khs instruments

analog::blocks

Transmission Line Module Configurations

Application Note

Rev. 1.0

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1. Introduction

The analog::blocks Transmission Line Module provides two signal paths with controlled transmission line geometry. It is designed for the investigation and development of analog circuits, passive filters, impedance networks and high-frequency signal connections.

In addition to the transmission lines, the module provides component positions for resistors, capacitors and inductors. These positions allow a wide variety of circuits to be implemented without requiring a dedicated PCB for each application.

The module can be used as a simple signal connection, a passive filter, a damping network or as part of a more complex analog circuit.

This application note describes different circuit configurations that can be implemented by populating selected component positions and leaving unused positions unpopulated.

The examples illustrate possible configurations rather than providing optimized filter designs.

2. Transmission Line Module

2.1 General Description

The Transmission Line Module provides two largely symmetrical signal paths between the input and output connections of the analog::blocks Base Board.

The signal paths include component positions for series and parallel networks. Additional connections to ground allow shunt components to be installed where required.

Most optional component pads are implemented as solder mask openings on the existing copper structures. This minimizes changes to the transmission line geometry when the optional components are not installed.

The module can be configured for single-ended or differential applications.

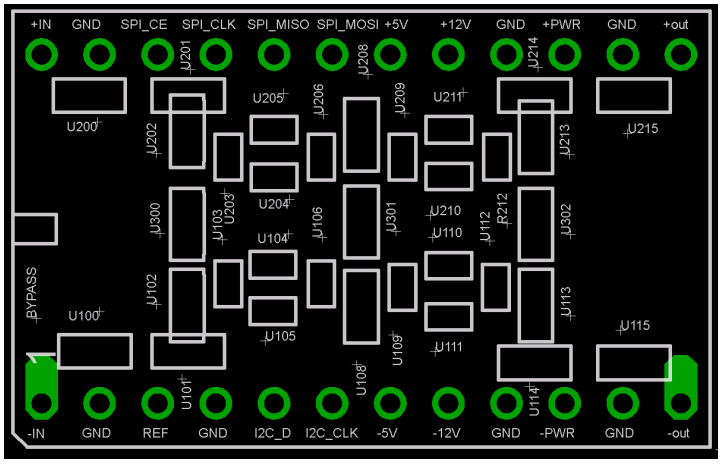


Figure 1: Transmission Line Module PCB

Note: Earlier PCB revisions are labeled "Bypass Module".

The module is now designated "Transmission Line Module".

2.2 Complete Circuit

Figure 2 shows the complete circuit with all available component positions.

The circuit includes direct signal paths, alternative paths for additional components, and connections for shunt elements.

For example, U104 provides a direct component position between two signal nodes. An alternative path consisting of U103, U105 and U106 is connected in parallel with U104.

This arrangement allows an inductor to be connected in parallel with a damping resistor or other impedance network.

Selected nodes can also be connected to ground using optional solder bridges.

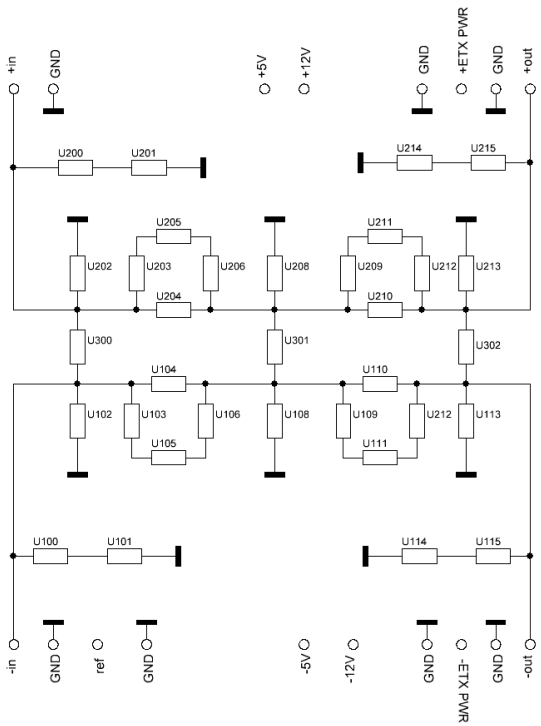


Figure 2: Complete circuit with all component positions

2.3 Component Population

The following examples are derived from the complete circuit by removing unused components and selecting the required component values.

