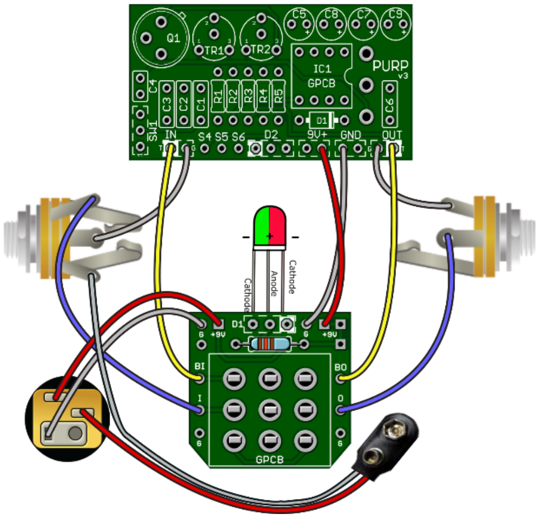
Analysis of the P.U.R.P. – Pump'd Up Rangemaster Plus by Big O

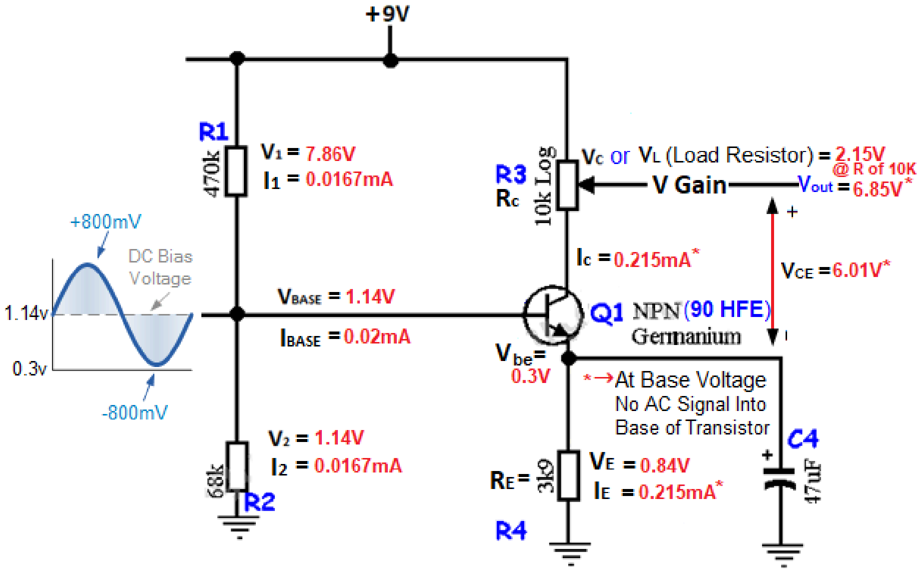
On what makes this GuitarPCB circuit different from the rest.

With special credit to R.G. Keen, Tonmann & Electrosmash.com



Aside from the obvious use of a Charge Pump to reverse the polarity which exists outside the audio path to allow the user to run this circuit on a modern-day pedal board there was more than meets the eye.

I went back and revisited electronics physics a bit, watched some videos on transistor biasing and read a couple of articles on amplifier circuits to try and gain more understanding of the Rangemaster circuit. My reading included an excellent webpage at Electrosmash.com on the Rangemaster subject. The above diagram is that of an NPN Rangemaster type circuit for simplifying negative/positive voltages. So some of the information provided here is from both R.G. Keen's evaluation of the Rangemaster and some of it is from the Electrosmash article. Below are my findings that help explain the original RM circuit and it is a little long winded, but I wanted to describe things in some detail.



First of all, this circuit is a typical **Common Emitter Amplifier** circuit using a Bipolar Junction Transistor and employing a Voltage Divider network to set a stable Bias Voltage at the transistor Base. The circuit also employs an Emitter Resistor off the emitter end of the transistor to further stabilize the Bias Voltage through negative feedback as heat induced increases in transistor current causes some instability of the device. Generally, the Common Emitter Amplifiers are referred to as "Voltage" amplifiers because they use a Small Input Voltage (typically a few mV to maybe up to 800 mV or so for guitar pickup signals) into a much Larger Output Voltage. That is, they are designed to amplify very small signal voltage levels of only a few micro-volts from audio signals and therefore are considered a Small Signal Amplifier. Power amplifiers, like a guitar amp, are Large Signal Amplifiers and amplify power (current amplifier) but that is all I am going to discuss regarding this topic.

