Pickups and Wood in Solid Body Electric Guitar – Part 2

by Butch Iafelice - Calaveras Fretworks Custom Guitars - May 2011

Introduction:

This is the second in a series of articles discussing the contributions and interactions of pickups and woods to the sounds produced by solid body electric guitars. In Part 1 I described the test setup and procedures, the frequency spectra similarities and differences between the Fender Texas Special, Gibson 57 Classic Plus and Seymour Duncan JB model bridge pickups when mounted in the same body wood type, and the frequency spectra differences between the same pickup mounted in two different body woods. Part 1 of the analysis allowed us to compare and contrast the amplitude (gain) and tonal (color) characteristics of the guitar sound from each of these pickups and the effect that the guitar body wood has on the sound of the instrument.

In Part 2 I will be concerned with sustain measurements using the same three pickups mounted in guitars with different body and/or neck wood types having different weights (or densities). The way I will go about discussing these new tests and findings assumes that the reader has already read at a minimum the introduction to Part 1 so I will not have to re-describe the test procedures, terminology, etc., that I will also be using here in Part 2.

The Data Discription:

1) The effect of total body-neckfingerboard wood weight on sustain:

I will now compare three body-neckfingerboard wood configurations whose total weight varies from the lightest that I currently have available in my shop, that is, Ash-QuarterSawnKorinaCocobola (AKC) through the heaviest Mahogany-MapleMaple (MMM) with Ash-MapleMaple (AMM) being a combination of both light and heavy components. Table 1 below shows the weights of each of the individual components that I will be discussing throughout this article along with their relative percent difference from the lightest.

Wood	Body Weight (oz)	% Difference	Wood	Neck Weight (oz)	% Difference
Ash	57	0	KorinaCocobola	22	0
Mahogany	78	37	MapleMaple	26	18

Table1: Guitar body and neck weights and relative percent differences.

The sustain measurements that I will be presenting in this article can be thought of by imagining the frequency spectrum shown in Figure 11 below. This plot displays the amplitude of the different frequency components at an instant in time immediately after a note has been picked. As time moves on the amplitudes will decrease until each of the peaks collapses into the background noise of the electronics. I can use what I will refer to as “narrow band” sustain measurements to answer the question, “How much time will it take for the amplitude of any particular frequency component to reach a certain dB level of loss after a note is picked". For example, if I want to consider the E4 harmonic I can look at a narrow frequency band centered around 330 Hz and use the spectrometer software to calculate the time it took for that harmonic to degrade -20 dB after the E note was picked. The answer may be, let's say, 2.45 seconds and I can then compare that sustain time to another sustain time from, say a different pickup or wood type.

I can also measure the "wideband" sustain which is the average sustain over the entire audible frequency range (from 20 to 20 kHz) for a particular measurement. This is a very informative way to look at sustain because our ears do not easily separate one frequency from another so this wideband response is more representative of what the ear actually hears as sustain. I will focus on wideband sustain measurements in this article and will often refer to it as simply sustain in the discussion. I will comment on the narrow band E4 and E5 responses if need be. Here are the low and high E note sustain results for the Texas Special pickups mounted in three different wood configurations.

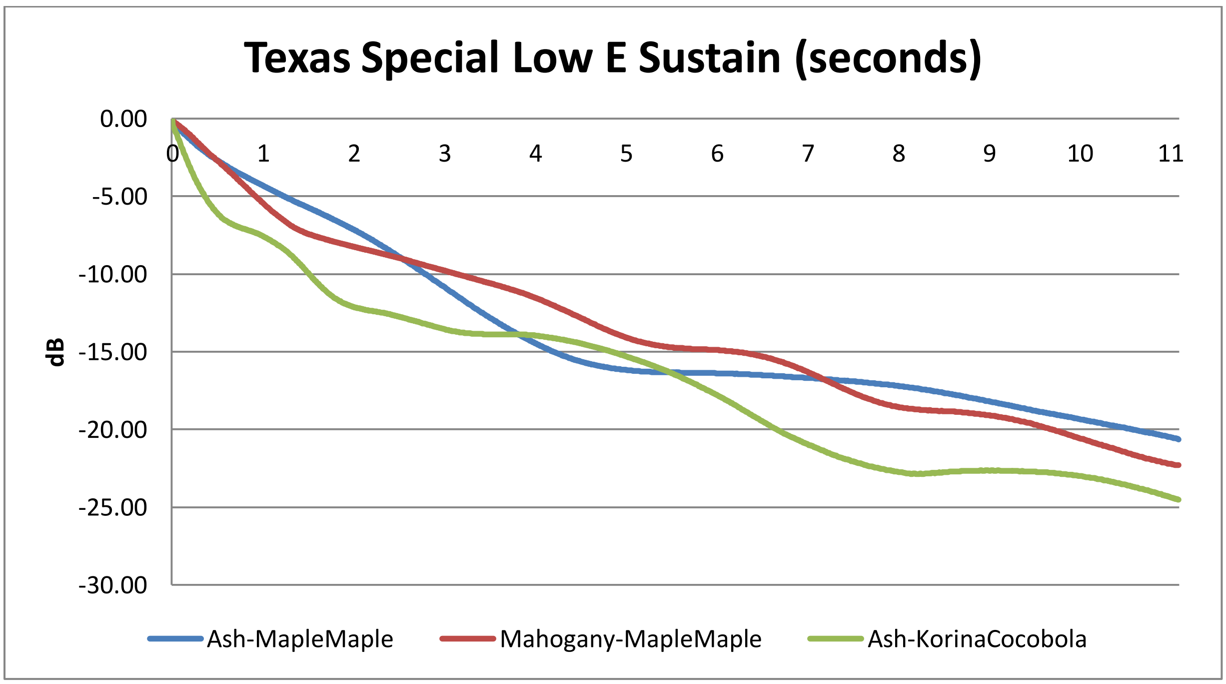

Figure 1: Low E note sustain for Fender Texas Special bridge pickup in three guitar woods.

