Direct Input (DI), Guitar Tones and The MPA685

Introduction

Guitar players are very familiar with the way a guitar with passive pickups interact with an amplifier and how the interaction affects the guitar tone. Most people have familiarity with the idea that the guitar pickup impedance is what interacts with the cable capacitance and the amplifier input impedance. This interaction is also important when performing or tracking is done through Direct Input (DI) boxes, or a guitar track is re-amplified since extra equipment and cabling are required. This application note summarizes in simple ways the impedance interaction and describes the importance of using good DI designs with guitars. The Ingram Engineering MPA685 dual channel mic pre-amp includes a DI that was designed to mimic a guitar amp load, and it is used as an example for demonstrating an appropriate design.

A baseline situation that will be used for comparisons is a simple setup where the player is playing a guitar with passive pickups, is standing in the same room as the amp, and uses a 10 foot cable between the guitar and amp. This paper will suggest ways to mimic the sound of this golden reference setup, no matter what other situation exists.

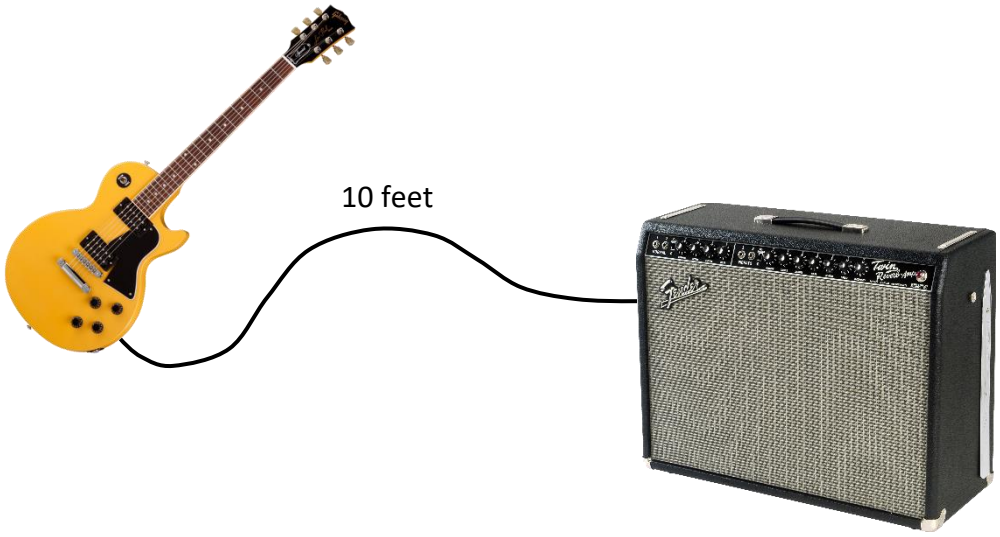

Figure 1: Baseline Setup

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The inductance of a passive guitar pickup is very high, and it interacts with the total combined load capacitance to create a frequency response peaking that typically falls in the audio band. This sets the tone of the guitar / amplifier combination. The generally accepted equivalent circuit for a passive pickup is a simple resistor, inductor, capacitor combination. The diagram below shows the guitar pickup equivalent circuit, the capacitance provided by the guitar cable, and the load impedance provided by the guitar amp.

Much information can be found on the internet that discusses the actual pickup resistance, inductance and capacitance values for various guitar pickups. For the purposes of this discussion, values like those of a Gibson Humbucker are used to illustrate the points. These values create a peak that falls around 3 kHz for this scenario. This peak is what sets the timbre of the guitar / amp interaction. This discussion does not focus on what the exact pickup impedance is. Instead, for a Humbucker or any guitar pickup, the point is to show the value of a properly designed DI.

A typical reasonable quality guitar cable may have 30 pF capacitance per foot, so a 10 foot cable will have 300 pF total capacitance. Better quality guitar cables will have less capacitance, but for this app note, the lesser quality cable will be considered.

For the diagram below, the amplifier load is represented as a simple 1 Mega Ohm resistor. The detailed amplifier circuit is shown on the following page.