Depending on the application, individual component positions may be populated with resistors, capacitors, inductors or 0 Ω links.

Unused component positions remain unpopulated.

The reference designators correspond to the PCB layout and remain unchanged throughout this application note.

3. Basic Transmission Line

The simplest configuration uses the module as a direct connection between the input and output.

Only the component positions required to establish the signal path are populated. All additional filter and damping components are omitted.

This configuration can be used to investigate signal transmission, insertion loss and the influence of the surrounding circuit.

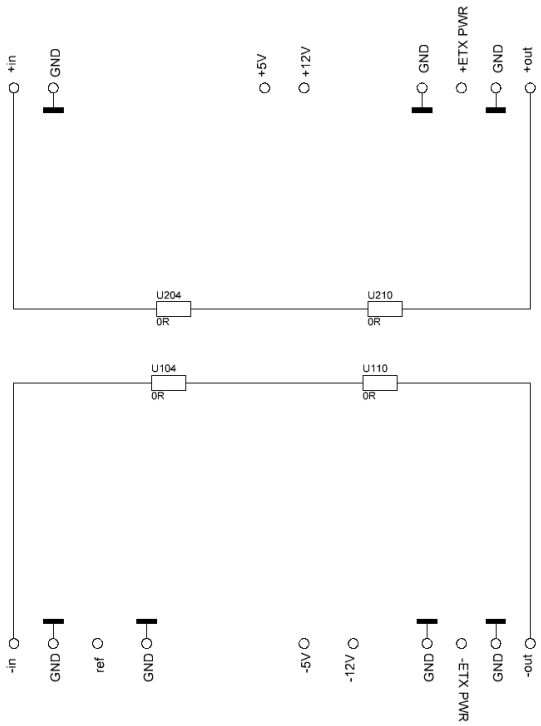


Figure 3: Basic transmission line configuration

4. RC Low-Pass Filter

A simple RC low-pass filter can be implemented using a series resistor and a capacitor connected from the signal path to ground.

The filter attenuates higher-frequency signal components while allowing lower-frequency signals to pass.

The cutoff frequency of an ideal first-order RC low-pass filter is:

$$f_c = \frac{1}{2\pi RC}$$

The actual frequency response also depends on the source impedance, load impedance and parasitic properties of the circuit.

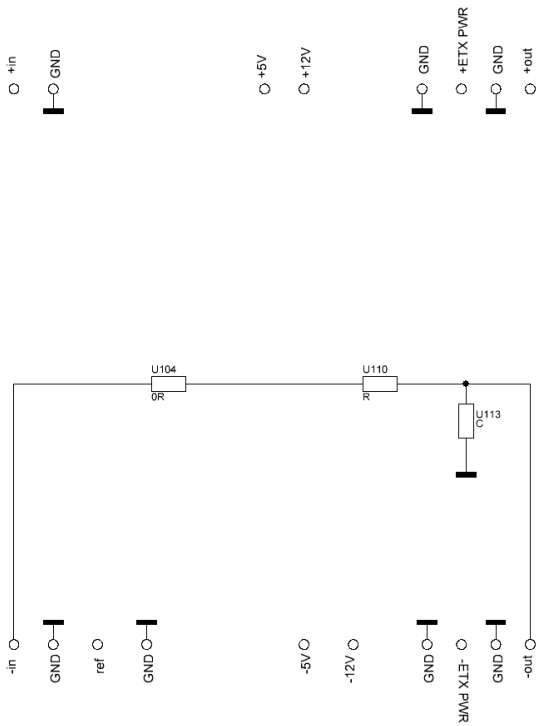


Figure 4: RC low-pass filter configuration

5. RC High-Pass Filter

An RC high-pass filter can be implemented using a series capacitor and a resistor connected to ground.