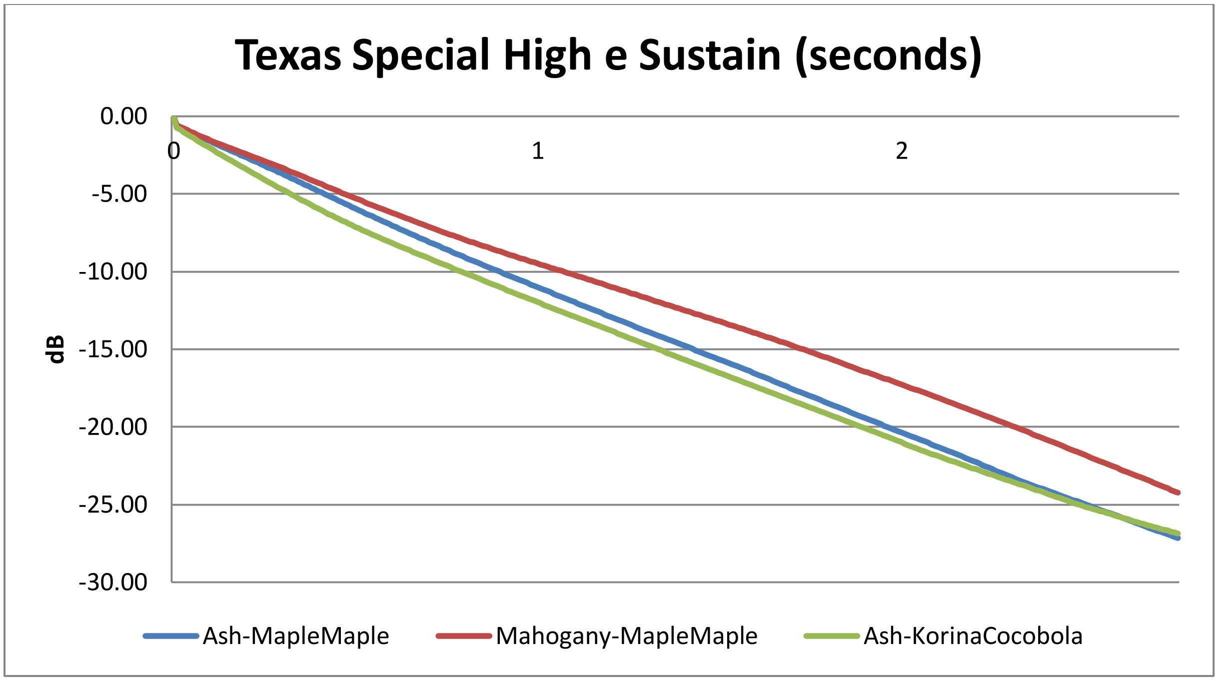

Figure 2: High e note sustain for Fender Texas Special bridge pickup in three guitar woods.

Note here that the lightest guitar (AKC) produces less sustain, however, for the low E note the heaviest configuration (MMM) does not always appear to produce the longest sustain time. In fact for sustain times to a -20dB loss or greater the nod would have to go to the AMM guitar for having the longest sustain.

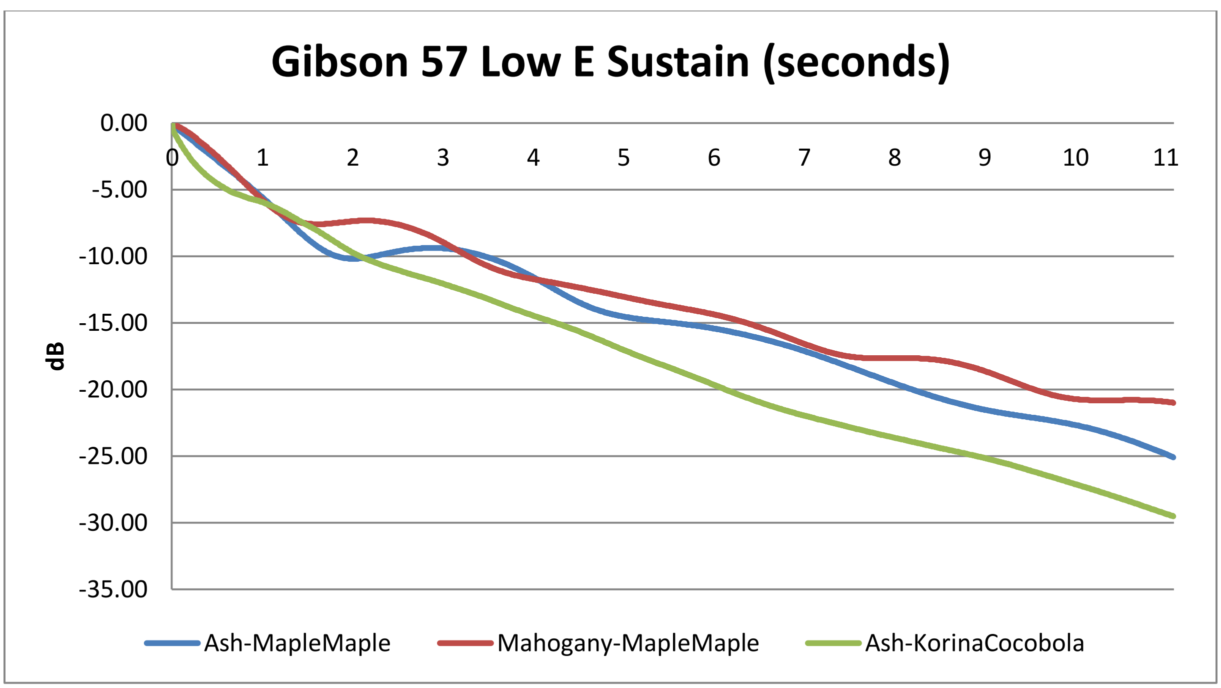

Figure 3: Low E note sustain for Gibson 57 bridge pickup in three guitar woods.