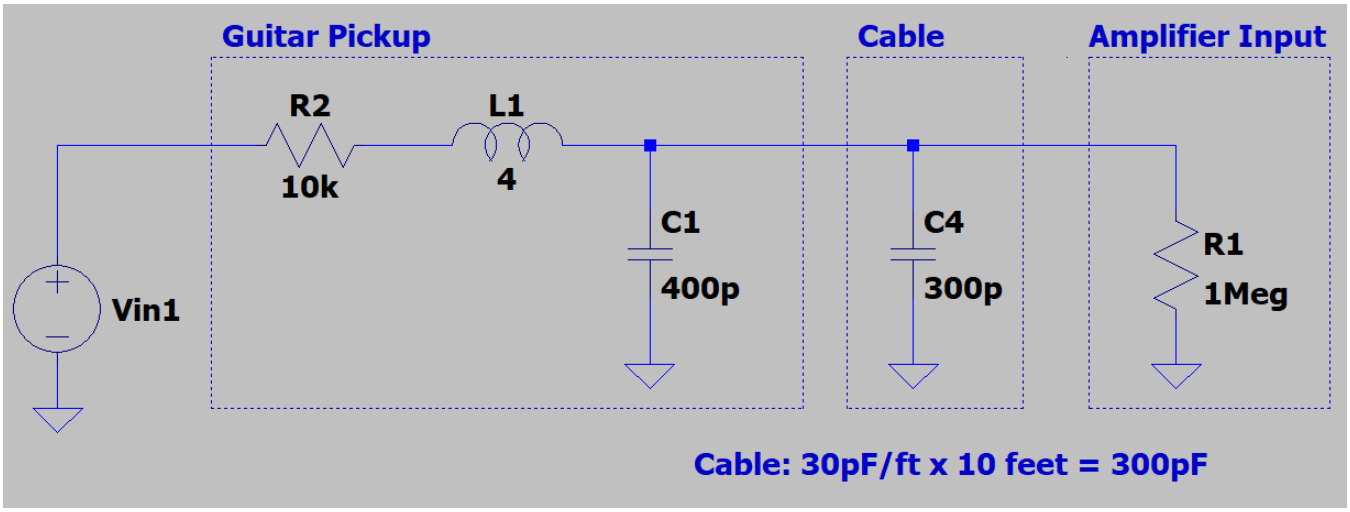

Figure 2: Guitar Pickup Simulation Circuit

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For this paper, the amplifier is assumed to use a 12AX7 tube input stage, as does a Fender Twin and many other amps. For simulations, the Fender 65 Twin Reverb Reissue input stage circuit is used.

Following is the circuit used for simulating guitar pickup, cable, and Fender input stage. What we care about is the signal that appears at the amplifier input jack, because this signal is what will be amplified and passed to the speaker.

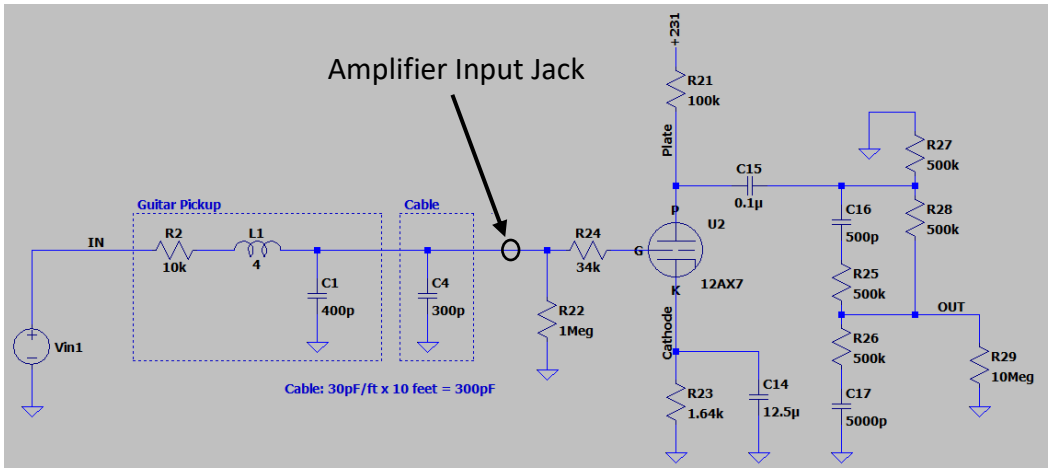

Figure 3: Simulation Circuit for Guitar, Cable, and Tube Amplifier Input Stage

A simulation of this circuit is shown below. It shows that the interaction of guitar, cable, and amplifier load will create a peak at 2.8 kHz. This is what will be amplified. If you change anything about the guitar/cable/amp interaction, it will change the peaking and change the timbre.

