Audio DSP with crossover and gain

This minor will take place in the 2nd semester (February) of study year 2022 / 2023.

Introduction

DSP stands for digital signal processor, but is also called digital speaker processor or loudspeaker management system. A DSP is nowadays an indispensable part of a professional audio system. With a DSP, the audio signal can be modified completely as desired. For example, certain pre-sets can be applied so that the music sounds classical or suddenly has a lot of bass. The digital crossover filters the output signals so that the top speaker only get the high frequency signals, and the subwoofers only get the low frequency signals. The gain can be used to control the master volume.

Abbreviations and difficult words

AD converter	Analog Digital converter
Cutoff frequency	The cutoff frequency is the frequency at which the signal is at -3dB (halving) of the original signal. The cutoff frequency is important for setting filters.
DA converter	Digital Analog converter
DMX	Digital MultipleXed is a protocol used to control Lights. This they use when working with a lot of lights on festivals.
DSP	Digital Signal Processor
EQ	EQualizer
FPGA	Field Programmable Gate Array
HPF	High Pass Filter
LPF	Low Pass Filter
RCA	Radio Corporation of America. RCA connectors are one of the most common used audio connectors and are also called tulip connectors.
Sample rate	the number of measuring points in a given time.
VU	Volume Units
XLR	eXternal Line Return. XLR connectors are the industry standard for balanced audio signals.

Figure 1: Picture of an DSP

See appendix 1 for the Global block diagram of an DSP with crossover and gain. There are several inputs present on the DSP giving the user a lot of flexibility. After the input select, the signal goes through the ADC where the analog signal will be digitized. This digitized signal is processed by the DSP to apply various filters. After the DSP core has applied the filters, it controls the gain and separates the high and low frequencies. After this, the signal is reconstructed by the DACs into a neat analog signal, which is amplified by an amplifier with a fixed gain to a higher voltage, after which it is buffered to go to the various outputs. Among others XLR connectors are used for the inputs and outputs, because they are balanced. As a result, the circuit has a much higher noise immunity.

Seen from the outside, an analog signal is supplied to the device, and the analog output is an modified version of this signal.

Figure 2: Crossover consisting of an HPF and LPF

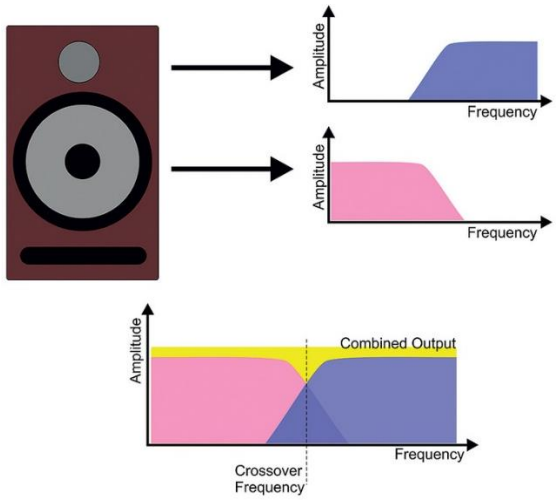
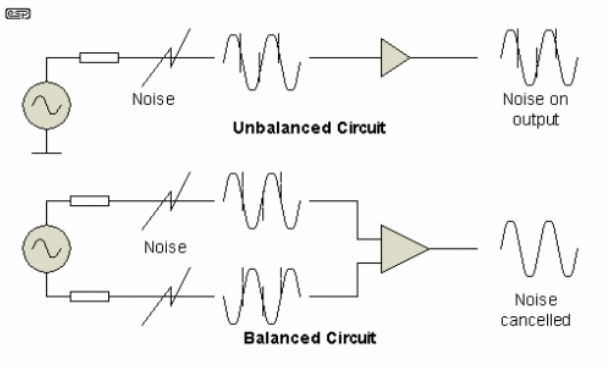


Figure 3: Unbalanced vs balanced audio noise immunity



Requirements

The following requirements have been made. These are divided into must have, should have, could have and won't have.

