ANALOG SIGNAL TRANSMISSION
DL 3155M60
PRACTICAL GUIDE
TIME Laboratory
This Training Software analyzes the analog signal modulation principles:

PRACTICAL GUIDE

Units:
- Introduction
- Understanding oscillators
- Understanding filters
- Understanding amplitude modulation (AM)
- Understanding amplitude demodulation (AM demodulation)
- Understanding frequency modulation/ demodulation
- Understanding PLL frequency modulation (PLL FM)
- Understanding FM modulator- quadrature demodulator
- Understanding PM- phase modulator/ demodulator. Individual work
Unit N.3: Understanding filters

Objectives:
- Understanding the characteristics of filters
- Understanding the use and manipulation of active filters
- Designing and operating with filters
- Controlling N-order filters with integrator circuit

Requisites:
- Minimum level of communication techniques understanding
- Medium level of electronics components and devices understanding
- High level of health and safety risks understanding
- Communication systems theoretical manual DL 3155M60

Operative instruments:
- DL 3155AL2 or stabilized supply source
- 20MHz double trace oscilloscope
- set of connection cables
They are classified according to filtering range, frequency response in pass band, and circuit component. Classified by filtering range, there are four types of filters: low-pass, high-pass, band-pass, and band-reject filters.

Because the frequency response is the main reason of use those, according to frequency response in pass band, there are two types of filters: Butterworth and Chebyshev filters. One the other hand, according to circuit component, they are active and passive filters.

The passive filters are the circuits that contain only passive components (resistors, inductors and capacitors) connected in such a way that they will pass certain frequencies while rejecting others.

The active filters employ active components (transistors or operational amplifiers) plus resistors, inductors and capacitors.

Active filters are widely used in modern communication systems, because they have the following advantages:

- the transfer function with inductive characteristic can be achieved by particular circuit design, resistors can be used instead of inductors;
- the high input impedance and low output impedance of the operational amplifier means that the filter circuit is excellent in isolation characteristic and suitable for cascade;
- active components provide amplification, therefore active filters have gain;

In the next experiment activity, we will focus on the characteristics of the N-order low-pass and high-pass active filters (including second-order filters).

As we already know, a low-pass filter is an electronic circuit that has a constant output voltage from dc up to a cutoff frequency. As the frequency increases above the cutoff frequency, the output voltage is attenuated.

The cutoff frequency, also called the 0.707 frequency, the 3DB frequency, or the corner frequency, is the frequency where the output voltage is reduced to 0.707 times its pass band value.

### Identifying the panel filters

For the experiment purpose, we have to identify the available devices, with all interactive ports. Interactive ports (inputs and outputs ports) are related to:

- filter’s outputs (voltage level, cutoff frequency);
- controlling the filtering DSB into SSB;

Usually, the controlling voltages output are terminals (one port referenced to the general ground, or to the zero supply), also called **test points**.

For controlling the outputs, there is a variable resistor. **Test points** are called also the terminals designed to collect oscillator’s signals.

Please be carefully with using ports: don’t connect filter’s inputs and outputs ports together, manipulate carefully power cables in order to make proper connections.
For running transmission system an important module is 10th order low pass filter, with the code G on DL 3155M60 board.

![10th order low pass filter module](image)

**Figure 3.1 - The module is designed to exercise low pass filter characteristics**

<table>
<thead>
<tr>
<th>Tasks to study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locate the 10th order low pass filter circuits on the module DL 3155M60.</td>
</tr>
<tr>
<td>Locate the ports. Locate the controlling possibilities.</td>
</tr>
<tr>
<td>Understand ports meaning.</td>
</tr>
</tbody>
</table>

Please identify it, then, by consulting the circuit diagram, try to understand the role of the main components (R6).

- Make your comments

Set the input of oscilloscope to AC position and connect to board input terminals (O/P). Observe the waveform and frequency for DSB. Then, set the input of oscilloscope to AC position and connect to output terminals (O/P). Observe the waveform and frequency for SSB.

- Make your comments

Use the variable resistor controls for controlling the output voltage level variation.

- Make your comments

**Quiz. Test yourself and be ready to accept new questions**

- Why there is a need to have access to control the output voltage level on Nth order filter?

- What are the advantages of the active filters?
This module (10 kHz 4th order low pass filter), with the code P on DL 3155M60 board, is used for controlling the audible signals-as information signal into the transmission process. The quality of this circuit defines the distortions into the process of modulation/demodulation.

![P - 10kHz 4th order low pass filter](image)

**Figure 3.2 - 4th order low pass filter with 10 kHz cut-off frequency**

### Tasks to study

| ![Tick] | Locate the 10 kHz 4th order low pass filter circuits on the module DL 3155M60. Locate the ports. Locate the controlling possibilities. For this experiment you must use a frequency generator with the central frequency around 10 kHz, and an oscilloscope with measurement range focused on 10 kHz frequency. Connect the output of the generator to IN port of the filter. Connect the oscilloscope inputs to the OUT port of the filter |

With the frequency control button from the generator, adjust the frequency, and note the signal behavior to the oscilloscope. Pay attention to the level of voltage.