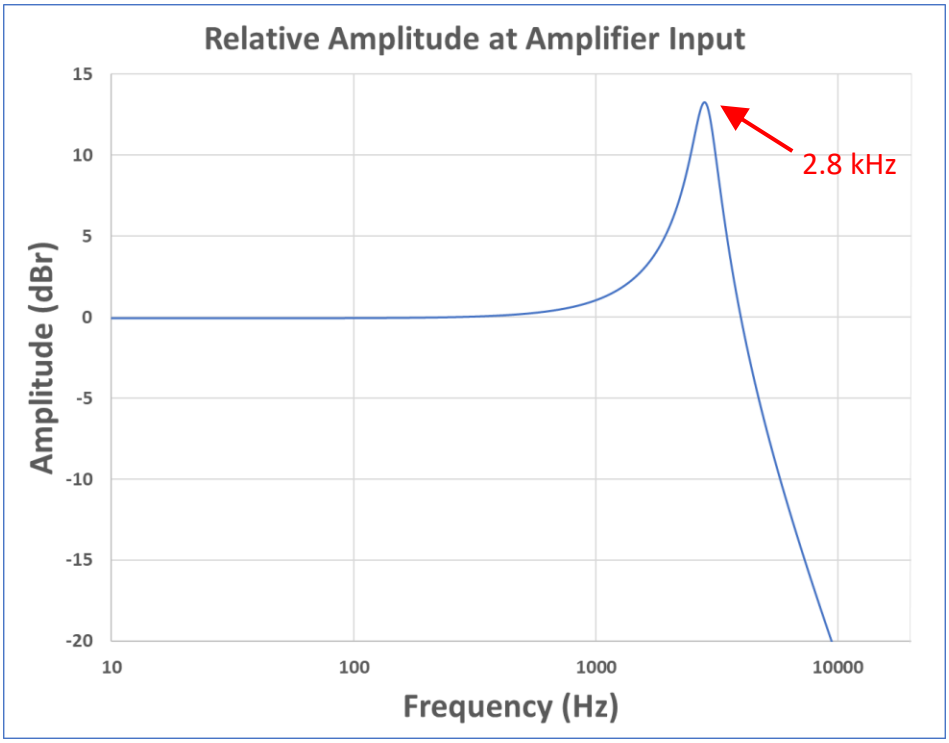

Figure 4: Frequency Response Peaking for Guitar + Cable + Amp

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Since this will be considered the golden reference situation, if we now change the equipment or cabling, we must compare performance against this reference.

For example, consider using a 30 foot cable instead of the 10 foot cable. This might be needed in a recording studio if the amplifier is some distance away in an isolation booth. Cable capacitance increases to 900 pF, simulations show that the resonant peak shifts down to 2.1 kHz, and the guitar tone changes.

For this reason, it would be beneficial to buffer the guitar from a long cable run. A well-designed buffer of this type would preserve the tone realized by connecting directly to the amp with a short cable. Therefore, this buffer would have an input impedance that exactly equals the input impedance of a tube stage like the Fender Twin. And this buffer would have an output stage that can drive the long cable without affecting the tone. Therefore, it would have a very low output impedance so that there would be essentially no interaction of the buffer, cable, amp, or pedal impedances. Then, nearly any cable length or external processing gear could be inserted after the buffer with no bad effects.

For this discussion, the buffer will be called a "DI" or Direct Input, but it is not a DI of the classical type that converts the output to mic level signals. Rather, it simply handles the impedance interfaces correctly so that guitar timbre can be preserved, and passes the signal with unity gain.