R1 and R2 in the circuit are the resistors in the voltage divider to set the **Bias Voltage** of the transistor. For example, if the bias voltage is 1.0V, and addition or subtraction of voltage (AC sine wave signal) coming from a guitar pickup may be up to around +/- 800mV as discussed above, the bias voltage allows room for the transistor to provide amplification through the full range of input voltage swing (1.0V +/- 800mV or 0.20mV to 1.80V transistor base voltage). If the incoming signal voltage is greater than 1.0V, then a part of the negative voltage swing would fall below zero and no signal will be getting to the output. As the base (bias) voltage approaches Zero, a small amount of clipping begins, which is a characteristic of Germanium transistors. More about this later.

The Bias Voltage to the Transistor Base can be figured in one of two ways if the resistor values are known. Either use **Kirchoff's Voltage Law** (Sum of Voltage = 0) or the **Voltage Divider formula**, V2= (Source Voltage)(R2)/(R1+R2) or in this case V2= (9V)(R2)/(R1+R2) = (9V)(10K/538K) = **1.14V**. Using **Kirchoff's Voltage Law** and **Ohms Law**, **V=I x R**, 9V-(470K)(I)-(68K)(I) where **I=Current**, one gets 9V = (538K)(I) and the Current into the resistors is **0.0167 mA**. Using V=IR, the **Voltage** across **R2** is (0.0167mA)(68K) = **1.14V**, same as above. Using the same method, **Voltage** across **R1** is **7.86V**.

The part of the circuit on the transistor side includes the **Load (**aka **Collector) Resistor (Rc)** and the **Emitter Resistor (RE)**. The Emitter Resistor section of the circuit is attached to a **Bypass Capacitor** that preferential filters AC (noise) above certain frequencies to ground, letting certain AC frequencies to bypass the Emitter Resistor and go to ground, while the rest, mainly DC, flows through the Emitter Resistor.

The resting or quiescent current through the transistor side of the circuit with *NO* AC signal (guitar pickup signal) flowing into the base of the transistor can be determined by using known resistor and voltage values across the Emitter Resistor. Since the voltage across the transistor emitter leg is fixed, **(Vbe)** is given as **0.3V** for a Ge transistor (0.7V for Si), and knowing that voltage across R2 is the same as the voltage on the other side, the voltage across the Emitter Resistor **(RE)** is equal to V2 (or Base / Bias Voltage **Vb**) and therefore **V2** or **Vb=Vbe+VE** or 1.14V= 0.3V+VE whereby **VE =1.14V-0.3V** giving **0.84V** across the Emitter Resistor **(RE)** in the case of the Rangemaster. Using Ohms Law V=IR, the Current **(IE)** across the Emitter Resistor **(RE)** is I=V/R where **IE = 0.84V/3.9K = 0.215mA**. Don't confuse Voltage across the leg of the **transistor emitter (Vbe)** with Voltage across the **Emitter Resistor (RE)** as these two voltages sound similar, but are different things.

Knowing that the Current flowing through the **Collector (Load) Resistor** without any added AC signal voltage, **Ic** is approximately equal to the Current flowing through the Emitter Resistor, **IE**, then **Ic=IE**, which allows substituting **IE** for **Ic**, or **0.215mA**. Now we know that the Current flowing through the **Collector (Load) Resistor (Rc)** is 0.215 mA, the maximum **Voltage Drop** across the resistor (V=IR) is V=(0.215mA)(10K), or 2.15V. This leaves **6.85V** at the ground (negative) side of the resistor as the source (battery) voltage is 9V, that is **9V-2.15V=6.85V**. This corresponds to the ~7V measurement at the collector that one should obtain with a multimeter. This amount can also be deemed as **Vout**.

Knowing that the **Base Current (Ib)** of **0.02mA** for a Base (Bias) Voltage (Vb) of ~1.0V (somewhat complex calculation for this, with value given in the Electrosmash article). Using the ideal **HFE** (also known as **β**) of the Ge transistor of **90**, the **Current** at the junction of the Load/Collector resistor **(Rc)** at Saturation is **1.8mA**, much larger than the Base Current and calculated using **Ic=(β)(Ib)** = (90)(0.02mV).