![Note] Make your comments

| ![Tick] | Locate the tone generator circuits on the module DL 3155M60. Locate the ports. Locate the controlling possibilities. |

Connect the output of the tone generator to the input of the 10 kHz 4th order low pass filter. Connect the oscilloscope inputs to the OUT port of the filter. Adjust tone generator frequency and note the signal behavior on the oscilloscope display.

![Note] Make your comments
Connect the output of the noise generator to the input of the 10 kHz 4th order low pass filter. Connect the oscilloscope inputs to the OUT port of the filter. Adjust noise generator voltage level and note the signal behavior on the oscilloscope display.

Make your comments

Quiz. Test yourself and be ready to accept new questions

Please imagine another method for evaluating 10 kHz 4th order low pass filter behaviour.

If we want to change the bandwidth of this kind of filter how can we proceed?
Now, the situation is a bit more complicated. The fault scenarios are simulated with dip-switches. The F2 is made by adjusting the switches like in next figure.

If the panel is connected directly to your PC via De Lorenzo TIME interface, then the fault can be inserted directly by clicking on INSERT shown below.

The experiment under investigation is shown in next figure, and probably you remember it very well.

Remember please, we were experimenting SSB receiving signal. Because of low level of the output of SSB detector, we were using also the general purpose amplifier.
Let’s suppose the fault is happening when we are excited by the nice results we get with SSB
detection.
We show that in next figure- you remember it!

In our simulation, for the fault situation we get no signal at the output of module D.
The fault situation F2 make a difference on Ch2 like next figure.

Let’s try to translate this situation: the output signal of the amplifier is not detectable- it is extremely
low.

What are the possible causes?
Looking on the block diagram, we might say that they are six modules with six possible causes.
Because the modules are serial connected from functional point of view, we might have the
possibility to investigate modules from the left to right or in opposite direction.

What is the best “direction” to investigate?
We should start thinking to answer, by evaluating the levels of signals we are manipulating during
experiments.
What are the easiest signals to be detected?
The tone generator and the carrier generator have high level of voltage (volts!). The modulator and the filter have also strong signals. More difficult situation is to check the output of the SSB detector (around 50 mV!), where also the ratio signal/ noise is low. Well, after this review, signal, we know the answer: from the left side to right side (from generators).

As in previous scenario (F1), we need to be sure about any other possible outside causes of faults. Then, we use the scope and we check the output signals, module after module.

In our case, after few actions, we will get a situation similar with next figure.

![The input of module G](image1)
![The output of module G](image2)

The final diagnose is: the 10th order low pass filter is not working properly. Again, we say that we are happy that is only simulation of the fault!

Beside the actual fault explanations, we would like to recommend you to be careful with manipulation of the cables during measurements- it is very easy to make a short circuit because they are a lot of metallic parts of electronic circuits! So, during measurements, please handle with one cable a time, use both ends of one cable in one hand, and do not touch any other conductive parts then the connection points.
Unit N.7: Understanding PLL frequency modulation (PLL FM)

Objectives:
- Understanding the principle of frequency modulation/demodulation using PLL circuits
- Understanding the waveform and frequency spectrum of FM signal
- Designing an frequency modulator using dedicated circuits
- Measuring and adjusting modulator circuit

Requisites:
- Minimum level of communication techniques understanding
- Medium level of electronics components and devices understanding
- High level of health and safety risks understanding
- Communication systems theoretical manual DL 3155M60

Operative instruments:
- DL 3155AL2 or stabilized supply source
- 20MHz double trace oscilloscope
- set of connection cables
For the frequency modulation, the carrier frequency is changing its parameter with the modulating amplitude.

The main parameters of this process are:

- $A_{DC}$ - dc level
- $A_m$ - audio amplitude
- $A_c$ - carrier amplitude
- $f_m$ - audio frequency
- $f_c$ - carrier frequency
- $Pm$ - power of signal
- $B$ - bandwidth of signal

**Identifying the panel filters**

On the theoretical part, that supports the experimental kit- frequency modulation section, there is a full description of possibilities of running with frequency modulation techniques. On the experimental board there are some modules (electronic circuit) that are used to conduct well FM experiments.

First we will take into consideration to use again, the carrier generator (module M), the tone generator (module F), and some other modules depending by the level of experimentation. Ones again, it is important to underline all blocks that are involved in FM modulation and demodulation.
As you know from all domestic applications, the most popular ‘electronic’ method for FM/PM modulation and demodulation is the Phase Locked Loop (PLL). The heart of PLL is the Double Balanced Mixer, where in a PLL, the DBM is used in combination with a low pass filter (or time constant) as a Phase Detector.

Remember please the block diagram of the PLL. Another important component of it is the voltage controlled oscillator. A more general explanation of the PLL's behaviour is that it continuously adjusts the VCO output to maintain phase quadrature.

