History

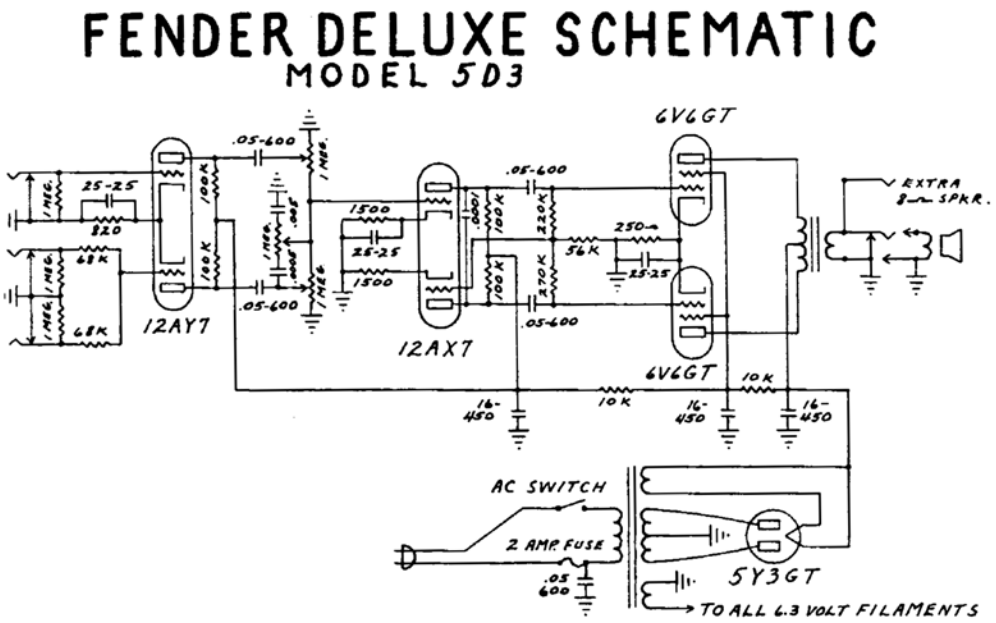

Figure 6 - Early Fender Deluxe circuit

To some degree the history of guitar amplifiers (or in guitarist slang, an “amp”) is satisfyingly circular. The first amplifiers were small affairs. Of necessity, given the period, they were based entirely on valves (vacuum tubes). The loudspeaker and amplifier were usually integrated into the same cabinet (a *combo*). A typical early guitar amplifier is the Fender *Deluxe*: the circuit is illustrated in Figure 6. Its modest output was enough to support the sound of the electric guitar in the small *jazz*, *surf* or *rock-&-roll* combo against the sound of a small *trap* drum-set and an acoustic bass in a small setting. (Scotty Moore used the Fender Deluxe on Elvis' *Sun Sessions*.) These early designs were all fairly low-gain affairs and the intention was not to overdrive the amplifier. But *rock-&-roll* changed: the venues got bigger, and the music got louder ... a LOT louder! Guitarists responded to this change by driving their amplifiers far harder than their designers’ ever imagined. In so doing, they discovered new, distorted sounds - sounds they found out they liked. The hallmark sound of *Rock* was born!

Figure 7 - The original Fender *Bassman*

As powerful public address amplifiers rendered the vocalists much louder, all the instrumentalists, including the guitarists, needed more power to cut through. The guitarists ploy was first to adopt amplifier combos designed for the electric-bass; necessarily more powerful and robust for bass duties. The Fender *Bassman* became adopted by guitarists in search of greater volume for this reason. In fact, the 1959 *Bassman* (circuit 5FC-A, see below) set the trend for amplifiers for years to come because, in 1962, the new, British amplifier manufacturer Marshall virtually copied the circuit to produce the early *JTM45*.

Jim Marshall and his engineer partner housed their amplifier in a separate cabinet (a *head*) and combined this with four, powerful, loudspeakers in a separate, closed cabinet (Figure 3 left). This change resulted in a deeper, chunky, less-"twangy" and more focussed sound which underwrote the sound of British rock. Within a short time Marshall had increased the output power of the head by the expedient of doubling-up the amplifier design - a bit like taking a V6 engine and creating a V12 and, at the request of The Who's Pete Townshend, combined a second, four-loudspeaker, cabinet with the first. Thus the first guitar *stack* was born. Amplifiers grew, speaker-stacks grew and volumes kept on growing throughout the 60s and early 70s. This was the era of the *backline*; a wall of amplifiers and loudspeakers on the back of the stage for the guitarists.