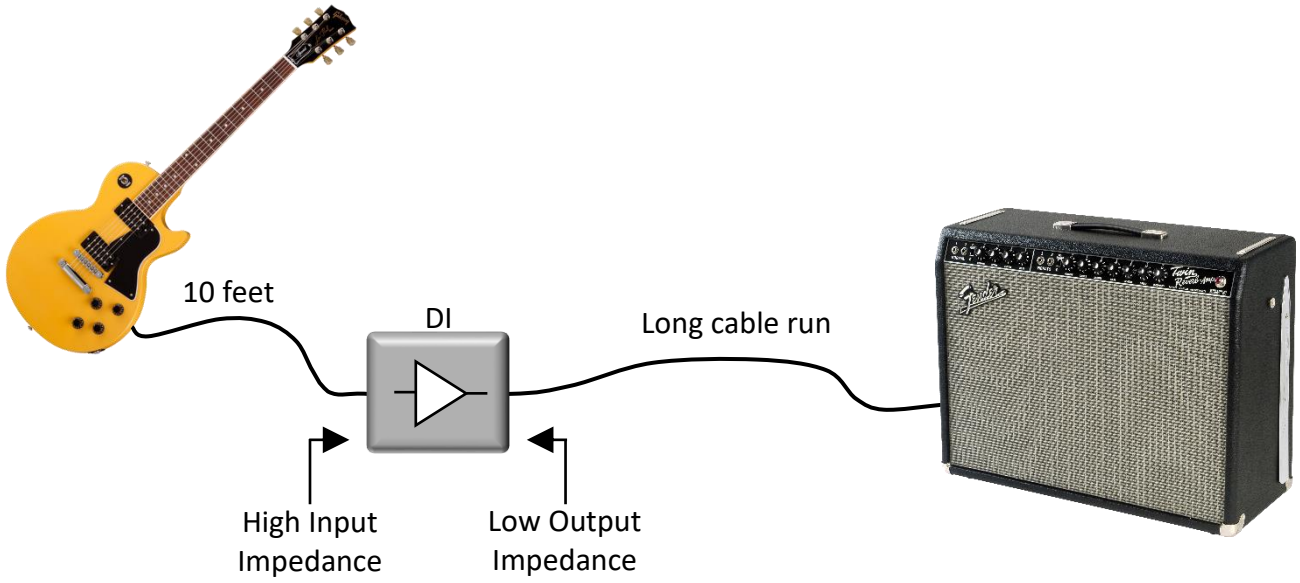

Figure 5: Guitar Buffered by a Unity-Gain DI

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A true measure of the DI described is to insert it between the guitar and the amplifier and evaluate whether the guitar timbre changes. If the DI is doing its job, it sounds the same as when the guitar is plugged directly into the amp.

Figure 6: Comparing Timbre With and Without the DI

Another use for this type of DI is for capturing the guitar signal directly from the guitar, without an amp. The signal can be recorded so that it can be played back later through an amplifier. This is frequently useful for re-amplifying tracks that had issues when originally recorded, or for trying different pedals or amplifiers for a different sound. A DI designed with input impedance that exactly equals a tube amplifier input impedance will realize timbre that matches the golden reference. This is described graphically below.