Here are the wideband sustain results for the Gibson 57 Classic Plus pickup.

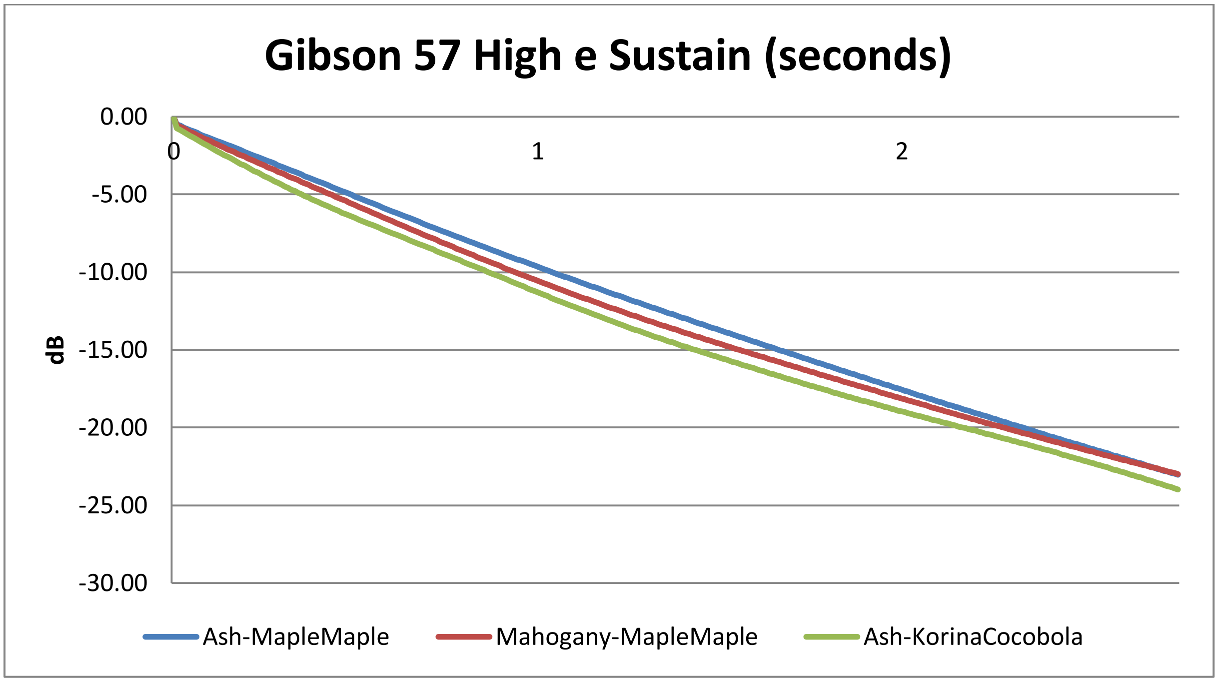

Figure 4: High e note sustain for Gibson 57 bridge pickup in three guitar woods.

For the low E note the wideband sustain clearly increases with the total weight of the wood but the high e note seems to favor the AMM configuration for producing greater sustain (if only slightly). This is also observed in the E4 narrow band sustain data.