Regarding the **Emitter Bypass Capacitor**, it is used to **Increase** the **Gain** for **AC signals**, and **filters AC** (noise) to ground helping to **stabilize** the **bias voltage** of the transistor. The way it works is the way all capacitors do by filtering out (stopping) Low Frequencies and requiring them to pass through the Emitter Resistor. The Higher Frequencies will take the path of least resistance *Bypassing* the Emitter Resistor and instead pass through the capacitor to ground. The capacitor (**Ce)** will be chosen so that it effectively **short circuits AC voltages around RE.**

The calculation for the capacitor value is as follows, and unfortunately math is involved. The formula used is **C=1/(2πf)Xc** where **C=Capacitance**. The **time constant** of the **resistor** and **capacitor** is **t=RC** where **t=1/f, f=20 Hz** is the **lowest** AC **frequency** in this case. The **Reactance** (**Xc)** of the capacitor is to be one-tenth **1/10th** of the resistance across the emitter resistor (**RE)** at the lowest frequency intended to be bypassed. Therefore, **C=1/(2πf)(0.1)(R>E)** or 1/(0.8283)(20)(3.9K)=**20.4uF**. Note that the lowest frequency of human hearing, **20Hz**, is used. So this means that a **22uF** capacitor should be fine in this circuit, and I have seen some RM schematics drawn with a 22uF cap in place of the 47uF capacitor in the original circuit (47uF capacitor passes frequencies above 9Hz which is below the audible range of human hearing).

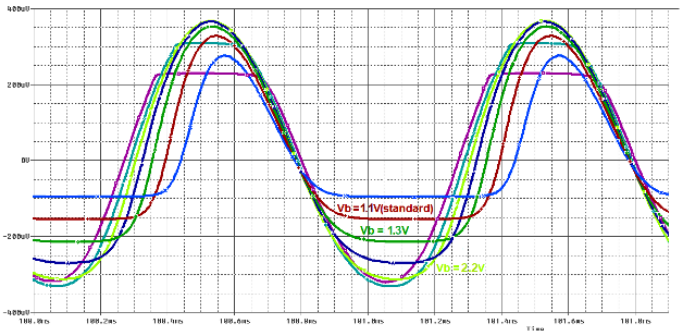
Regarding the increased gain achieved by using a bypass capacitor, the **gain** of the circuit **without** a **bypass capacitor** across the emitter resistor is approximately **Rc/RE**. The **gain** of the circuit **with** a **Bypass Capacitor** can be calculated as **Gain=VRc/VThermal = VRc/26mV**. **VThermal** is related to Base-Emitter Voltage through the emitter leg of the transistor, **Vbe**. Small signal bipolar transistors have an **internal resistance (Rbe)** in the emitter leg of the transistor that is the product of **25mV ÷ IE** (25mV being the internal volt drop across the Emitter junction layer). The internal resistance using 25mV/0.215mA is **116 Ohms**. Knowing that the at **Low Frequencies**, Voltage goes to ground through **RE** as well as through the **Bypass Capacitor**, **gain** is related to **Rc/(Rbe+RE)**. At **High Frequencies**, the **AC voltage** preferentially goes to ground short circuiting **RE** and **Gain** is related to **Rc/Rbe**. With **Rbe=25mV/0.215mA**=**116 Ohms**, gain at **lower frequencies** is equal to

10K/(3.9K+116R)=10K/4.016K, or a **2.5**X gain in voltage. For **High Frequencies**, the **gain** is equal to **Rc/Rbe** or **10K/116R=86**, so for higher frequencies the voltage gain is approximately **83 times** more that the gain for low frequencies.

The Rangemaster provides a gain of up to 24db at frequencies above about one to 2 kHz. It has about unity gain at the lowest normal guitar notes, and the **gain** about **doubles** with **each octave**. Since a doubling of level is a just-perceptible change in loudness, not a perceived doubling of loudness, this amounts to a fairly mild increase in level for higher notes, enough to make the guitar more “present”. As you can see, the **Bypass Capacitor** added in tandem with the Emitter Resistor (**RE)** results in the loudness increase with higher frequency notes, and shares this characteristic with other treble booster effects.