Must have:

- Separate digital crossovers with adjustable cutoff frequencies for the LPF and HPF. This allows the desired frequency spectrum to be sent to each speaker. Allowing speakers to be used without a built-in crossover.
- 2x (stereo) XLR (analog) input
- 2x (stereo) RCA (analog) input
- Quad XLR (analog) output (TOP R/L, SUB R/L)
- 2.1 and 2.2 speaker setup support (mono or stereo subwoofers)
- Bandwidth of 20Hz to 20kHz
- XLR and RCA input voltage of $\pm 12V_{PP}$.
- XLR output voltage of $\pm 12V_{PP}$.
- Audio sample rate of at least 44.1kHz
- 16 bit AD/DA converters
- Amplification factor adjustable per output
- Compact design

Should have:

- Cutoff frequencies adjustable per output. Each output therefore has its own filters (LDF or HDF).
- Delay between input and output must be less then 100ms
- User interface with screen (e.g. 16x2 LCD)
- Standard EQ presets like: house, pop, classic, bass, rock, etc.
- Audio sample rate of at least 96kHz
- 24 bit AD/DA converters
- Everything neatly integrated on the PCB.
- Option to save settings in non-volatile memory so that they are remembered after a reboot.

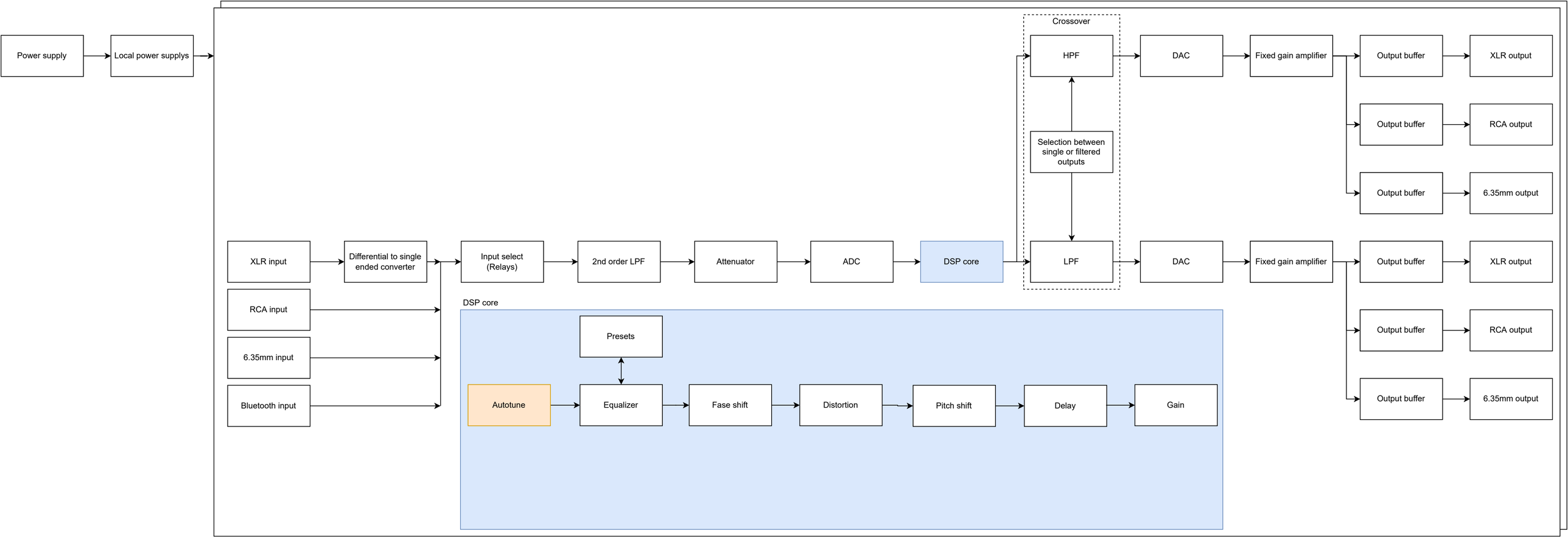
Could have:

- Audio sample rate of at least 192kHz
- Bluetooth stereo input
- Neat finished and durable housing.
- Built-in VU meters for all input signals
- Built-in VU meters for all output signals
- Control the product via computer interface (GUI).
- Hex XLR (analog) output (TOP R/L, MID R/L, SUB R/L).
- DMX output to control lights depending on VU levels.

Won’t have:

- Self-made/designed mains power supply (for safety reasons this will be purchased, or a lab power supply will be used).

Appendix 1:


Power supply
Local power supplys
Crossover
HPF
DAC
Fixed gain amplifier
Output buffer
XLR output
Output buffer
RCA output
Output buffer
6.35mm output
Selection between single or filtered outputs
XLR input
Differential to single ended converter
Input select (Relays)
2nd order LPF
Attenuator
ADC
DSP core
LPF
DAC
Fixed gain amplifier
Output buffer
XLR output
Output buffer
RCA output
Output buffer
6.35mm output
RCA input
6.35mm input
Bluetooth input
DSP core
Presets
Autotune
Equalizer
Fase shift
Distortion
Pitch shift
Delay
Gain