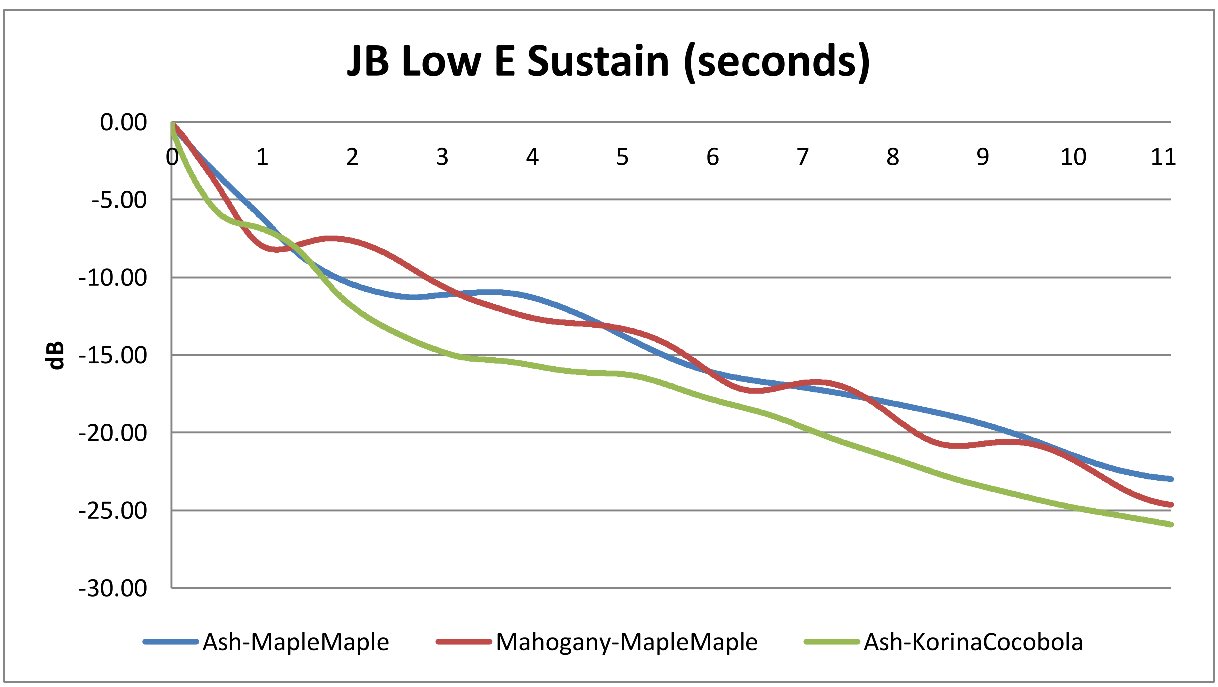

Figure 5: Low E note sustain for Seymour Duncan JB model bridge pickup in three guitar woods.

For completeness here are the wideband sustain results for the Seymour Duncan JB model pickup.

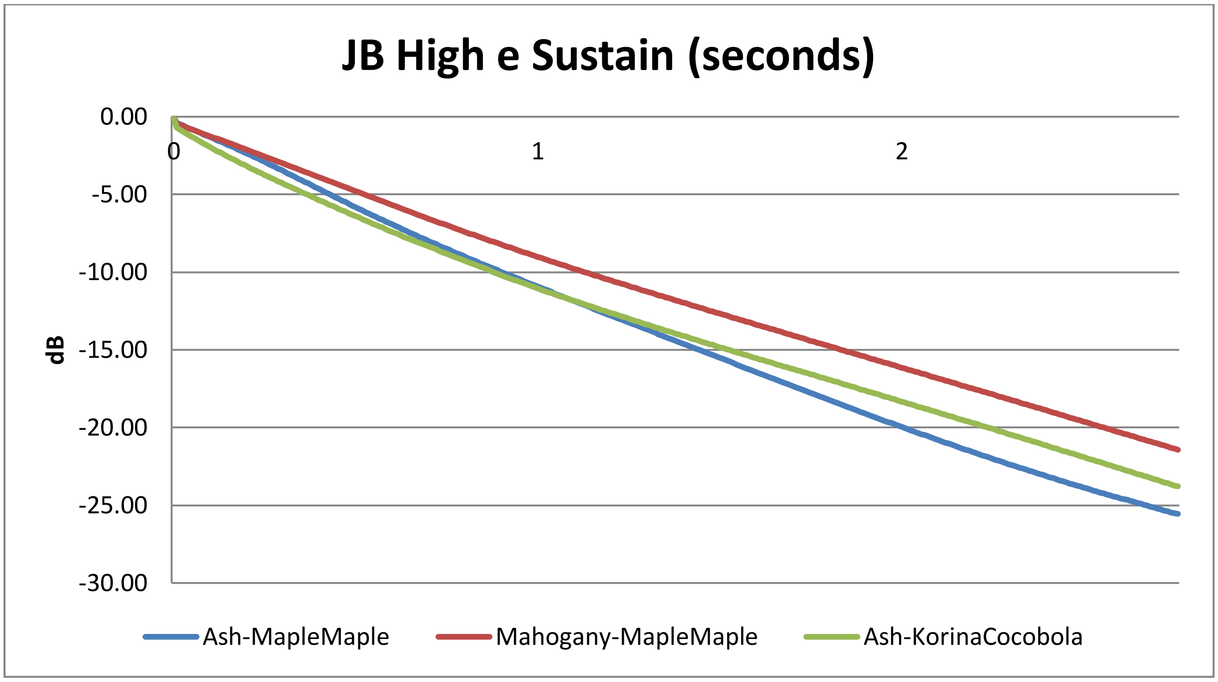

Figure 6: High e note sustain for Seymour Duncan JB model bridge pickup in three guitar woods.

Again the lightest guitar (AKC) produces less sustain, however, for the low E note the heaviest configuration (MMM) does not always appear to produce the longest sustain. For sustain times to a -20dB loss and greater the nod would have to go to the AMM guitar for producing the longest sustain.

To complicate matters even more for the JB pickup the high e sustain seems to favor the lighter neck AKC guitar over the heavier neck AMM demonstrating that the interaction between pickups and guitar woods does not lend itself to simple explanations. This enhanced treble end response is possibly due to some additional rigidity offered by the quarter sawn cut of the Korina neck compared to the flat cut Maple neck (more on this in the discussion section).

Suffice it to say that in many cases the observations support the notion that sustain is proportional to the weight of the guitar wood , that is, the heavier the total wood configuration (neck + body) the longer the sustain at both the bass and treble ends of the instrument. Most times the E4 and E5 narrow band sustain data also follow this same trend. Deviations from this general rule that weight is proportional to sustain occurred in the case of all three pickups looked at here. It is interesting to note that in these cases there is a strong correlation with the frequency spectrum responses presented in Part 1-Table 2, that is, if the sustain measurements are longer for a particular wood type then that wood type has also produced higher gain over some portion of the frequency spectrum.

2) Proportional changes in body weight vs. changes in neck-fingerboard weight:

I would now like to see if I can answer the question, "What part of the guitar (neckfingerboard or body wood) contributes most to sustain?" We already know from the previous section that this is a complicated question. I would like to compare and contrast proportionality changes in the body vs. neck weight in order to determine which component is more important to sustain in the guitar.