As a result of the use of Germanium devices and careful biasing, there is a Subtle **Distortion** added as well. The sound of the Rangemaster is heavily dependent on the bias point. Normally transistors are biased as close to the *middle* of their linear swing area as possible to get the biggest possible non-distorted signal out, or maximum headroom. The maximum swing operating point in the NPN Rangemaster happens when Vb=2V approximately and Vc=5V approximately. This is not the case of the Rangemaster, where the bias is a bit off the center, around 1.0V, creating an asymmetric gain. The supposed best sounding biasing happens with Vb at approximately 1V and Vc at approximately 8V. This is because the transistor amplifier is not biased at the <u>center</u> of the linear region.

It is commonly agreed that the ideal bias point for a NPN Dallas Rangemaster Treble Booster is to have Q1 collector voltage at around 7.0V, if the voltage is referred to ground. Using standard amplifier design concepts, the bias voltage should be around 1.3V (VE of 1.0V + Vbe of 0.3V) for the given circuit (without considering the biasing resistor network). This gives slightly more leeway above **cutoff** if there is an additional 800mV AC guitar signal voltage about the bias voltage providing more room above cutoff (2.1V to 0.5V for +/- 800mV) This is for a Ge transistor Vbe of 0.3V where the transistor is not as closely approached compared to a bias voltage of 1.0V. It should be noted that at a base voltage of 0.3V, there is no longer forward bias (no current flow) through the emitter emitter leg of the transistor as the Vbe>Vb and cutoff occurs, that is no forward current flow through the emitter leg occurs. Approaching a base voltage of 0.3V results in an asymmetry of the signal waveform due to being near clipping, a characteristic of Ge transistors. Note that for the RM circuit, the base bias is calculated to be approximately 1.14V, so a very strong input signal of 800mA will be minimally above the cutoff voltage of 0.3V.



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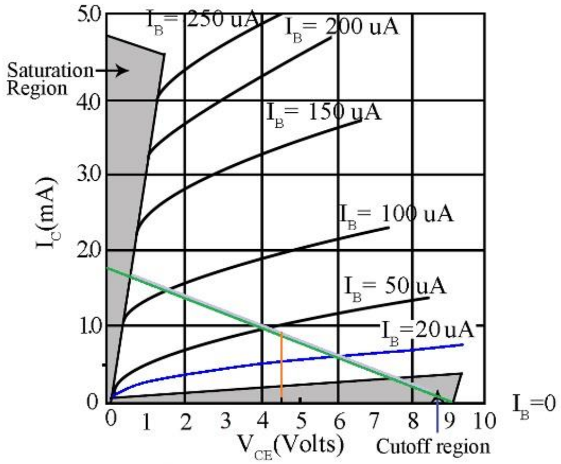


output characteristics Ge Transistor

Above is a guestimate of the output characteristic curve for a Germanium transistor. The load line (Green Line) is drawn between Saturation and Cutoff of the transistor. The blue curvilinear line is the Input/Output current curve at a base current of 0.02mA. Saturation is where the transistor is turn fully on and any increase in base current does not change the maximum output current (more or less). Saturation is calculated by (HFE)(Ib). Cutoff is where there is no flow throw the emitter (base voltage <Vbe or a lower potential than Vbe) and hence Ib=0. The voltage change produced by the transduce fluctuates about the *midpoint* of the load line, being slightly less than 4.5V. If you notice that 4.5V in either direction along the load line puts the voltage in the *non-linear* section of the Input/Output current curve on one side and at *cutoff* on the other, resulting in distortion.

Building/Designing a Common Emitter Amplifier

Next I will discuss the building and designing of a music signal amplifier using a transistor, and most signal amplifiers primarily apply to having a clean, non-distorted amplified output signal. The reason for discussing the building of a CE amplifier is to see how the original designers of treble booster and other booster pedals used certain principles to come up with their circuits, and how they slightly changed or modified the circuit. Basically, early booster pedals are fairly simple common emitter amplifier circuits with known design parameters using "formulas" such as what is laid out below. The subtle differences in the Rangemaster circuit will be indicated below.

