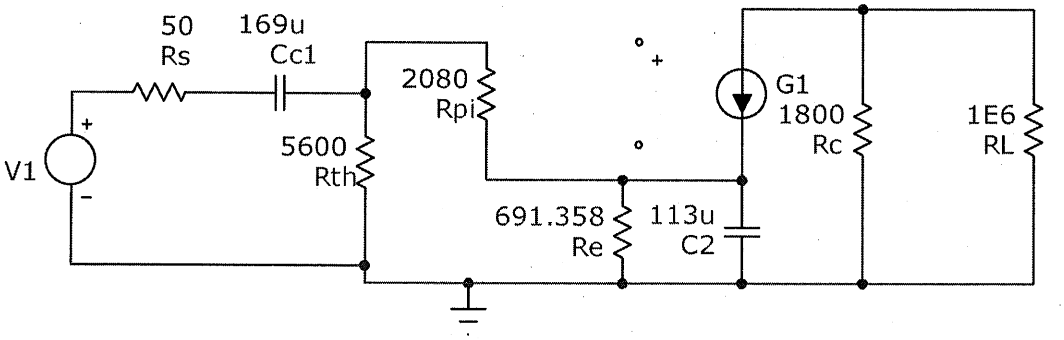


Figure 2: AC equivalent

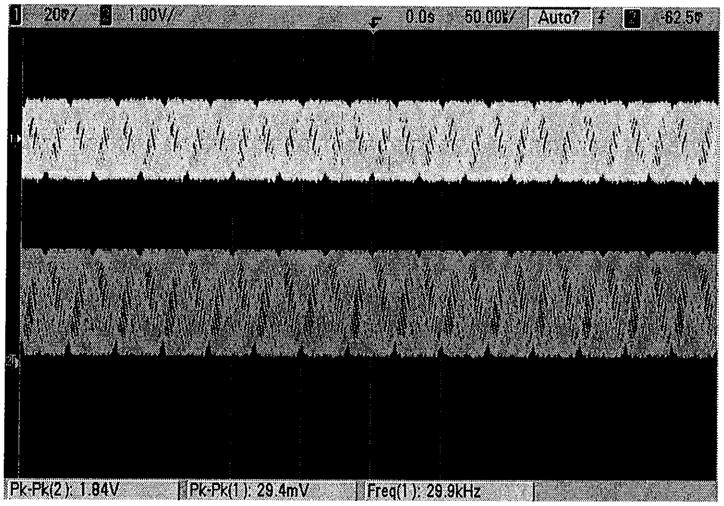


Figure 5: Midband Gain region

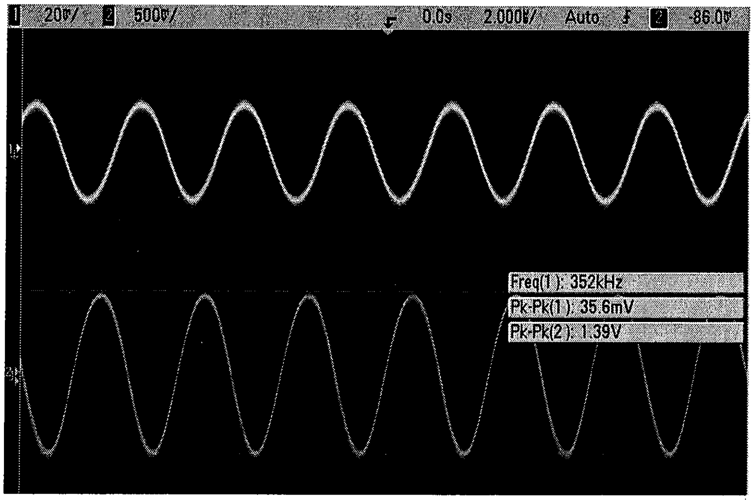
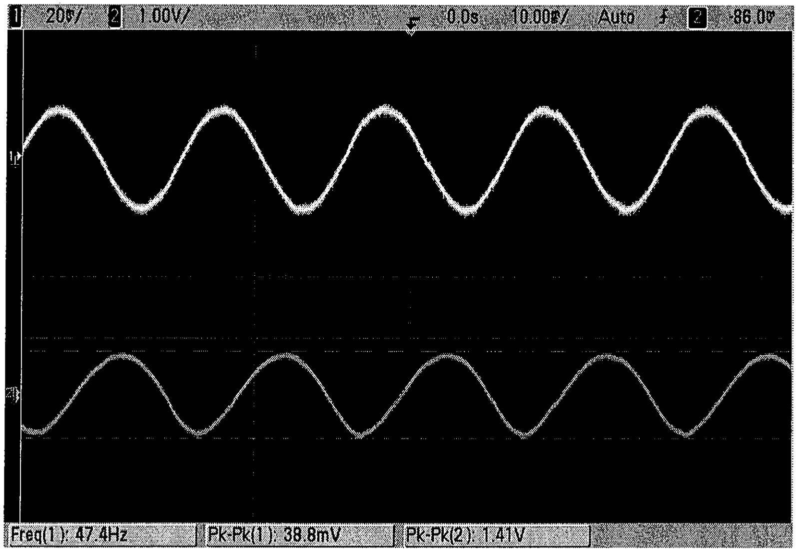
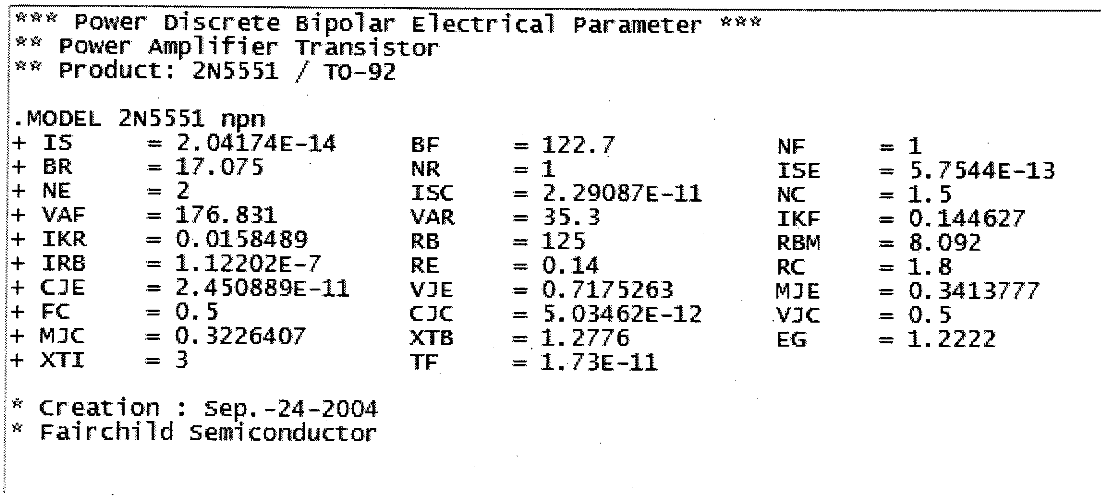