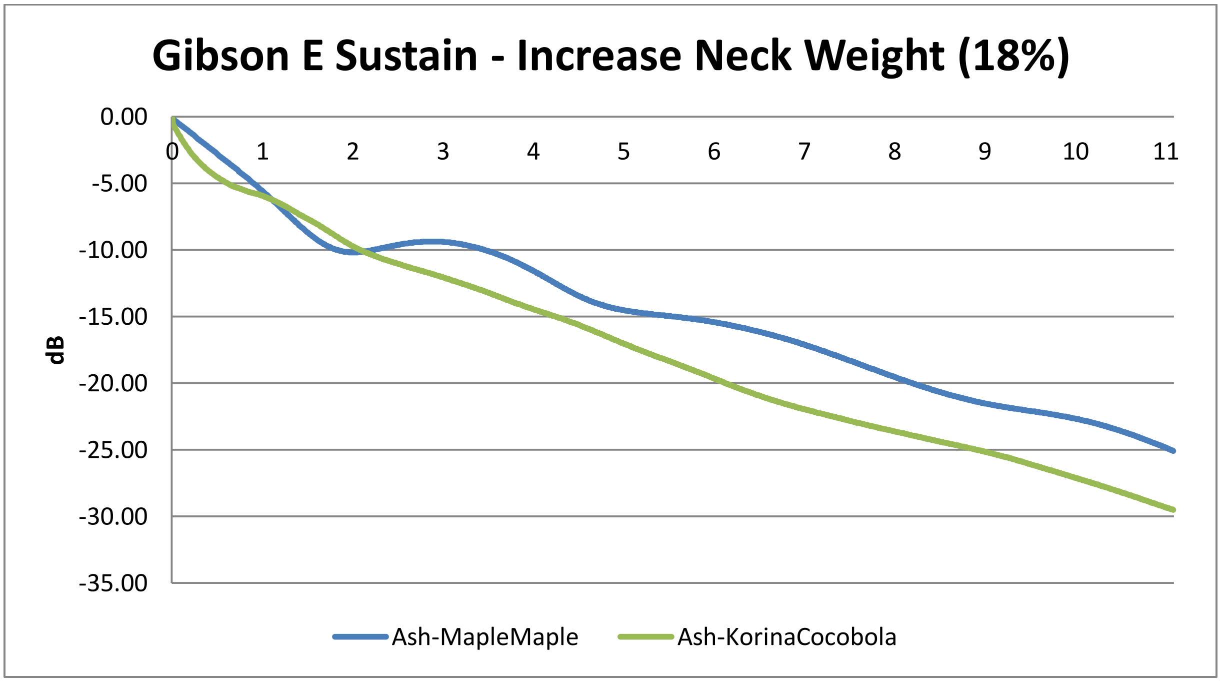

Figure 7: Low E note sustain difference after 18% increase in neck weight.

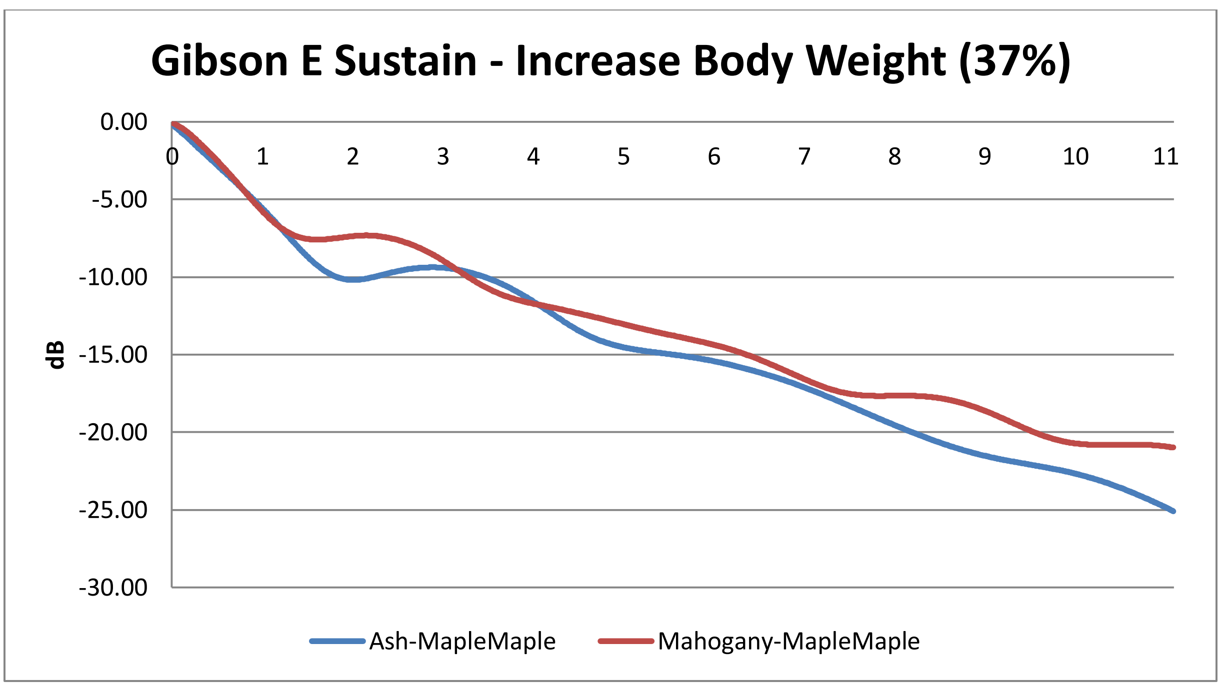

Figure 8: Low E note sustain difference after 37% increase in body weight.

