Analog Motor Speed Control

Lab Manual

Using Feedback Analog Servo
Fundamentals Trainer 33-002 Motor

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OBJECTIVES:

Observe a feedback control system for a dc motor using the Analog Unit 33-110 board.

EQUIPMENT & SOFTWARE:

Feedback Analog and Digital Servo Fundamentals Trainer 33-002

- 33-100 Mechanical Unit (Motor)
    - 34-way terminated cable
    - Leads 200mm, 2mm plug
    - Leads 400mm, 2mm plug
- 33-110 Analogue Unit

Feedback PS446 or 01-00 power supply
HP 33120A Function Generator/Arbitrary Waveform Generator
HP 54645A Oscilloscope

Description of the System:

The plant to control is a DC motor. The objective is to achieve motor speed control that is able to perform well under different loads using the Analog Unit 33-110 board to create different circuits.

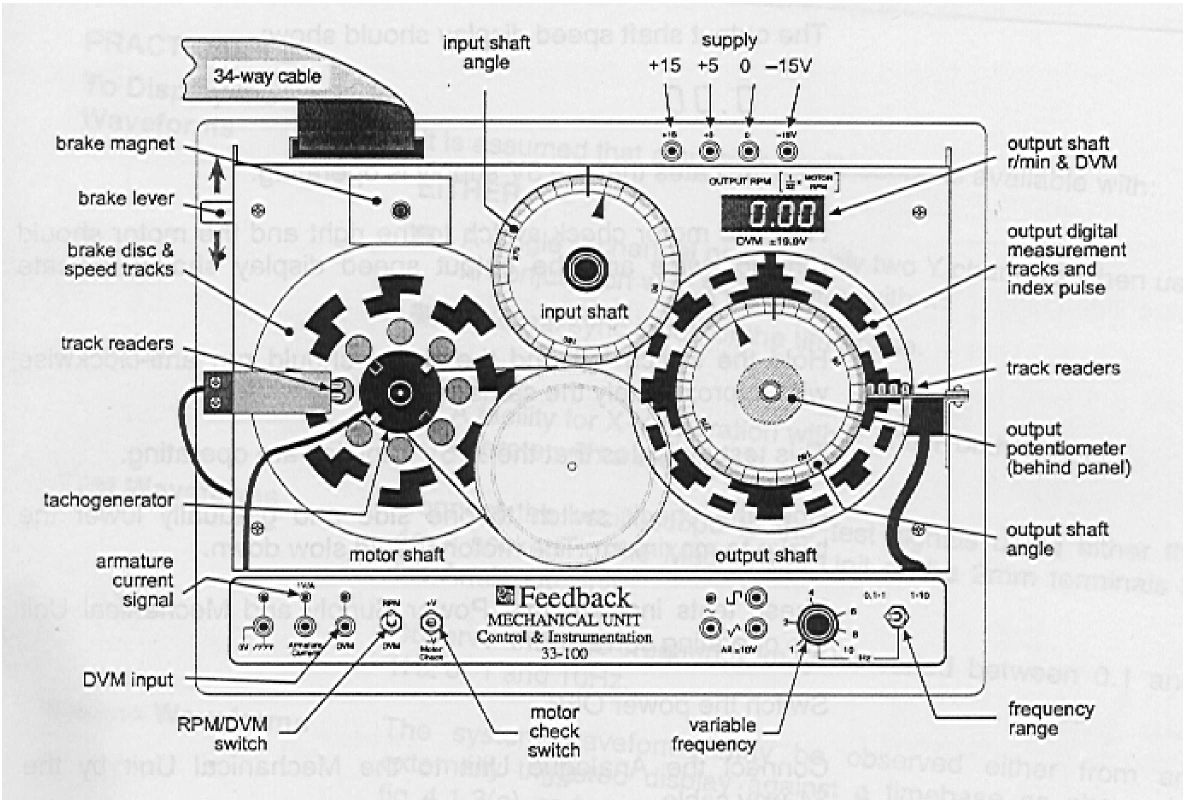
APPROACH (THEORY):

Mechanical Unit (Motor):

Some facts about the Mechanical Unit:

- Contains a power amplifier that drives the motor from an analogue or switched input.
- Motor's output rotational speed undergoes a 32:1 belt reduction.
- Contains a magnetic brake to simulate a load.
- Contains tachogenerator (analogue speed transducer).
- Contains a brake disk with tracks on it. Motor has a two-phase pulse train that reads a digital output from the brake disk and displays it.
- Output shaft carries analogue (potentiometer) and digital (64 location Gray code) angle transducers (we're concerned with analogue signal here, but we could also use the digital signal with the data acquisition card).
- Contains a simple signal generator to provide low frequency test signals, sine, square, and triangular waves.

Below is a picture of the Mechanical Unit.



<u>Definitions</u>:

<u>Motor Shaft</u>: This carries the brake disc, together with a 2-phase speed track and tachogenerator.

<u>Brake disc and magnet</u>: The brake is applied by the lever projecting at the left. The lever scale is provided to enable settings to be repeated.

<u>Speed tracks and readers</u>: These provide two-phase, 0-5V square waves at 8-cycles per revolution. These signals are available on the 34-way socket but are not used in the Analogue system.

<u>Motor check switch</u>: This enables the motor to be rotated as an initial check.

<u>Armature current signal</u>: This is a voltage waveform indicating the armature current with scale of 1V/A.

<u>Input shaft</u>: This carries the input potentiometer and scale and gives a signal θ_i in the range +- 10V.

Test signal frequency and range switch: These control the internal oscillator to provide ±10V square, triangular and sine waveforms with nominal frequency 0.1 to 10Hz in two ranges. The square and triangular waveforms are connected to the 34-way socket.

Output shaft: This carries the output potentiometer and digital angular measurement tracks. The potentiometer provides θ_o in the range ±10V.

Digital measurement and readers: The digital tracks give 6 bit Gray code (64 locations) information and are read by infra-red readers. The 6-bit information is supplied as 0 or 5V to six pins on the 34-way socket.

Index pulse: At one pulse per revolution this provides an output shaft reference point for incremental control connected to a pin on the 34-way socket.

Output speed display: This provides a direct reading of output shaft speed in r/min in the range 00.0 to 99.9, derived from the tachogenerator. Since the reduction ratio is 32:1, a motor speed of 1000 r/min gives 31.1 r/min at the output shaft.

Break disc and magnet: Provide an adjustable load for the motor.

Tachogenerator: Mounted on the motor shaft and provides a voltage proportional to motor speed; the voltage is available with reversed polarity.

Analogue Unit:

The analogue unit connects to the Mechanical Unit through a 34-way ribbon cable which carries all power supplies and signals enabling the normal circuit interconnections to be made on the Analogue Unit using the 2mm patching leads provided.

We will use the Analogue Unit to implement our control system. It will allow us to generate an input, modify the signal, send it to the motor, and received the output from the motor. Provided are definitions for some of the more important components of the Analog Unit.

Error Amplifier

This is the component on the analog unit in the upper left corner. It has resistors of various resistances. The function of the unit is to sum the signals entering on the left and also it can amplify the resulting difference. The gain or amplification of the component is simply determined by the ratio of the resistors used. The voltage signals enter through 100 Kilo Ohm resistors. If we put a another resistor in parallel with the amplifier we achieve a voltage gain equal to the ratio of the new resistor R_2 and the 100 kilo ohm resistor $R_{1\ \text{the}}$ gain ratio equals:

$G = R_2/R_1$ Error Amplifier Gain Equation

The importance of gain is that the higher the gain the faster our motor accelerates to the reference velocity expressed as some voltage. The difficulty with high gain is sometimes it makes the system more difficult to control.
To obtain the difference between two signals using the Error Amplifier invert one the signal before entering it into the amplifier. In this lab we will invert the tahogenerator (motor velocity) signal before summing it with our reference signal.

Wave Generator

This device is located in the lower left corner of the analog controls unit. For our experiment this means any device that generates a voltage input with a definite characteristic pattern. Three types are available from the analog unit: a non-oscillating (flat) wave (+/-), and an oscillating triangular and rectangular wave. These waves are compared with our output wave from our tacho-generator.