Figure 6: Upper cutoff frequency after changing Rs





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*** Power Discrete Bipolar Electrical Parameter ***
** Power Amplifier Transistor
** Product: 2N5551 / TO-92

.MODEL 2N5551 npn
+ IS     = 2.04174E-14     BF     = 122.7          NF     = 1
+ BR     = 17.075          NR     = 1              ISE    = 5.7544E-13
+ NE     = 2               ISC    = 2.29087E-11    NC     = 1.5
+ VAF    = 176.831         VAR    = 35.3           IKF    = 0.144627
+ IKR    = 0.0158489       RB     = 125            RBM    = 8.092
+ IRB    = 1.12202E-7      RE     = 0.14           RC     = 1.8
+ CJE    = 2.450889E-11    VJE    = 0.7175263      MJE    = 0.3413777
+ FC     = 0.5             CJC    = 5.03462E-12    VJC    = 0.5
+ MJC    = 0.3226407       XTB    = 1.2776         EG     = 1.2222
+ XTI    = 3               TF     = 1.73E-11

* Creation : Sep.-24-2004
* Fairchild Semiconductor
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Table 3: Fairchild 2N5551 SPICE model

FAIRCHILD
SEMICONDUCTOR®

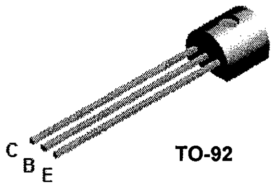
April 2006

2N5551- MMBT5551
NPN General Purpose Amplifier

Features

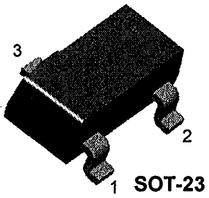
- This device is designed for general purpose high voltage amplifiers and gas discharge display drivers.
- Suffix "-C" means Center Collector in 2N5551 (1. Emitter 2. Collector 3. Base)
- Suffix "-Y" means h_{FE} 180~240 in 2N5551 (Test condition : I_C = 10mA, V_{CE} = 5.0V)

2N5551



TO-92

MMBT5551



SOT-23
Marking: 3S

1. Base 2. Emitter 3. Collector

Absolute Maximum Ratings * T_a = 25°C unless otherwise noted

Symbol	Parameter	Value	Units
V_{CEO}	Collector-Emitter Voltage	160	V
V_{CBO}	Collector-Base Voltage	180	V
V_{EBO}	Emitter-Base Voltage	6.0	V
I_C	Collector current - Continuous	600	mA
T_J, T_{stg}	Junction and Storage Temperature	-55 ~ +150	°C

* These ratings are limiting values above which the serviceability of any semiconductor device may be impaired.

NOTES:

1. These ratings are based on a maximum junction temperature of 150 degrees C.
2. These are steady state limits. The factory should be consulted on applications involving pulsed or low duty cycle operations.

Thermal Characteristics T_a=25°C unless otherwise noted

Symbol	Parameter	Max		Units
		2N5551	*MMBT5551	
P_D	Total Device Dissipation Derate above 25°C	625 5.0	350 2.8	mW mW/°C
$R_{\theta JA}$	Thermal Resistance, Junction to Case	83.3		°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	200	357	°C/W

* Device mounted on FR-4 PCB 1.6" × 1.6" × 0.06."