Low E note sustain: Surprisingly an 18% increase in the weight of the neck (AKC -> AMM) produces a measurably larger increase in low E note sustain when compared to a 37% increase (AMM -> MMM) in body wood weight for the Gibson 57 pickup.

In general, one does not always get any appreciable increases in low E sustain by simply increasing the body weight of the guitar. In fact the data from the Texas Special and JB pickup measurements shown in Figures 1 and 5 above indicate that the heavier mahogany body data did not show a decisive increase in sustain when compared to the 37% lighter ash body data.

<u>High e note sustain</u>: The trends for sustain found in the low E note data seem to work in reverse for the high e note measurements. For the high e note and the Gibson 57 pickup the increased neck weight seems to be the dominant factor for any small increase in sustain (see Figure 4 above).

The Texas Special and JB pickups show little increase in sustain with just an 18% increase in neck weight alone. An additional 37% increase in body weight is responsible for considerable improvement (about 20%) in sustain for both these pickup (see Figures 2 and 6 above).

<u>The Data Discussion:</u>

1) The effect of total body-neckfingerboard wood weight on sustain:

In Part 1 I talked about the characteristic frequency spectrum for three pickups installed in body woods of two different weights. We saw how each pickup has its own characteristic amplitude (gain) and tone (color) spectrum and how that spectrum will change for the same pickup in different body woods.

For simplicity, these tests were performed at two extreme ends of the guitar scale, that is, the low E and high e open strings. The assumption here is that this data is representative of the general response found at the bass and treble ends of the instrument. Keep in mind that all the notes in between (and beyond) these strings will include characteristics of each of these two examples depending on their distance from these endpoints.

In Part 2 I introduced the idea of "narrow band" sustain, that is, the amount of "hang time" in different regions of the spectrum after a note is picked. I also introduced the idea of "wideband" sustain to give

	Light-Light weight	**Light-Heavy weight**	**Heavy-Heavy weight**
Gibson 57	Ash-KorinaCocobola	Ash-MapleMaple	Mahogany-MapleMaple
Low E Sustain			x
High e Sustain		x	
Texas Special	Ash-KorinaCocobola	Ash-MapleMaple	Mahogany-MapleMaple
Low E Sustain		x	
High e Sustain			x
JB	Ash-KorinaCocobola	Ash-MapleMaple	Mahogany-MapleMaple
Low E Sustain		x	
High e Sustain			x

Table 2: Summary of pickup and woods types for optimized wideband sustain.

us the idea of the overall or “frequency averaged” hang time of the note or chord. A guitar with long wideband sustain will be a more responsive and dynamic instrument to play.

Table 2 above is a summary of the effect of body-neckfingerboard wood weight on the wideband sustain. The x mark indicates which wood configuration produced the longest sustain. Note the similarity of this information compared to the frequency spectrum information given in Part 1 Table 2. If the sustain measurements are longer for a particular wood type then that wood type has also produced higher gain over some portion of the frequency spectrum.

For example, the summary data from Part 1 shows that the Gibson 57 produced higher gain (higher frequency spectrum amplitudes) for the low E note in the MMM guitar and higher gain for the high e note in the AMM guitar. A similar relationship appears in the wideband sustain data above.

The Texas Special and the JB produce higher gain for the low E note in the AMM guitar. A similar relationship also appears in the sustain data above. The high e note frequency spectrum data for both these pickups was inconclusive as to what particular wood type proved better, however, the sustain data above gives us another way to identify conditions for optimizing the treble end guitar response for these two pickups. Both of these pickups will have more sustain at the treble end of the instrument in the MMM guitar and therefore will be a more responsive and dynamic guitar to play at the high end of the guitar.

One can’t help but wonder if there may be some connection between sustain and gain and to ask the question, “If a particular configuration produces a higher gain over a portion of the frequency spectrum does sustain also increase over that same portion of the spectrum?” I took a look at the narrow band sustain results and was surprised to find that there appears to be a strong correlation between narrow band sustain and what I will refer to as “regional gain”. Table 3 summarizes the reported Low E gain results from Part 1 (p.7) and the narrow band sustain data for the E5 (660Hz) harmonic measurement.

	Sustain at E5 to -20dB (seconds)		Gain Differences at E5
Pickup	AMM	MMM	
Texas Special	3.6	3.4	MMM same as AMM
Gibson 57	3.4	4.4	MMM is 20dB higher
JB	0.8	2.6	MMM is 5dB higher

Table 3: Narrow band sustain results compared to observed gain differences at E5 for AMM and MMM woods.

The differences in the E5 harmonic amplitudes (gains) correlate well with the E5 narrow band sustain measurements, that is, the configurations (pickup + wood) that produced the longer narrow band sustain also have the higher regional gain. In nearly every instance all the gain differences that I have reported on in Part 1 and Part 2 over different regions of the frequency spectra correlate very well with the narrow band sustain results measured over those same regions. For example, in Part 1 (p.7) I reported that, “The Fender Texas Special shows essentially no difference between the MMM and AMM guitars at E5. In general, the AMM guitar shows an increase of 5 to 10 dB at frequencies greater than 1.2 kHz.” These observations agree with the results shown in Table 3 above and Figure 9 below.