But then something changed profoundly - and it's actually a change which we are still coming to terms with. That change was due to the greatly increased power of the PA. Although the PA was originally intended simply for the vocals, as solid-state amplifiers evolved from 30 Watt wimps to 1000 Watt behemoths, the desire to take all the signals into the PA (from the drums, the keyboards *and* the guitars) so that they might be mixed properly by a *front-of-house* mix engineer became paramount. This provided much better control over the sound balance, but it caused a problem for the guitarists because the heavily overdriven, and fabulously loud, backline now became something of an embarrassment. With the PA now providing the power, the front-of-house mix-engineer persistently asked the guitarists to "turn down the backline!" Simple enough, you might think, but the problem was that the sound of the overdriven amplifier was part of the guitarists' instrumental sound. With the volume control on 2 rather than 11, the cutting guitar sounds just weren't there.

The way out of this impasse was provided by Marshall who, in 1975, created the first *Master Volume* guitar amplifier. The concept behind the master-volume was to provide enough voltage gain in the amplifier that the guitarist could overdrive, not the output, power-stages, but the early, so-called, *preamplifier* stages. The *master* volume-control followed the preamplifier meaning that a controlled amount of the overdriven signal could be fed to the power amplifier. The result? An amplifier which could be overdriven but at reasonable volume levels.

In retrospect, as a pure engineering solution, the master volume amplifier was a bit of a sledgehammer to crack a walnut. Here, after all, was an amplifier which could produce a vast amount of noise which it wasn't really required to do: a big amplifier "hobbled". Nevertheless, the invention of the master-volume topology, allowed guitarists to explore levels of overdrive impossible with previous designs. Small signal stages (valve or solid-state) may be contrived to overload to a virtually unlimited degree, and certainly to a degree impossible in a power stage, where similar levels of overdrive would cause the output valves' anodes, or the output transformer or the speaker voice-coil, to melt! The result was a generation of guitarists who drove their amplifiers deeper and deeper into distortion until the essential harmonic structure and dynamic envelope of the guitar signal had been radically changed. Another hallmark sound had been discovered ... *Heavy metal*!

Recently, as powerful, and cheap, reliable and high-quality PA has become available to all, more and more guitarists are turning back to the small amplifiers with which we started our story. Volume is no longer the prime consideration: the prize is tone quality. These small amplifiers may be driven hard to re-create the urgent sound of early rock and may be miked-up and passed to the PA mixer for amplification if more volume is required. The amplifiers themselves may be treasured (and nowadays, very valuable) originals, lovingly maintained or restored. Alternatively, they may be modern copies of older

designs; or entirely new conceptions. The “amps” are often hand-built, using similar techniques to those employed in the equipment of the nineteen-fifties and early sixties: valves, hand-wired circuits, panel-mounted controls. In this world, there is no room for printed-circuit boards and microprocessors!

Classic amplifiers

A good place to start a study of valve guitar amplification is the 1959 *Bassman* product from Fender (design 5F6-A), as illustrated in Figure 7 and with circuit given in Figure 8. This design started as a bass amplifier combo, as the name suggests. The *Bassman* design proved so good that guitarists quickly adopted it and the British manufacturer Marshall based their first guitar amplifiers on this design in the early nineteen-sixties. This amplifier is regarded by many as the finest guitar combo ever produced and it represents one of the roots of classic and modern, guitar amplifier design.

The circuit is relatively conventional and uses 6L6GT (5881 equivalent) valves in the output stage, running as beam tetrodes in Class AB; in which valve conducts for appreciably more than 50% of the conduction cycle but not all of it. Using this technique, and running the valve on about 400V HT, it is possible to produce 50 Watts output and remain within the anode dissipation specification of the output valves. The output stage uses a fixed, independently-derived negative bias supply for the grids of the output valves; via a tapping on the HT winding and an early semiconductor rectifier. A version of this arrangement is the preferred configuration for nearly all guitar high-wattage amplifiers for two reasons. Firstly, precious HT isn’t wasted generating a positive voltage via cathode biasing. And secondly, cathode bias in a class-AB stage is tricky because the anode currents of the valves are not constant and therefore a constant voltage cannot be derived via a resistor in the cathode circuit without very heavy decoupling. The output stage is fed by a long-tailed pair, phase-splitter; this stage providing both the phase-splitter action and the gain for the power amplifier section. A small amount of feedback is sent back to the opposite grid of the phase-splitter. This feedback is modified by the action of a special tone control, known as the *Presence* control which reduces the feedback at HF resulting in more top-end and more distortion at HF; hence the rather exotic term for the control.