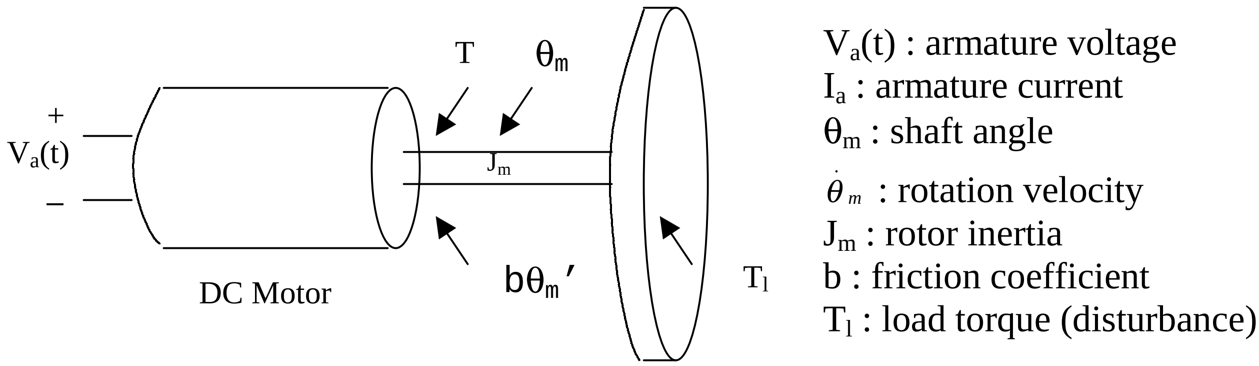
Gain Potentiometer

Varies our signal strength from 0-100% of its current value. Gain potentiometers are P1, P2 and P3 on our analog board.

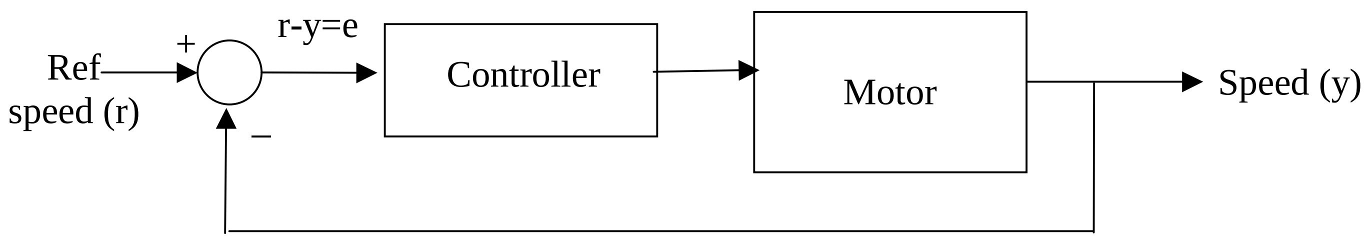
Signal Inverter

One signal inverter is present on the tacho-generator signal on the control board. Another signal inverter is associated with the output of the error amplifier. This enables us to find the difference between two positive signals (or two negative). First we invert one signal. Then we find the sum of the two signals, one normal and one inverted, using the error amplifier.

Controlling the Motor:
The motor (Mechanical Unit) can be modeled as a simple DC motor.



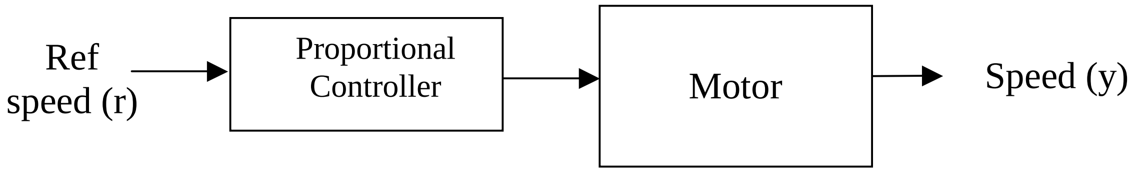
The closed loop system can be modeled as:



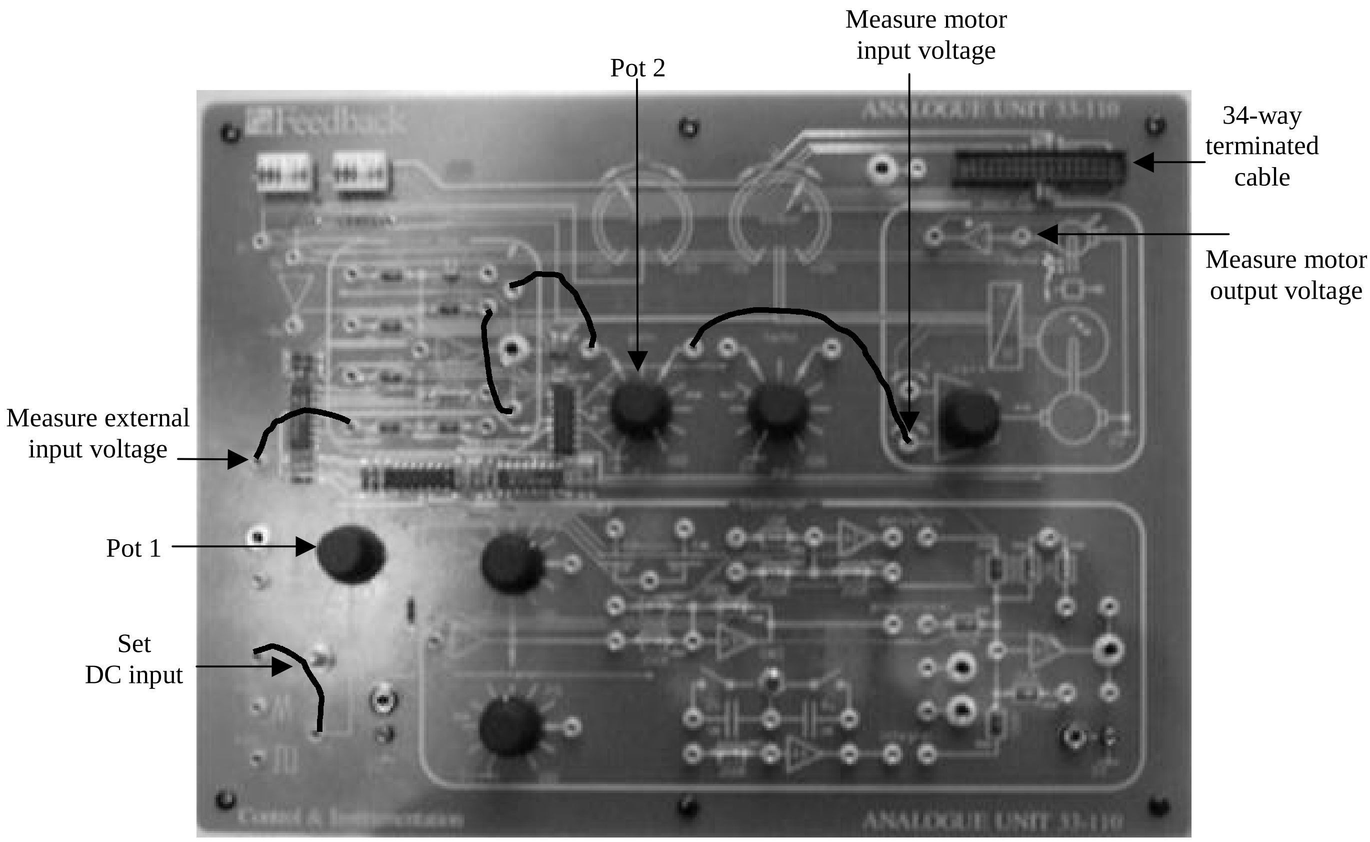
The basic goal of our control system is to enable the system to maintain a certain speed regardless of the load placed upon it. We can accomplish this by using negative feedback control. The feedback allows our system to calculate error and provide control that will compensate for different loads.

PROCEDURE:

Part 1 - Without Feedback:
First we'll observe and record the effects of a load on a system without feedback. Below is a box diagram for a control system without feedback.