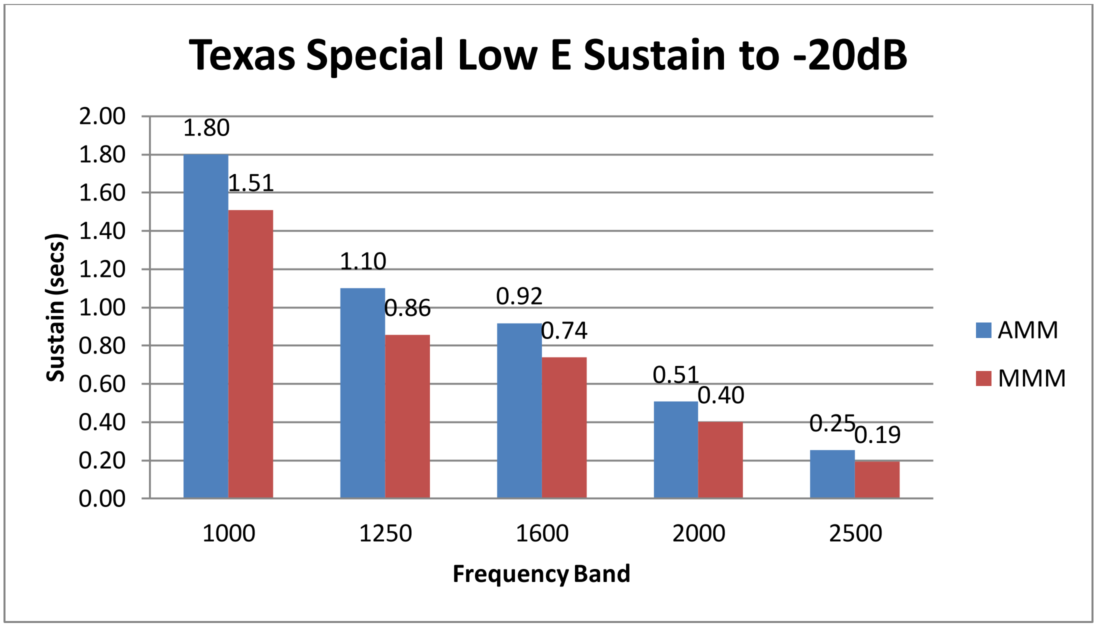

Figure 9: Texas Special Low E note sustain for frequency bands greater than 1 kHz.

I think I see the beginnings of a Part 3 article here….

2) Proportional changes in body weight vs. changes in neck-fingerboard weight:

Another way to look at the data is with the help of the bar graph below. The sustain differences to

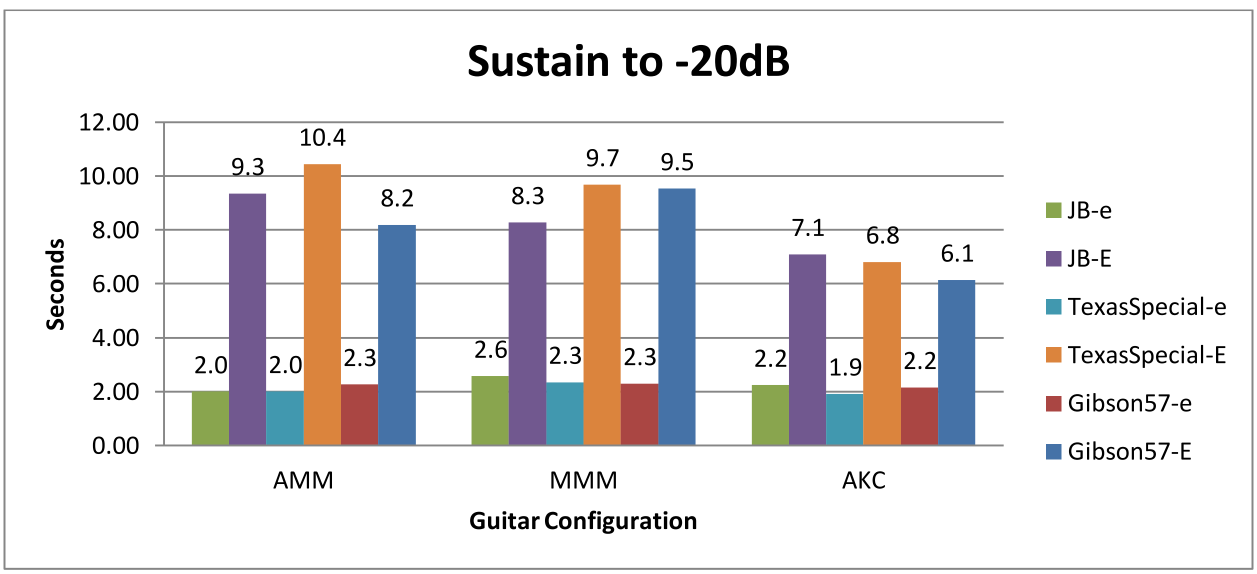

Figure 10: Comparison of sustain times to -20dB of Low E and High e notes for different wood and pickup combinations.

-20dB between the lightest total body weight guitar (AKC) and the other two woods is made visually obvious in this graph, however, the differences between the AMM and MMM are mixed.

The advantage of using heavier neck wood instead of body wood weight to improve sustain is obvious. In fact, for all the types of pickups and woods that I have looked at in these tests (and in others at CFCG) I have found that additional weight or density in the neck will most often produce higher levels of sustain in the guitar. This seems to make sense because a denser more rigid neck wood construction will absorb less energy from the vibrating string and produce more sustain in the note or chord. Or conversely a lighter less rigid neck wood construction will absorb energy from the string more readily and produce less sustain in the note or chord. However this may not be the only thing one can do to improve sustain. I have already shown examples of how some configurations can also benefit from the use of heavier body woods to further improve sustain at both the bass and/or treble ends of the instrument.