First of all, a Common Emitter Amplifier is so named because the emitter is the element "common" to both input and output. That is, the input signal is applied between the base and **emitter** terminals while the output signal is taken between the collector and **emitter** terminals, or in other words, the **emitter** is **common** to both the **base** and to the **collector**. In this configuration the input parameters are Base-Emitter Voltage (Vbe) and Base Current (Ib) and the output parameters are Collector-Emitter Voltage (Vce) and Collector Current (Ic).

For designing an amplifier, the following parameters are chosen.

1. **Decide on the DC supply voltage VCC**

Values of 6 to 12 volts are common for a common emitter voltage amplifier. Of course for a guitar pedal, a supply voltage of a 9.0V battery is pretty standard.

2. **Choose a transistor**

Usually a low gain NPN or PNP transistor is sufficient. We will choose a NPN Germanium transistor with an HFE of 90.

3. **Decide on a suitable quiescent collector current Iq**

Iq is the *Collector current* when *no signal* is applied. Using the transistor datasheet, the maximum value must be less than the maximum Ic(max) figure for the transistor. The circuit is supposed to be a VOLTAGE amplifier so current should be kept quite low. However, the lower the current you choose, the higher the value of load / collector resistor RL (aka Rc) will be. This *increases* the *output impedance* of the amplifier, which will be *approximately* the *value of the* *load resistor*, and ideally this *should be low*. A compromise figure of 10 to 20% of the transistor´s Ic(max) and a commonly selected current of around 1mA is used by many. For example, parameters I found on both OC44 and OC75 Datasheets give a Maximum Collector Current (Ic max) of 0.01 A, or 100mA. A value of 10 to 20% of the Ic(max) is 1.0mA – 2.0mA.

Let us choose 1.5mA, right in the middle.

4. Calculating a value for the Load Resistor RL (collector resistor Vc)

Once the supply voltage and collector current are decided, the value of the Load Resistor (**Collector Resistor Vc)** can be calculated. The transistor quiescent collector voltage needs to be slightly less than half of Vcc (range Vbattery/3 < Vce < Vbattery/2) so that the output signal can swing by equal amounts above and below this value without driving the transistor into saturation (0.0V and maximum collector current) or cut off (Zero current and Vc = Supply Voltage Vcc). This will define the resistor value using Ohms law and therefore RL (aka Rc) will therefore be slightly less than half Vcc divided by Iq. For this example, let's choose a voltage of 4.45V along with the Ic of 1.5mA for 4.45V/1.5mA = 2.97K with the closest available value of 3.0Kohm.

This gives a Voltage Drop across Rc of 4.5V, and matches half of the battery Supply Voltage Vcc of 9.0V.

In the Rangemaster, the Maximum value of Rc can be up to 10K, greater than the 3K for Rc in our design. This is probably to coax more gain out of the circuit as voltage gain is related to the size of the collector resistor. From the general gain formula, voltage gain is related to Rc/Re. If you make Rc larger, then gain will be greater.

5. Calculating the value of Re

To provide efficient bias stabilization, the Emitter Voltage (Ve) should be about 10% to 15% of Vcc. So choosing a value of 15% of the Vcc value of 9.0V (1.35V) for Ve and assuming that Ie is the same as Ic (It is only different by the small amount of the base current), the value for the resistor Re can be calculated by dividing the *Emitter Voltage* Ve by the *Emitter Current* Ie (1.35V/1.5mA = 0.9KOhms). Choosing the nearest preferred value of 910 Ohms or the more common 1.0KOhms may be used. Let us choose 1.0K in our design.

The Rangemaster uses 3.9K emitter resistor, and although I don't know the exact reason for this, it is probably related to providing greater thermal stability of the transistor. The higher the value of Re, the greater the stability of transistor current when it comes to temperature induced changes.

6. Estimate a value for base current Ib

This can be found by *dividing* the Collector Current Ic by the transistor´s current gain HFE (aka Beta) obtained from the data sheet. Because the HFE varies from one transistor to another (even the same transistor model number) it should be known that this is a *typical* value, or as a range between minimum and maximum values for a bunch of these transistors. HFE also varies with collector current, so whatever value is chosen for HFE, the result of calculating Ib will be an approximation and therefore the measured base voltage may not be entirely accurate with respect to the calculation. However, this can be ‘fine tuned’ when the amplifier is being constructed.