The power amplifier is preceded by the preamplifier, consisting of one high-gain 12AX7 valve and one 12AY7 first-stage valve [1]. It is uncommon to see the 12AY7 in contemporary *Bassmans*; modern guitarists preferring to standardise on the 12AX7 in all positions. The first valve is configured as a dual amplifier mixer. This dates the amplifier as it is no longer considered necessary or desirable for two instruments to share the same amplifier. Using the high-gain 12AX7 (ECC83) the input stage - even allowing for mixing attenuation - gives an overall gain of 11 times. This is followed by the volume control which feeds a common-cathode and cathode-follower stage with a gain of about 50. The low impedance output of the cathode-follower is ideal for feeding the unusual bass, middle, treble, passive tone-control circuit; universally referred to - in guitar amplifier circles - as the *tone-stack.*

[1] The 12AY7 valve is the commercial (near) equivalent with 6072 used in the famous AKG C12. The anode resistance is 25k ohms and mutual conductance is 1.75mA/V, making the maximum gain (**μ**) about 44 times.

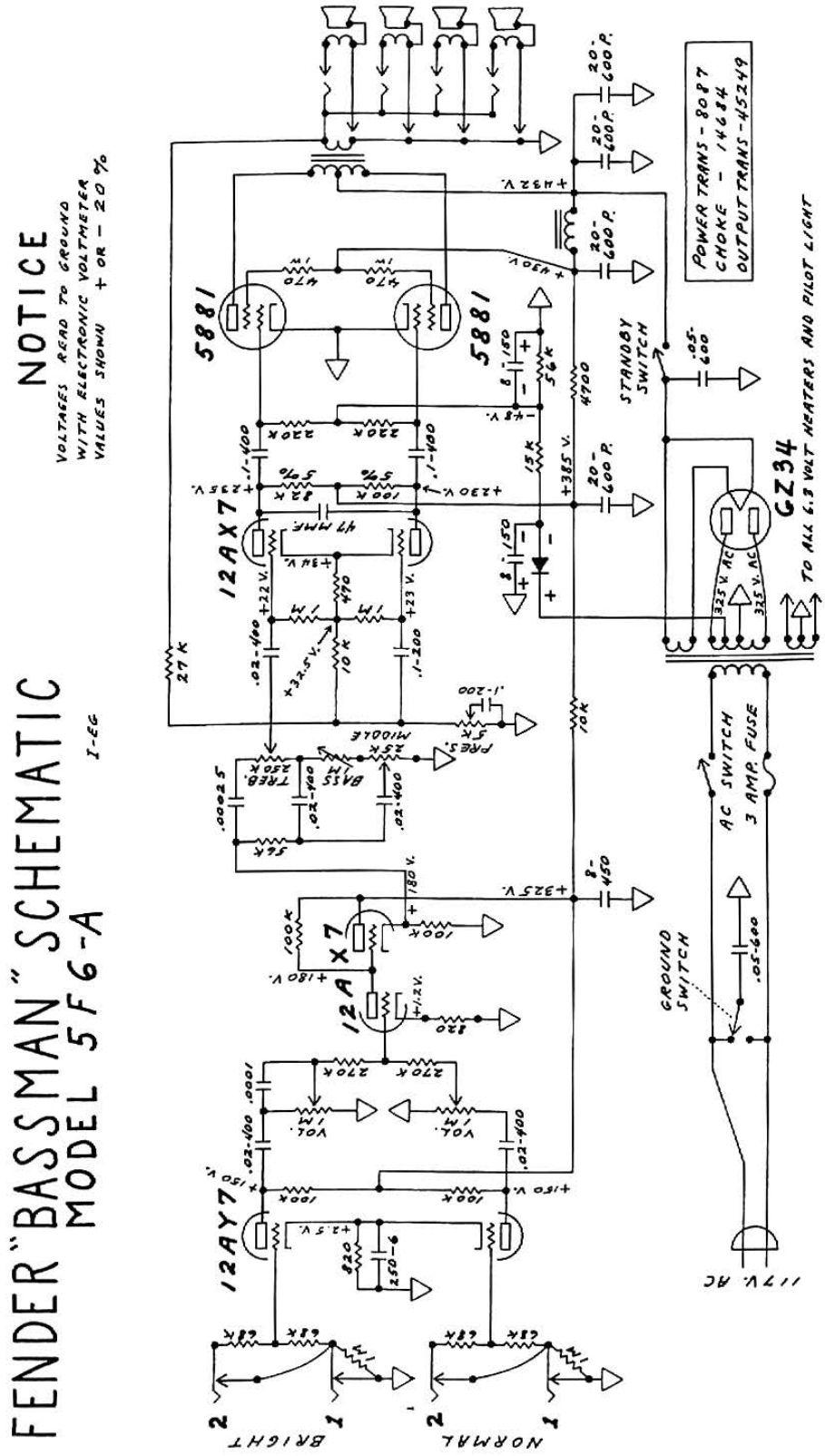

Figure 8 - The classic Fender *Bassman* circuit (5F6-A)