That means that any change in the input FM wave's frequency or phase tends to produce a DBM output which causes the VCO to ‘track’ the input.

In order to maintain a constant phase relationship they must keep ‘in step’ — i.e. their frequencies must always be the same.

Since the VCO's frequency depends upon the control voltage, it follows that this voltage varies in proportion with the FM wave's frequency. Remember, this one of biggest advantage of PLL FM modulator/demodulator.

The PLL is a very interesting and useful building block available as single integrated circuits from several well known manufacturers. It contains a phase detector, amplifier, and VCO, see Fig. 1 and represents a blend of digital and analog techniques all in one package. One of many applications and features is tone-decoding.

There has been traditionally some reluctance to use PLL's, partly because of the complexity of discrete PLL circuits and partly because of a feeling that they cannot be counted on to work reliably. With inexpensive and easy-to-use PLL's now widely available everywhere, that first barrier of acceptance has vanished.

And with proper design and conservative application, the PLL is as reliable a circuit element as an op-amp or flip-flop.

From the catalogue datasheet of 4046, we understand that the phase comparator II is an edge-controlled digital memory network. It provides a digital error signal and lock-in signal (phase pulses) to indicate a locked condition and maintains a 00 phase shift between signal input and comparator input.

The linear voltage-controlled oscillator (VCO) produces an output signal (VCO Out) whose frequency is determined by the voltage at the VCOIN input, and the capacitor and resistors connected to pins C1, R1 and R2.

The source follower output of the VCOIN (demodulator out) is used with an external resistor of 10 kΩ or more.
In upper figure there is the block diagram of internal structure of CD 4046. The VCO is externally controlled by C1, R1, and R2.  
For running experiments with De Lorenzo product board (DL3155M60) we will use FM modulator with PLL (module I), FM demodulator with PLL, tone generator (module F), and 10 kHz 4 order low pass filter (module L) - we will explain why latter.

Here, there the time to fix up a technical detail: in any transmission, there is a specific parameter for the data that have to be sent - the bandwidth of the data. Let’s suppose that we want to broadcast audio tone in a bandwidth of 10 kHz. It means that we need electronic modules that process 10 kHz of data - like a low pass filter.

It is important to mention this, because this bandwidth is influencing the bandwidth of high frequency (please read the FM paragraph from theoretical manual).

Next figure shows the connections between modules.
In our experiment, the FM modulator, built around 4046, with the external element R1, C1, develop 88 kHz in VCO, with 12 V_{pk-pk}.

Again, our target is to send an audio signal through a transmission environment (like FM modulated radio wave), then, at the receiver side, to recuperate entirely the audio signal. For that reason, main measurements are done at output of tone generator (Ch1), and at output of FM demodulator with PLL. But they are also some intermediate measurements, like VCO parameters. Next figure shows that.

For our experiment, we are establishing the output of the tone generator at frequency below 5 kHz, with an amplitude maximum 4 V_{pk-pk}. 
Tasks to study

First, please make the proper setup, as previous presentation.

Then, make fine adjustments in tone generator’s frequency. Check the output of FM demodulator (module L).

Please make your comments related. What about output phase signal? What about output level of signal?
Well, the signal is not very accurate.

What can we do next?
Please connect the output of FM demodulator to the input of 10 kHz 4 order low pass filter, like next figure.
Let’s see what is happening.
By measuring the output signal of module P, we will be much satisfied about results.
Next figure shows for comparison, the measured signal at the outputs of module L, and P.

Please make your comments related, about the quality of recuperated audio signal, and other related parameters.

As far as you followed the recommendations for experiments, and you got almost similar results, now we can go father with quality analysis.
An important parameter of modulation/demodulation process is the linearity of the process.

First, based on catalogue data of the 4046, please calculate the VCO frequency, based on values of the electronic circuit: \(C_1=680\ \text{pF}, \ R_1=27\ \text{k}\Omega, \ R_2=100\ \text{k}\Omega\).
Check for the calculated results comparing with measured results.
Check for the linearity of the chosen values for external VCO components.

Second, into the imposed limits of tone generators parameters, with fixed amplitude of it, please make an analysis of the output signal in accordance with tone generators frequency.
Please complete the next table, and then build up a graph related.

<table>
<thead>
<tr>
<th>(F_{\text{tone}}) [kHz]</th>
<th>(U_{\text{out filter}}) [V]</th>
<th>Delay [%]</th>
<th>Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F_1)</td>
<td>(U = ?)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F_2)</td>
<td>(U = ?)</td>
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<td>....</td>
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</tbody>
</table>

Please make your comments related.
**Quiz. Test yourself and be ready to accept new questions**

1. Please review the advantages of using PLL technology in implementing FM transmission system.

2. Who influences the modulation/demodulation process?

3. Who are FM modulating/demodulating parameters?

4. Please prove the use of module P.