Typical Performance Characteristics

Figure 1. Typical Pulsed Current Gain vs Collector Current

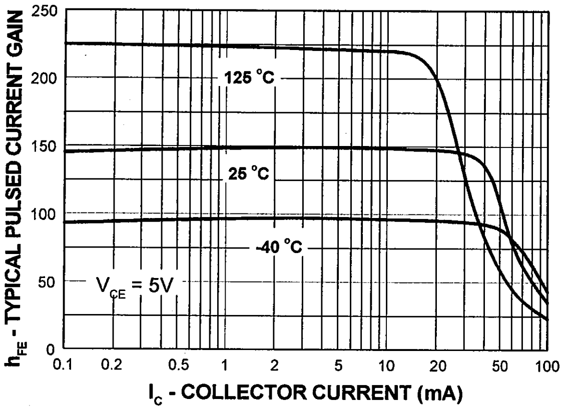


Figure 2. Collector-Emitter Saturation Voltage vs Collector Current

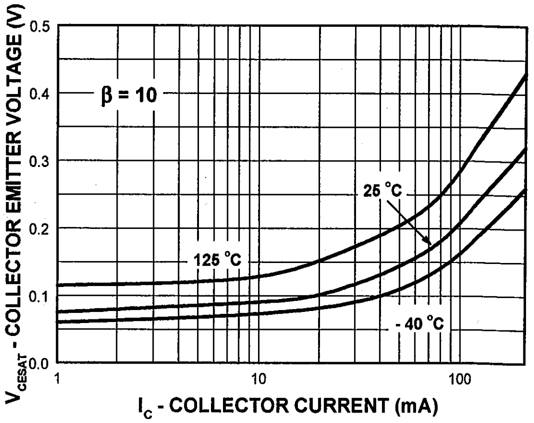


Figure 3. Base-Emitter Saturation Voltage vs Collector Current

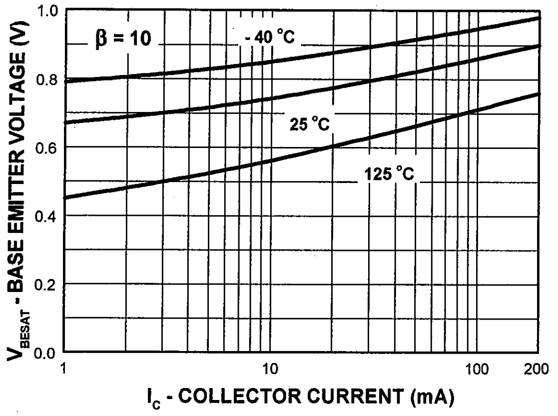


Figure 4. Base-Emitter On Voltage vs Collector Current

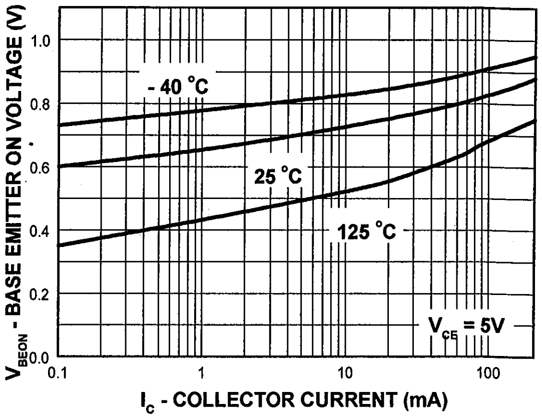


Figure 5. Collector Cutoff Current vs Ambient Temperature

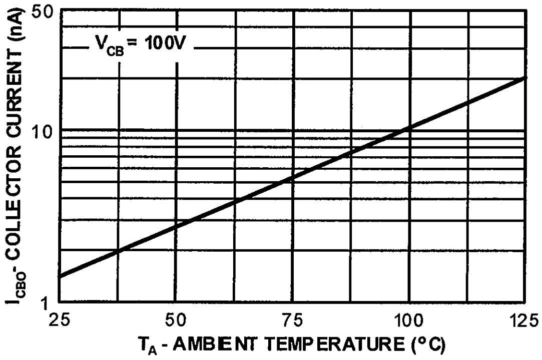
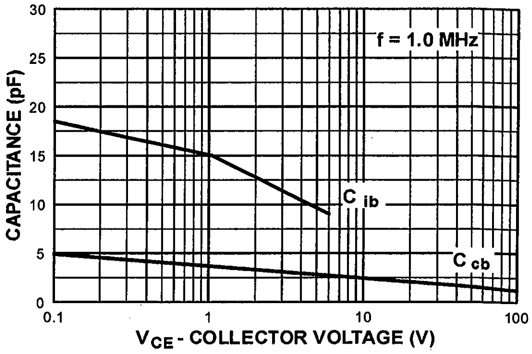


Figure 6. Input and Output Capacitance vs Reverse Voltage



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No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
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