I should also point out that throughout this analysis I have been assuming that there is minimal energy loss at the neck-body interface. In the case of a bolt-on neck this means that I have good wood-on-wood contact in the neck pocket. The age old argument of bolt-on vs. neck-thru design has never made any sense to me. As long as the joint is solid at the neck-body interface then losses will be at a minimum. Some people claim that the wood-on-wood contact of a bolt-on neck will propagate resonances better and be brighter than that of a neck-thru design because of neck-thru losses at the glue joint. My guess is that if you compared two identical guitars whose only difference was the neck-body joint (the ultimate bolt-on vs. neck-thru experiment) that there would be no significant difference in resonance and sustain between the two. There are more important reasons why, let's say, a Gibson LP (neck-thru) and a Fender Tele (bolt-on) guitar sound and play different. It should be clear from my discussions in these two articles that the pickups are most important in defining the sound of the instrument followed by choice of neck and body woods, and design issues like scale length and other physical design parameters. Another thing that is often overlooked when making such comparisons is how well the particular guitar was built and how well the instrument was set up. All guitars are not created equal, especially when they are mass produced.

I have shown in a number of examples in this article of how one configuration may improve sustain at the bass end of the instrument while another will work better at the treble end. What is really important is the final overall sound produced by the instrument. A good example to look at here is the case of the Texas Special pickup. The bass end of the instrument is found to be brighter with longer sustain using the traditional Fender wood configuration (AMM). On the other hand I often prefer the mahogany body (MMM) which produces more sustain at the treble end of the instrument and more bottom at the bass end. So the loss in one attribute may be acceptable in light of the benefits offered in other areas, albeit at the price of heavier overall guitar weight, which may be a big drawback for some players.

Another favorite sound I recommend is the AKC with the JB pickup. Figure 10 above shows that the JB pickup produces the longest sustain in the AKC guitar when compared to the other two pickups. However if you compare sustain time for the AKC with JB pickup to that of the JB in other guitar woods you might think that AKC is not the ideal wood configuration to use with the JB. My ears (and other player's ears) tell me just the opposite. A quick look at the frequency spectrum data may shed some more light on this situation. We can see from the Figure 11 below that the low E note AKC data in gray shows a 10 to 20 dB amplitude gain between 1.5 kHz and 9 kHz when compared to the AMM data in purple. This is a huge gain difference (shown in black) which has a considerable impact on what you hear. I am speculating here that this mid-high frequency gain may be due to the extra rigidity provided by the quarter sawn cut of the lighter Korina neck as compared to the heavier flat sawn Maple neck. This may be worth some additional test work to figure out - more on this topic later.

So even though there is a large increase in sustain at the bass end of the instrument for the AMM guitar the AKC guitar shows an increase in treble end sustain while also producing a 10 to 20 dB mid to high frequency gain at the bass end of the instrument! So the AKC produces a guitar sound having greater treble end sustain and brighter attack and bite at the bass end - albeit at the cost of bass end sustain. Depending on your style of play, either of these conditions may be preferred.

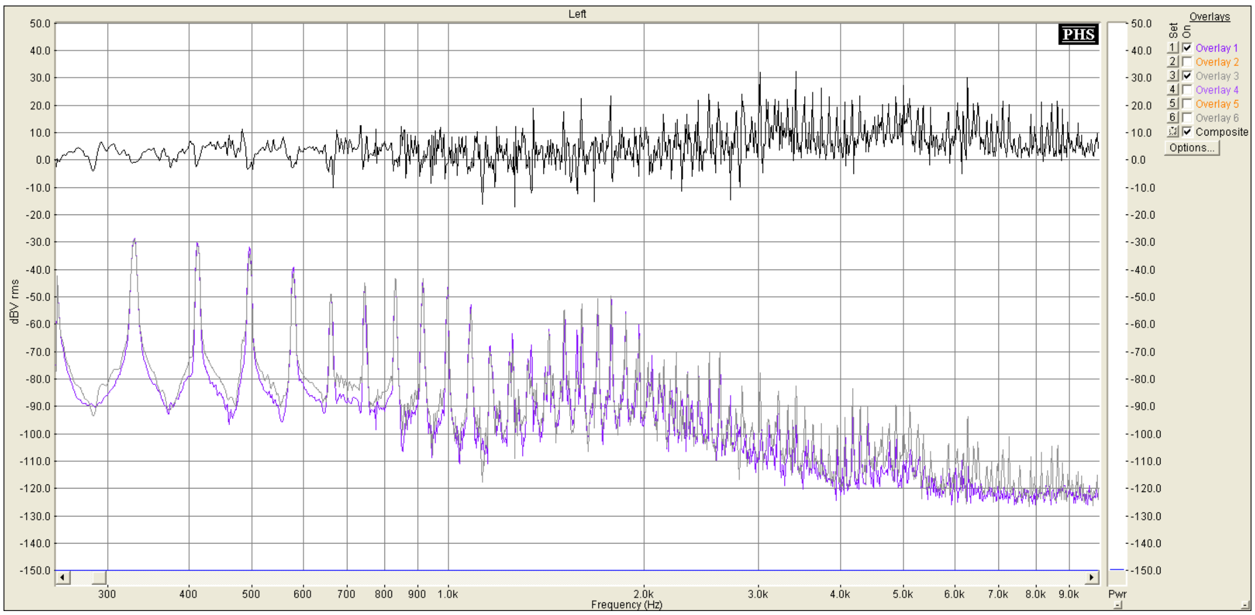

Figure 11: Low E note comparison for JB bridge pickup. AKC guitar in gray, AMM guitar in purple, data difference in black.

At CFCG I have been able to characterize many of my most favorite pickups and wood types using both frequency spectrum analysis and narrow and wideband sustain measurements. My intent as a luthier has been to use this type of analysis as a guideline to instrument design and optimization. The final decisions as to the optimum instrument design parameters should be left to the individual player depending on their own style of play and musical preferences and ultimately to their own ears.