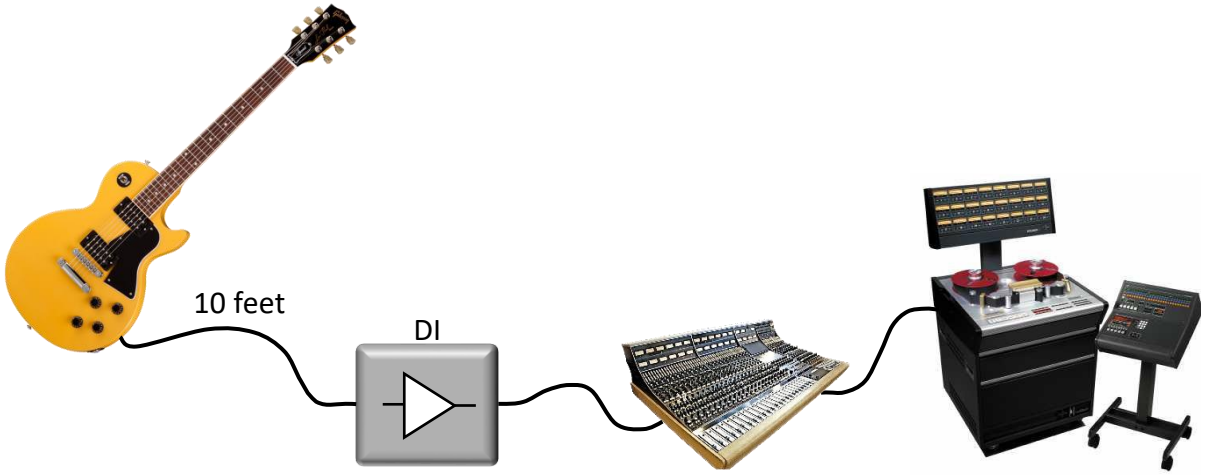

Figure 7: Recording a DI Signal

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The same well-designed DI that captures the direct guitar signal can be used to re-amplify the recorded track. The difference is that the tape machine or DAW does not interact with the DI like the guitar pickup does, so there is no change to timbre. The DI then serves to transparently pass the signal through and properly drive long cable runs or pedals.

Because the DI faithfully preserved the timbre you got by connecting directly to the amp when the signal was recorded, the signal played back later will sound just like the guitar is actually plugged into the amp.

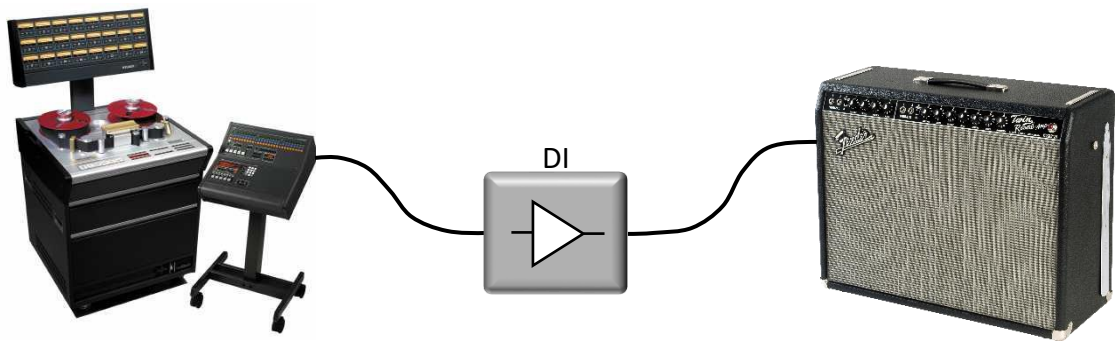

Figure 8: Re-amping a Recorded Signal

Recording the Original Take Using the MPA685

The Ingram Engineering MPA685 dual channel mic pre-amp has an integrated DI that can be used for capturing direct guitar signals and for re-amplifying previously recorded tracks. The MPA685 utilizes a FET DI circuit with 1 Mega Ohm input resistance with low capacitance that faithfully mimics a guitar amp tube input stage impedance. The MPA685 uses low impedance balanced output stages that are well suited to driving long cable runs, processing gear and amplifiers. The MPA685 is a perfect tool for capturing DI signals and for re-amping.

Instrument outputs can be first routed to the MPA685 via the front panel DI. The direct signal can then be tracked through the MPA685 and later used for re-amplifying. The MPA685 also has a DI loopthrough so that the instrument can simultaneously be connected directly to the guitar amplifier and speaker cabinet. The instrument source impedance "sees" the guitar amplifier load and the MPA685 load in parallel. Line level instruments and guitars with active pickups and will not be affected, but guitars with passive pickups will have a slight shift in timbre due to the double loading. For passive guitar pickup cases, it is recommended to use an Aux send to amplify and record a signal at the same time as the direct signal is recorded.

The amplifier and speaker cabinet can be mic'ed up and recorded through another MPA685 channel at the same time as the direct signal is recorded. This way, the original amplified and mic'ed audio track can be kept as a primary part, a scratch part, doubled track, etc. The direct and amplified tracks can be time aligned later, if necessary. This scheme is shown in the diagram below.