To accomplish this circuit we'll use the Analog Unit. A DC signal will be sent to the motor and the output speed will be displayed by the tachogenerator. Below is a picture of how to set up the Analogue Unit for this system:

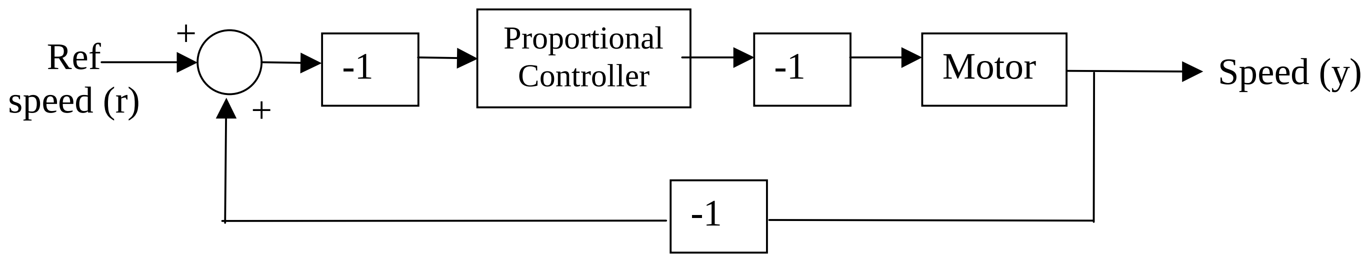


Once your circuit is complete (and the power supply is connected and on) you should see the motor begin to turn counter-clockwise. You can observe from the setup that the circuit is simply takes the DC input, sends it through an inverting amplifier, and then inverts the signal. When you have the motor turning, observe how altering Potentiometer 2 can increase or decrease the speed of the motor by providing an adjustable gain. When you have reached this point you are ready to observe the effects of a load placed upon the system. Complete the following table:

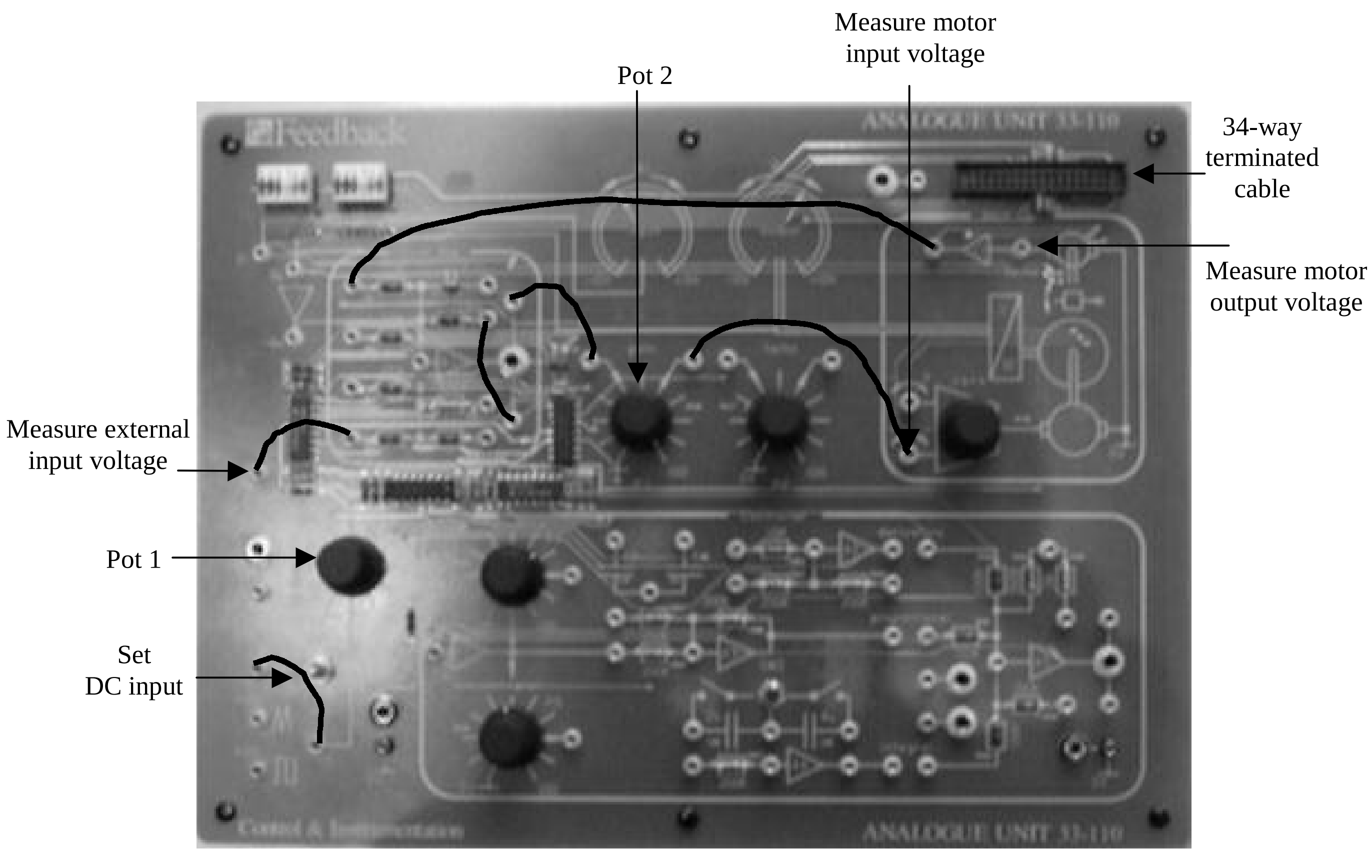
External Input (V)	K	Input into Motor (V)	Brake-up Motor Output (V)	Brake-up Motor Speed (RPM)	Brake-down motor output (V)	Brake-down Motor Speed (RPM)	Motor Output Difference (V)	Speed Difference (RPM)
.5	5							
.5	10							
1	5							
1	10							