For this example, we will choose an HFE of 90 so that Ic/90 = 1.5mA/90 = 0.0167mA.

7. Calculating Base Voltage Vb

The base voltage should be about 0.7V for Si transistor (0.3V for Ge) greater than Ve to ensure that the input signal is biased on the linear part of the transistor input characteristics. For this example of a CE amplifier with a Ve of 1.35V and powered by a Ge transistor, this means Vb = 1.35V + 0.3V = 1.65V for a non-distorting bias voltage.

Note that compared to the Rangemaster, the calculated bias voltage here is further away from the cutoff emitter leg voltage of 0.3V, so even with a high voltage negative amplitude pickup signal of -600mV (highest a vintage PAF pickup produces) that the base voltage does not approach cutoff. That is, there is still greater than +1V base voltage on the greatest negative amplitude voltage swing, so there should be no flattening of the negative amplitude portion of the signal waveform. Therefore, there should be only clean non-compressed and non-flattened output signal. So there is no Rangemaster “magic” here with a standard amplifier design.

The Rangemaster was intentionally biased on the low side so there would be mild distortion of the output signal, as discussed in the first installment.

8. Calculating the DC bias network current.

To ensure adequate bias stability, the current flowing through R1 and R2 should be about 10 times greater than the base current Ib so the current flowing through R1 and R2 will be simply Ib x 10. For this example, (Ib)(10) is (0.0167mA)(10) = 0.167mA for Io (bias network current).

9. Calculating the resistance for R1

The value of this resistor will be the difference between Vcc (Source or battery voltage) and Base Voltage (Vb) divided by the bias network current through R1 and R2. Therefore, (Vcc-Vb)/Io = (9V-1.65V)/0.167mA = 44.01K, choosing the closest value of 43K.

10. Calculating the resistance for R2

The value of R2 will be the Base Voltage (Vb) divided by the bias network current through R1 and R2. Therefore, Vb=(R2)(Io) and R2 = Vb/Io = 1.65V/0.167V = 9.89K or rounded to 10K.

Note that the Rangemaster has much larger values of R1 and R2. Again, I do not know why the original designer chose these values, but one of the formulas that can be used for biasing the transistor using a divider network is **R1+R2~(10)(R3+R4)**. This would give larger values for R1 and R2, but not quite as large as the original circuit. However, I note that Tonmann must have recognized this and his bias network uses smaller resistor values (200K for R1 and R2 should be around 29K using the trimmer). Tonmann's version is closer to this concept as a 10K max Rc and 10K max Re multiplied by 10 would be around 200K.

11. Emitter bypass capacitor

The gain of the circuit without a capacitor across the emitter resistor is approximately Rc/Re. To increase the gain of AC signals and further stabilize the bias voltage, an emitter resistor bypass capacitor C3 is added. This should be calculated to have a Reactance equal to one tenth of Re at the lowest frequency of operation. The formula to calculate bypass capacitor C3 is given below.

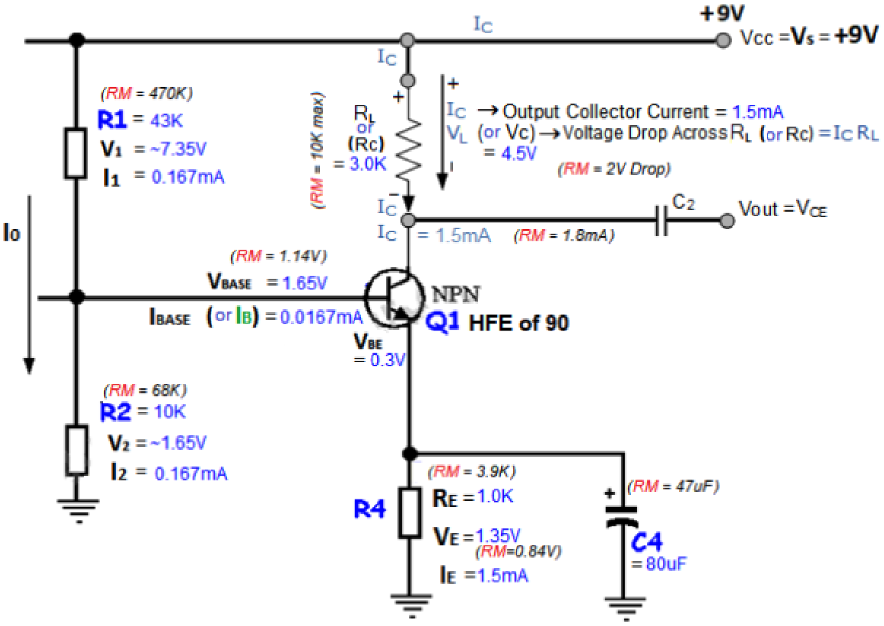
$C=1/(2\pi f)X_c = 1/6.283(f)(0.1)(Re) = 1/0.6283(f)(Re)$