The circuit attenuates low-frequency signals and blocks DC while passing higher-frequency components.

For an ideal first-order RC high-pass filter, the cutoff frequency is:

$$f_c = \frac{1}{2\pi RC}$$

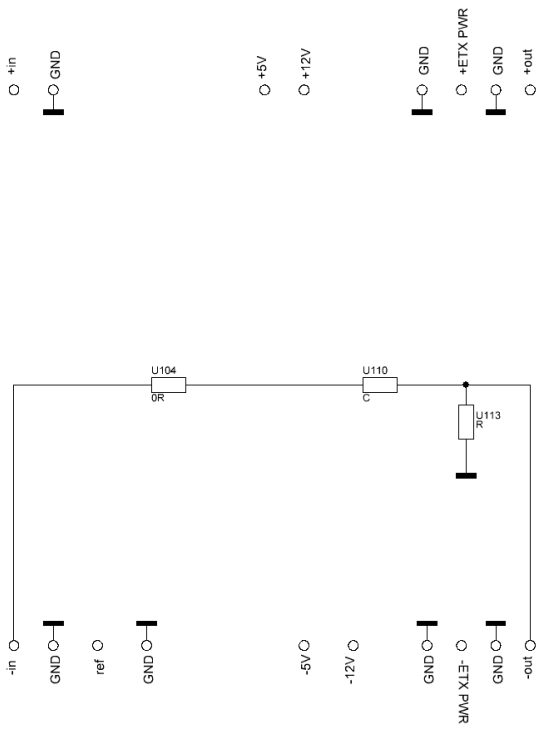


Figure 5: RC high-pass filter configuration

6. LC Low-Pass Filter

An LC low-pass filter can be implemented using a series inductor and a shunt capacitor.

Compared with a simple RC filter, an LC filter can provide frequency-selective attenuation with lower resistive losses.

The actual response depends on the source and load impedances as well as the parasitic properties of the components.

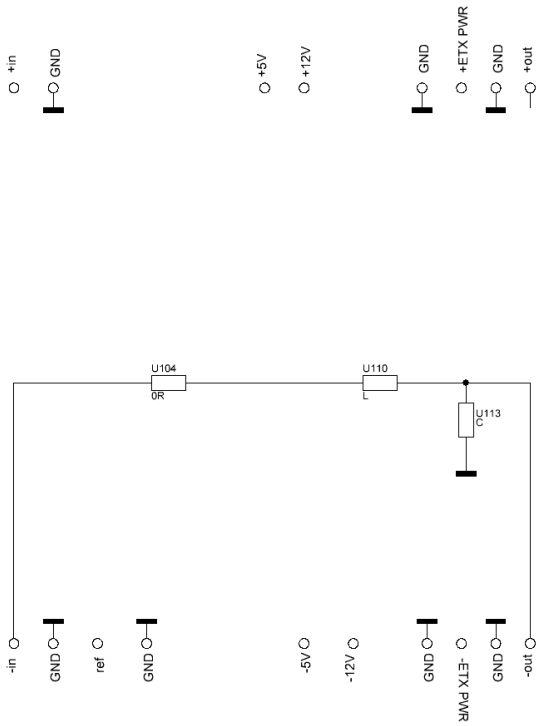


Figure 6: LC low-pass filter configuration

7. LC High-Pass Filter

An LC high-pass filter can be implemented using a series capacitor and a shunt inductor.

The circuit provides a frequency-dependent transmission characteristic and can be used to attenuate low-frequency components.

Component selection and termination determine the resulting frequency response.