This is an odd, and clearly empirically designed, circuit has responses at various control settings illustrated in Figure 9 (top). And, a collection of responses for this control in all possible configurations (my term is *response-skein*) are plotted in Figure 9 (lower axes). For the record, both the Treble and Middle control are linear controls, whereas the Bass control is audio-taper, so that its resistance is about 10% of the total value when it is positioned at half its travel. This tone-control configuration is odd, because it is almost impossible to obtain a level frequency response[2]. This is no tone-correction network, like the tone-controls on a domestic amplifier. And its effects are not subtle: even with all controls centralised, the mid-range "scoop" - relative to the bass and treble range is about 6dB! Given that this circuit was copied (with slight modifications) by Marshall, and still forms the basis of most guitar tone-control circuits, one can regard this Fender circuit as representing the fundamental voicing of the majority of guitar amplifiers.

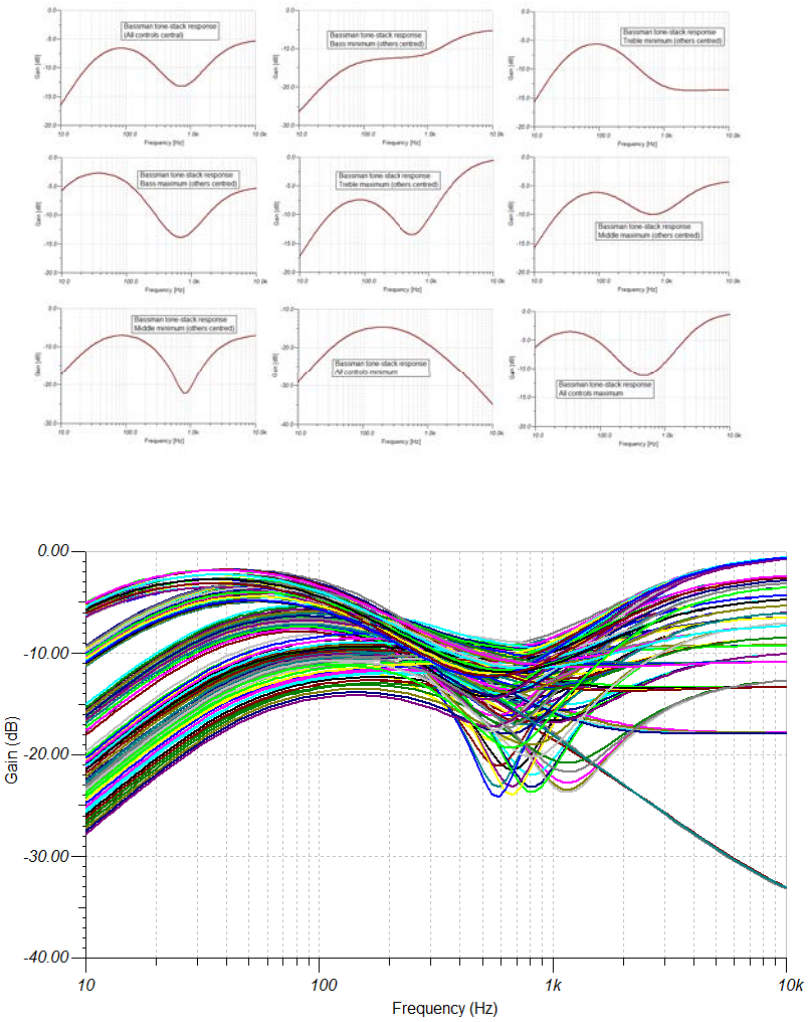

Figure 9 - A family of response curves from the rather eccentric Fender *Bassman* tone-control circuit (at positions as indicated). The lower curves indicate the entire *response-skein*.

[2] For testing purposes, it's useful to know that if the Treble and Bass controls are almost fully anti-clockwise, and the Middle control is fully clockwise, a level response may be obtained from 100Hz to 10kHz.