For our example, we will choose 20Hz, the lowest frequency of human hearing, as our frequency. Therefore,

C = 1/(0.6283)(20)(1.0K) = 80uF for the bypass capacitor value. If we chose 910 Ohms for the emitter resistor value, the bypass capacitor value would calculate out to 87uF.

The Rangemaster uses a larger emitter resistor (Re), so a capacitance of approximately 22uF would have been fine for increasing gain relative to the lowest frequency of human hearing. The 47uF used in the Rangemaster is fine as it passes passes frequencies above 9Hz which is below the audible range of human hearing. Maybe this was used because it was a commonly available capacitor at the time the originals were built.

Below is the schematic of our Common Emitter Amplifier circuit with a few Rangemaster values in parentheses for comparison.



Armed with the knowledge of common emitter amplifiers as it relates to treble boosters, I took another look at the Silicon Hornby-Skewes treble booster that I previously built as well as others including the modern Naga Viper and a Germanium Hornby-Skewes treble booster I recently breadboarded. They are all similarly constructed with a few variations. Knowing that the Silicon Hornby-Skewes has a 1K emitter resistor similar to our amplifier example above, the bypass capacitor calculated at 80uF is exactly what is on the original HS schematic, providing confirmation of the principles outlined here. I think anyone with this knowledge could easily design their own working booster pedal.

Revisiting the Emitter Resistor

For installment #3 of the series, I am going to answer my original post. Why did Tonmann place a 10K trimmer off the emitter leg of the transistor? Well hopefully I have answered my own question correctly after doing research on various common emitter amplifier topics.

As discussed in the first section above, an Emitter Resistor is added to the Common Emitter Amplifier circuit to accomplish two purposes, reduce distortion and control gain.

The first purpose is to *reduce* Temperature induced *distortion* through the Emitter Resistor by *Negative Feedback*. That is, when Temperature increases, Collector Current (Ic) increases. When Collector Current (Ic) increases, the voltage drop across Re (Ve) increases. Vb, the voltage at the base, remains fixed due to the biasing arrangement, so to compensate the Base-Emitter voltage drop (Vbe) decreases. If Base-Emitter Voltage (Vbe) decreases, Base Current (Ib) decreases. If Base Current (Ib) decreases, then Collector Current (Ic) decreases, bringing it back to towards the original Q point value. The rise in Collector Current (Ic) due to temperature is countered by a fall in Collector Current (Ic) due to the feedback action of the Emitter Resistor (Re). The greater the value of the Emitter Resistor, the better the Temperature stability.

In Summary:

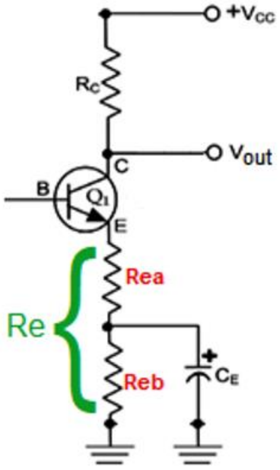
↑Temp = ↑Ic = ↑Ve (as Ic=Ie and V=IR) = ↓Vbe (as No Change in Vb due to bias network) = ↓Ib = ↓Ic

The second purpose is to *affect* amplifier *gain*. The *value* of the Emitter Resistor along with the Emitter Bypass Capacitor acting in tandem can result in an *increase* in amplifier gain. A good *AC voltage gain* requires a *low* value of emitter *resistance*.

This is where things can get tricky as good *AC gain* requires a *low* value of emitter *resistance*, but the opposite is true for Temperature induced distortion. Good *temperature stability* requires a *high* value of emitter *resistance*. In other words, to *reduce distortion* related to temperature, the value of the emitter *resistance* must be *increased*. In practice, a *compromise* is often made between these conflicting requirements.

