18m ISRO antenna used to track Chandrayaan (part of Indian Deep Space Network)

This antenna needed to track Chandrayaan.

Q. How to change the azimuth angle precisely according to the motion of Chandrayaan?
Manually through gears

Impossible: Too slow and imprecise
Potentiometer

Converts angle command into voltage
Use POT to convert angle command into voltage

Unrealistic arrangement! WHY?
Answer: Large motor requires a lot of power.
Use Power amplifier to magnify POT output voltage

STILL SOMETHING MISSING! WHAT?
Answer: Error Correction
The central theme: feedback

• Use another gear/pot to check whether actually the output is following the input.
• If not then use the difference/error to drive the system
One of the earliest examples of feedback

Regularly used along the Konkan coast: probably first used in South India
Control in Wright Brother’s 1902 aircraft

Aircraft Control
Wright 1902 Glider

Pitch Axis
Pitch

Roll Axis
Roll

Yaw Axis
Yaw

Center of Gravity
Modern Aircraft Attitude control loop
Glucose control feedback loop

- **Glucose**
- **Control**
- **Feedback Loop**

**Liver**
- **Glycogen**
- **Glucose**
- **Glucagon**
  - Stimulates breakdown of glycogen
  - Promotes insulin release
- **Insulin**
  - Stimulates glucose uptake from blood
  - Promotes glucagon release
- **Tissue Cells** (muscle, kidney, fat)
  - Lowers Blood Sugar
- **Pancreas**
- **Body**
- **Disturbances (Meal)**
  - **Insulin**
  - **Glucose Concentration**
  - Sense Tone
Functional Block diagram

Command
Input Angle

Pot
Input
Transducer

Voltage prop. to input

Error on Actuating Signal

Controller
Signal Power Ampl.

Plant
Motor Load + gears

Output

Sensor
Voltage prop. to output

Pot.

Output transducer
Schematic and Block diagram
Steps of Control System Design

Step 1: Determine a physical system and specifications from the requirements.


Step 3: Transform the physical system into a schematic.

Step 4: Use the schematic to obtain a block diagram, signal-flow diagram, or state-space representation.

Step 5: If multiple blocks, reduce the block diagram to a single block or closed-loop system.

Step 6: Analyze, design, and test to see that requirements and specifications are met.

Analog: Chapter 1
Digital: Chapters 2, 3
Chapter 13

Chapter 5
Chapter 13

Chapters 4, 6-12
Chapter 13
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<th>Function</th>
<th>Description</th>
<th>Sketch</th>
<th>Use</th>
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<td>Impulse</td>
<td>(\delta(t))</td>
<td>(\delta(t) = \infty) for (0^- &lt; t &lt; 0^+) [\int_{0^-}^{0^+} \delta(t) , dt = 1]</td>
<td>(f(t))</td>
<td>Transient response Modeling</td>
</tr>
<tr>
<td>Step</td>
<td>(u(t))</td>
<td>(u(t) = 1) for (t &gt; 0) [= 0] for (t &lt; 0)</td>
<td>(f(t))</td>
<td>Transient response Steady-state error</td>
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<tr>
<td>Ramp</td>
<td>(tu(t))</td>
<td>(tu(t) = t) for (t \geq 0) [= 0] elsewhere</td>
<td>(f(t))</td>
<td>Steady-state error</td>
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<tr>
<td>Parabola</td>
<td>(\frac{1}{2}t^2u(t))</td>
<td>(\frac{1}{2}t^2u(t) = \frac{1}{2}t^2) for (t \geq 0) [= 0] elsewhere</td>
<td>(f(t))</td>
<td>Steady-state error</td>
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<tr>
<td>Sinusoid</td>
<td>(\sin \omega t)</td>
<td></td>
<td>(f(t))</td>
<td>Transient response Modeling Steady-state error</td>
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Antenna Animation
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<th>( f(t) )</th>
<th>( F(s) )</th>
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<td>1.</td>
<td>( \delta(t) )</td>
<td>( 1 )</td>
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<tr>
<td>2.</td>
<td>( u(t) )</td>
<td>( \frac{1}{s} )</td>
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<tr>
<td>3.</td>
<td>( tu(t) )</td>
<td>( \frac{1}{s^2} )</td>
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<tr>
<td>4.</td>
<td>( l^m u(t) )</td>
<td>( \frac{n!}{s^{n+1}} )</td>
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<tr>
<td>5.</td>
<td>( e^{-at}u(t) )</td>
<td>( \frac{1}{s + a} )</td>
</tr>
<tr>
<td>6.</td>
<td>( \sin \omega t u(t) )</td>
<td>( \frac{\omega}{s^2 + \omega^2} )</td>
</tr>
<tr>
<td>7.</td>
<td>( \cos \omega t u(t) )</td>
<td>( \frac{s}{s^2 + \omega^2} )</td>
</tr>
<tr>
<td>Item no.</td>
<td>Theorem</td>
<td>Name</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>1.</td>
<td>$\mathcal{L}[f(t)] = F(s) = \int_{0^-}^{\infty} f(t)e^{-st}dt$</td>
<td>Definition</td>
</tr>
<tr>
<td>2.</td>
<td>$\mathcal{L}[kf(t)] = kF(s)$</td>
<td>Linearity theorem</td>
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<td>3.</td>
<td>$\mathcal{L}[f_1(t) + f_2(t)] = F_1(s) + F_2(s)$</td>
<td>Linearity theorem</td>
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<td>4.</td>
<td>$\mathcal{L}[e^{-at}f(t)] = F(s+a)$</td>
<td>Frequency shift theorem</td>
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<td>5.</td>
<td>$\mathcal{L}[f(t-T)] = e^{-sT}F(s)$</td>
<td>Time shift theorem</td>
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<td>6.</td>
<td>$\mathcal{L}[f(at)] = \frac{1}{a}F\left(\frac{s}{a}\right)$</td>
<td>Scaling theorem</td>
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<td>7.</td>
<td>$\mathcal{L}\left[\frac{df}{dt}\right] = sF(s) - f(0^-)$</td>
<td>Differentiation theorem</td>
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<td>8.</td>
<td>$\mathcal{L}\left[\frac{d^2f}{dt^2}\right] = s^2F(s) - sf(0^-) - f(0^-)$</td>
<td>Differentiation theorem</td>
</tr>
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<td>9.</td>
<td>$\mathcal{L}\left[\frac{d^nf}{dt^n}\right] = s^nF(s) - \sum_{k=1}^{n} \frac{n!}{s^{n-k}} f^{(k-1)}(0^-)$</td>
<td>Differentiation theorem</td>
</tr>
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<td>10.</td>
<td>$\mathcal{L}\left[\int_{0^-}^{1} f(\tau)d\tau\right] = \frac{F(s)}{s}$</td>
<td>Integration theorem</td>
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<tr>
<td>11.</td>
<td>$f(\infty) = \lim_{s \to 0} sF(s)$</td>
<td>Final value theorem$^1$</td>
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<td>12.</td>
<td>$f(0+) = \lim_{s \to \infty} sF(s)$</td>
<td>Initial value theorem$^2$</td>
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