- Connect 34-way terminated cable from the top right corner of the Analog Unit to the back of the Mechanical Unit (see picture).
- Set the DC input (see picture) to 10V. Set the External Input by adjusting Potentiometer 1 and using the multimeter to confirm your setting (see setup picture).
- K can range from 0-10V. Set the Potentiometer 2 to 50 for K to equal 5, and to 100 for K to equal 10.
- Find the Input into Motor voltage from the positive input of the zero dial (see setup picture).
- Find the Motor Output from the tachogenerator output (see setup picture).
- Find the Motor Speed by observing the display at the top right hand corner of the motor.
- Find the Motor Output Difference by taking the absolute value of the difference between the brake-up and brake-down motor outputs.
- Find the Speed Difference by taking the absolute value of the difference between the brake-up and brake-down speeds.
- Note your observations.

Part 2 – With Feedback:
Now we'll observe and record the effects of a load on a system with feedback. Below is a box diagram for the control system with feedback we will use.



The system will once again have a DC input. This time we will use a summing amplifier to accomplish feedback control. The DC input will be fed into the inverting, summing amplifier. The signal will then be inverted and sent to the motor. Finally, the output of the motor will be sent back to the summing amplifier, accomplishing feedback control. Below is a picture of how to set up the Analogue Unit for this system:



The main difference from the prior setup is that you now have the feedback into the summing amplifier. Refer to the previous examples instructions to complete the following table:

External Input (V)	K	Brake-up Input into Motor (V)	Brake-up Motor Output (V)	Brake-up Speed (RPM)	Brake-down Input into Motor (V)	Brake-down Motor Output (V)	Brake-down Speed (RPM)	Motor output Difference (V)	Speed Difference (RPM)
.5	5								
.5	10								
1	5								
1	10								

<u>CONCLUSIONS</u>:

Now that you've compared both control systems, answer the following questions:

1. Which system (no feedback or feedback) more effectively maintained speed under different loads?
2. Explain how feedback helps control.
3. Did the feedback system perfectly maintain its speed when a load was applied? If not, why?
4. Referring to your completed tables, in which system did the input voltage more closely resemble the output voltage.
5. In the feedback system, what happened to the input into the motor voltage when the break was applied? Why did this occur?