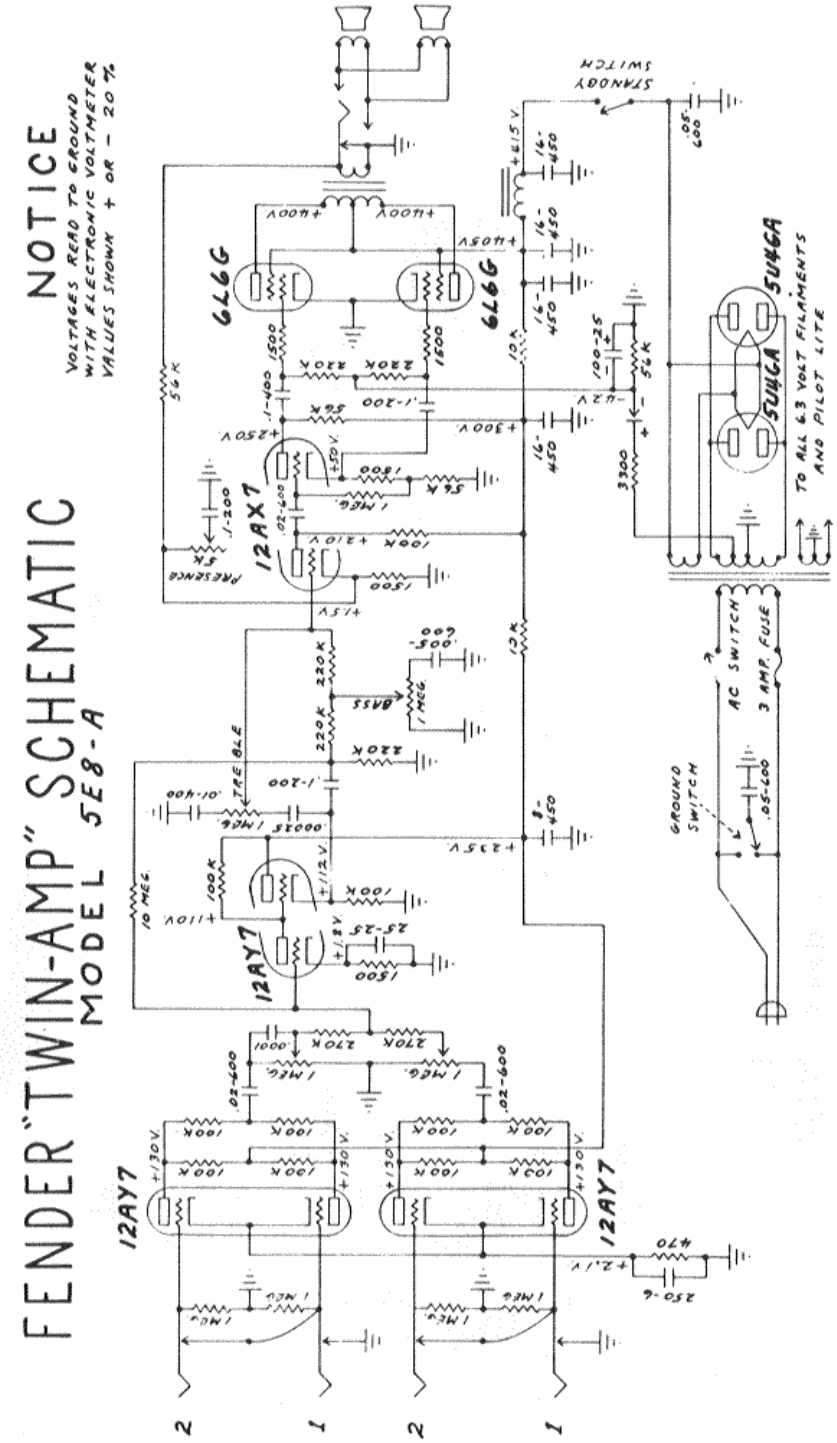

Figure 10 - Original Fender *Twin*

It is interesting to compare the 5F6-A circuit (59 *Bassman*) with the other great classic Fender amplifier (used by Eric Clapton of the group *Cream*), the *1957 Twin* (Fender design reference 5E8-A). The circuit for this amplifier is given in Figure 10. Whereas the *Bassman* drove 4 x 10" loudspeakers driven in parallel, the *Twin* drove a pair of 12" drivers in parallel. The circuit differences are revealing. Instead of the long-tailed-pair phase-splitter, the *Twin* design opts for a standard common-cathode amplifier driving a split-load phase splitter. Another interesting difference is that the *Presence* control in this design - as well as attenuating the HF feedback - also increases the open-loop HF gain (as the control gradually bypasses the first-stage cathode resistor). Note that the *Twin* adopts a more conventional treble/ bass tone-control circuit. One further (and apparently critical)