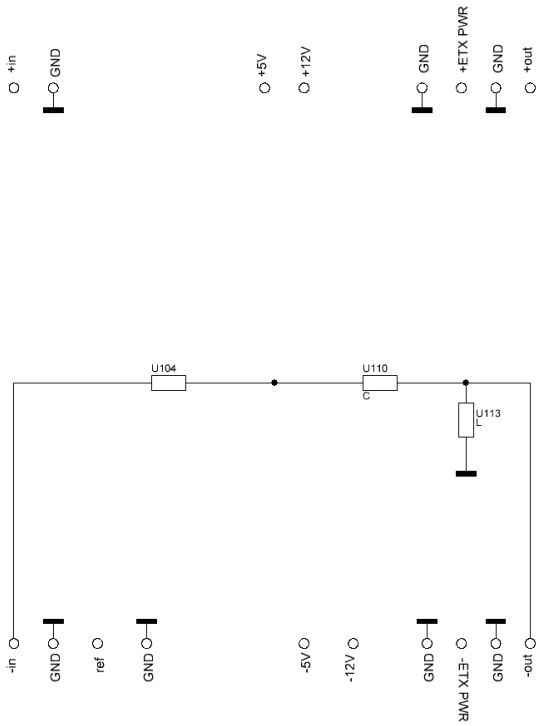


Figure 7: LC high-pass filter configuration

8. Multi-Element Filters

Several component positions can be combined to implement filters with more than two reactive elements.

Depending on the selected connections, these may include T-type and π-type filter networks.

Such configurations are useful when greater attenuation or a different frequency response is required.

Additional damping components can be used to reduce excessive resonance peaks.

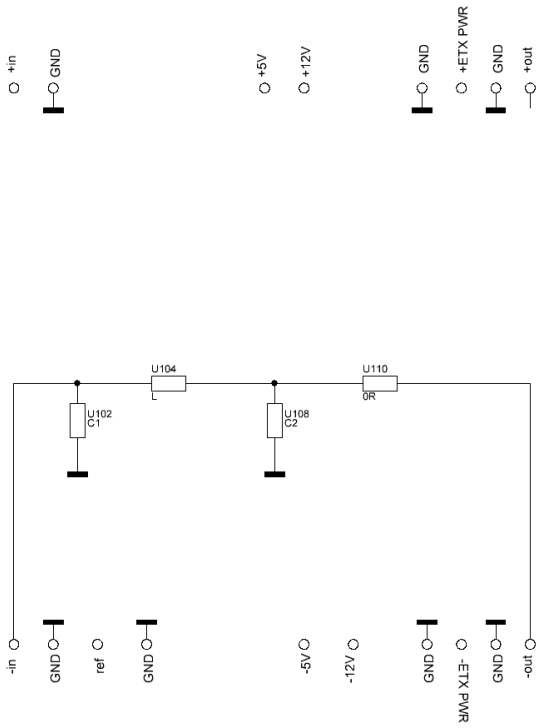


Figure 8: Example of a π-type LC low-pass filter

9. Damped Series Inductor

A useful configuration is a series inductor with a parallel damping resistor.

In the Transmission Line Module, the inductor can be installed at U104 while the alternative path through U103, U105 and U106 provides the parallel damping network.

The damping resistor limits the impedance at higher frequencies and can reduce resonance effects in the surrounding circuit.

For an ideal inductor L connected in parallel with a resistor R, the impedance is:

$$Z = \frac{j\,\omega\,L\,R}{R + j\,\omega\,L}$$

At low frequencies, the inductor provides a low-impedance path. At higher frequencies, the parallel resistor limits the impedance.

This configuration can be useful in power supply filters and EMC investigations.