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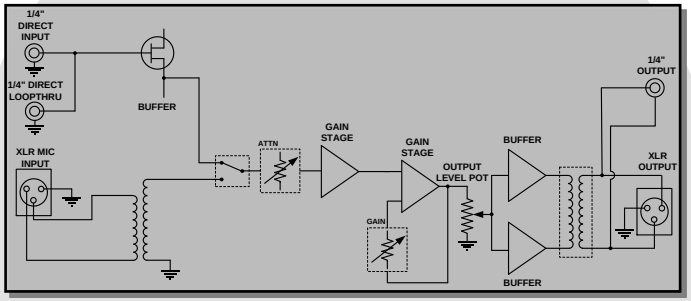
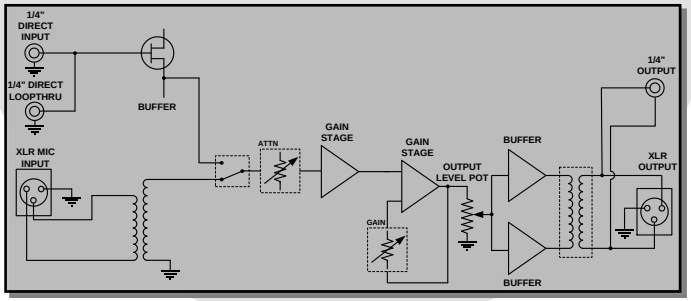
Figure 9: Recording Using the MPA685 Direct Input

Channel 1
Direct Input

MPA685



Loopthrough



To Recorder
Channel A

To Recorder
Channel B

Channel 2
Mic Input

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Re-Amplifying the Recorded Track Using the MPA685

After a track has been successfully recorded, it can be played back through the MPA685 to the amplifier and speaker cabinet. The speaker cabinet can then be mic'ed so that the re-amplified track is recorded additional times with different amplifier settings or with different pedals, amplifier, or speaker selections.

To do this, feed the recorded track from the tape machine or digital audio workstation to the MPA685 balanced microphone input or the unbalanced DI. Either input will work, and the choice may be made based on convenience. It should be noted that the microphone input is transformer coupled, so a high degree of CMRR will be achieved that will not be realized when using the Direct Input. Subtle sonic differences may exist between the two inputs, as the transformer will also have opportunity to add its character if driven with high enough levels. However, if the target is to feed clean, uncolored signal to the amplifier and speaker cabinet, then levels can be set suitably low that the transformer-coupled mic input will work very well for this application. A level of -10dBV from the recording medium will typically realize an operating point for the mic input transformer that has a relatively neutral sonic character and realizes the largest adjustment range for the MPA685 stepped switch.

Adjust the input stepped switch so that it is set as high as possible without the "Overload" LED being lit.

Connect the 1/4" MPA685 output to the amp that will be used for re-amping.

Adjust the MPA685 output level control so that the level is compatible with normal amp volume settings.

Mic the amp as normal and record the new, re-amplified tracks.

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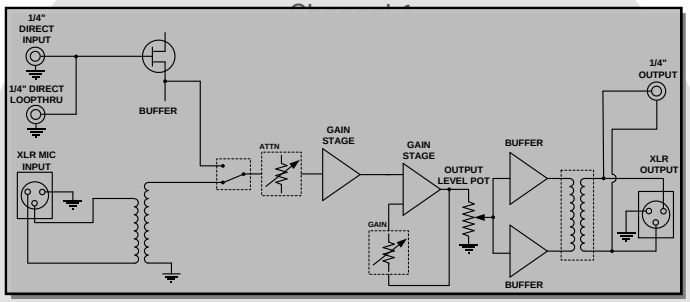
Figure 10: Re-amping recorded tracks using the MPA685

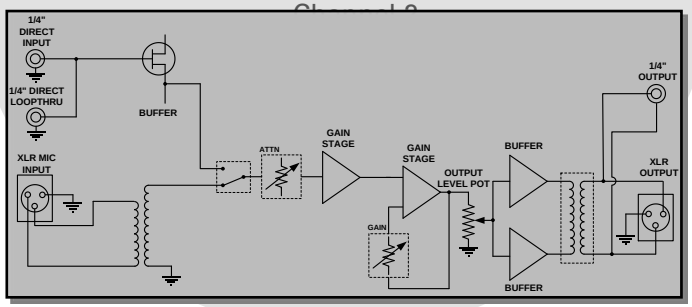
To MPA685
Direct or Mic
Input

From Recorder,
Clean Direct Track

MPA685



1/4"
Output



Mic
Input

To Recorder

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