So what is the best way to make a compromise on the value of the Emitter Resistor? Is it possible to get the best of both worlds, good gain and good temperature stability?

Well, the emitter resistance (Re) can be broken up into two parts, which we will call Rea and Reb. That is, you can take the Emitter Resistor value that you had planned to use and split it into two separate resistors in series that add up to the same value of the originally planned resistor value. For example, for an Emitter Resistor (Re) of 5K, you could use a1K and 4K resistors in series that add up to 5K. This is called a *Split Emitter Resistor* configuration.



If you tap off the Emitter Bypass Capacitor (as above) between the two resistors so that the capacitor is in series with the first resistor (Rea) and in parallel with the second resistor (Reb), you can get the best of both worlds! The resistor in the emitter leg has now been split into two parts: (Rea) and (Reb) forming a voltage divider network within the emitter leg with the by-pass capacitor connected in parallel across the lower resistor.

The upper resistor (Rea) is unbypassed by the capacitor so must be considered when calculating signal parameters. The value of (Rea) is chosen to provide the required compromise between gain and distortion as the AC signal current only sees (Rea). The second resistor (Reb) is connected in parallel with the capacitor and is considered to be *Zero* ohms as it becomes shorted out at high frequencies. In other words (Reb) the second resitor is bypassed by the capacitor and thus the AC current doesn't see R2. Because of this, AC Voltage Gain is partially determined by (Rea) and **for an AC signal** the total value of the emitter resistance is equal to (Rea + Rbe) where *Rbe* is the Base-Emitter resistance (25/Re). Since *Gain* comes from Collector Resistance divided by Emitter Resistance or Rc/(Rea + Rbe), the *smaller* value of *Rea*, the *greater* the *gain*.

Knowing that you want a small value of the upper emitter resistor (Rea) for greater gain, this would result in poor temperature stability and therefore some added distortion. However, the Bypass Capacitor basically blocks (filters out) DC, so DC (bias) is forced to go through the Emitter Resistors placed in series, which is fairly large value. Now you have your temperature stability and mitigate related distortion!

In summary, the *DC bias current* sees (Rea) and (Reb) in *series*, which results in *good temperature stability*, since total Emitter Resistance (Re) is seen by DC bias as a *large value*. The AC signal current only sees (Rea) since (Reb) is bypassed by Capacitor placed in parallel (AC current doesn't see R2) and so AC signal gain is related to (Rea) and (Rbe), therefore the amount of gain can be controlled by the size of (Rea).

As you can see, using a potentiometer as a Split Emitter Resistor allows one to adjust the amount of AC Signal Gain if you place the Emitter Bypass Capacitor off of the wiper leg, Lug 2. Adjusting the 10K pot controls the amount of resistance (Rea) that is in series with the bypass cap, so gain can be adjusted. Since in an amplifier, one usually wants a large gain, (Rea) should be kept small.

If you notice in the instructions for the Guitar PCB Pumped Up Rangemaster, that to "adjust the TR2 'GRIT' trimmer **properly, turn TR1** ***all the way up*****. The further** ***clockwise*** **you turn it, the** ***louder*** **and** ***more*** **of an** ***overdriven*** **sound you will get. Once you have it hooked to your amp, you may want to** ***adjust it*** **back up by** 5-15% **to suit your tonal preferences." Turning up the Trimmer apparently means making (Rea) a minimal value for the greatest amount of gain. Backing off the trimmer a bit decreases the gain slightly providing a slightly less "gainy" tone or sound. It should be noted that the early treble boosters were meant to have the gain all the way up (that is to "11").**

Tonmann provided us with a modern design of the old Rangemaster circuit. First, he changed the bias network and added a trimmer at R2, allowing us to fine tune the bias. A large 470K resistor at R1 was changed to 200K possibly for easier parts availability, but in Installment #2 of the series, you can see that Tonmann applied some known standard design concepts to the bias network to conform more with convention. The split emitter resistor is also a great addition providing greater temperature stability to the notorious finicky Germanium transistors that one finds these days along with more flexibility to control overall gain of the pedal (adjustable gain). All Hail to Tonmann