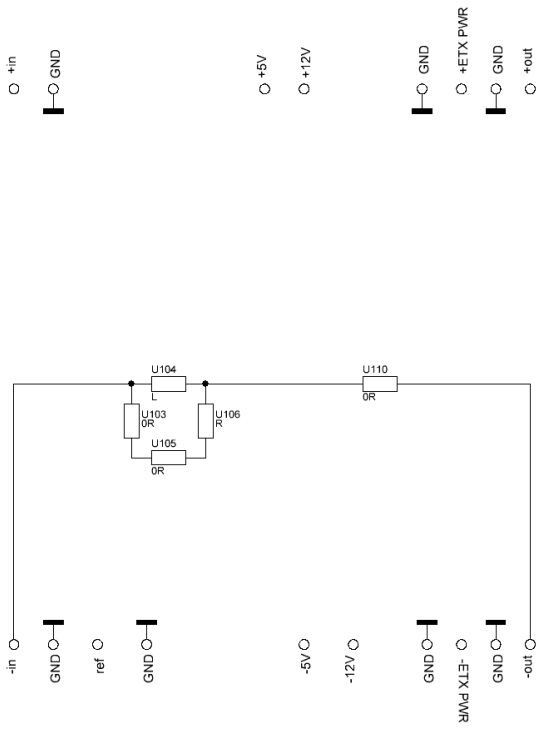


Figure 9: Series inductor with parallel damping resistor

10. Resonant and Frequency-Selective Networks

A series LC circuit connected between the signal path and ground can be used to implement a notch filter.

At the resonant frequency, the impedance of the LC circuit reaches a minimum, attenuating signals within a narrow frequency range.

The resonant frequency is determined by the inductance and capacitance. Additional resistance can be used to control the damping and the width of the attenuation band.

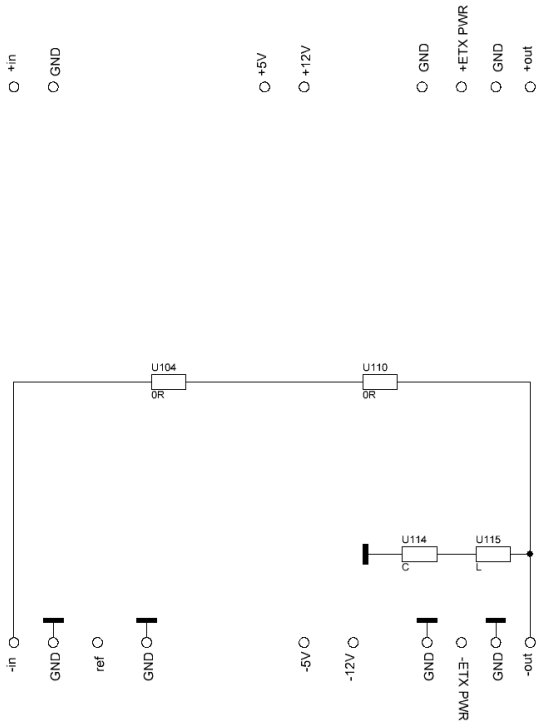


Figure 10: Series LC resonant circuit used as a notch filter

11. Differential Filters

The module provides two signal paths that can be populated with corresponding component values.

This allows symmetrical filter networks to be implemented for differential signals.

Possible applications include differential low-pass filters, input filtering and the investigation of common-mode and differential-mode interference.

The capacitor connected between the two signal paths attenuates differential-mode signals. For ideal common-mode signals, both terminals of the capacitor are at the same potential, so no current flows through it.

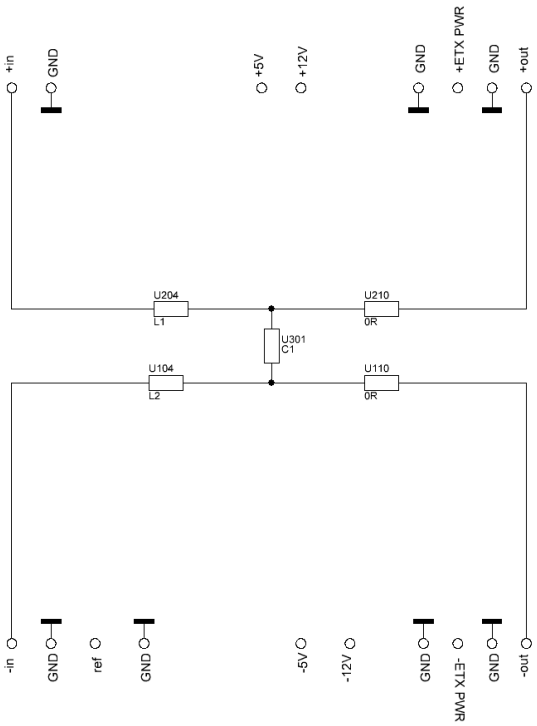


Figure 11: Differential filter configuration

12. External Feedback Networks

The Transmission Line Module can also be used as an external feedback network for operational amplifier circuits.

Resistors, capacitors and other components can be combined to implement frequency-dependent feedback.

This makes it possible to investigate amplifier frequency response, compensation and stability without modifying the OpAmp Module itself.

The configuration can be combined with the circuits described in the analog::blocks OpAmp Module Configurations application note.

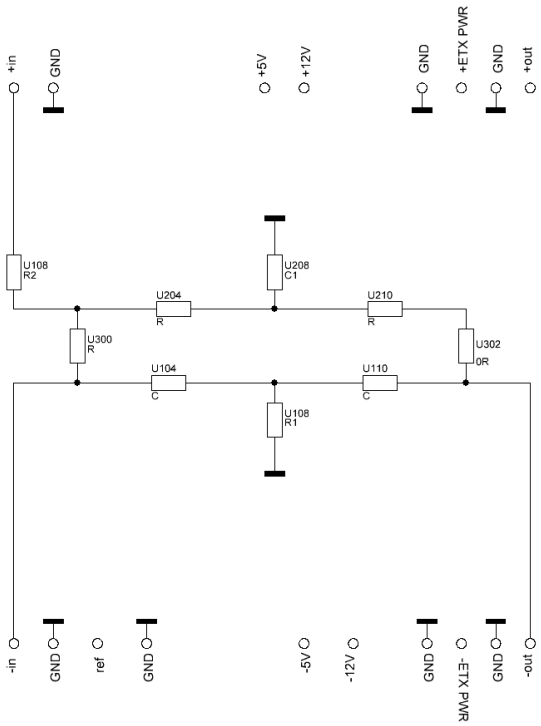


Figure 12: External feedback network for an OpAmp connected to -in and -out

13. Practical Considerations

13.1 Component Parasitics

At higher frequencies, the behavior of resistors, capacitors and inductors deviates from their ideal characteristics.

Inductors exhibit parasitic capacitance and self-resonance, while capacitors have parasitic inductance and resistance.

These effects can significantly influence the behavior of filter and resonance networks.

13.2 Source and Load Impedance

The frequency response of a passive filter depends on the impedances connected to its input and output.

A filter designed for a particular termination may exhibit a different response when connected to another circuit.

13.3 Damping

Undamped LC networks may exhibit pronounced resonance peaks.

Additional resistors can be used to control the quality factor and reduce unwanted resonances.

The alternative component paths of the Transmission Line Module provide several possibilities for implementing damping networks.

13.4 Measurement

The analog::blocks Base Board provides a defined environment for connecting and investigating the module.

Filter characteristics can be examined using a signal generator, spectrum analyzer with tracking generator, network analyzer or oscilloscope, depending on the frequency range and application.

14. Conclusion

The analog::blocks Transmission Line Module is not limited to connecting signals between modules.

Its configurable component positions allow a wide range of passive filters, damping circuits, resonant networks and frequency-dependent feedback circuits to be implemented on the same PCB.

The module can therefore be used both for practical circuit development and for investigating the influence of component values, parasitic effects and circuit topology.

By using different component populations, many circuit configurations can be evaluated without designing and manufacturing a separate PCB for each experiment.

History:

Revision	date yy/mm/dd	Changes
1.0	26/11/11	Initial.