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# Telemetry Systems

## Course No. 171

**FOR WHOM INTENDED** This course is intended for personnel involved in engineering applications of telemetry, in either commercial or defense/space organizations. Applications include telemetry as applied to control and monitoring of space vehicles as well as telecommunications, automotive testing, in-plant industrial system control and electrical power transmission telemetry systems.

**BRIEF COURSE DESCRIPTION** The course starts with an introduction to telemetry systems, carrier signal modulation and telemetry standards.

The presentation continues with background information on topics encountered in telemetry systems such as: dB, sensors, filtering, signal waveforms and Fourier analysis.

Telemetry modulation techniques, frequency modulation (FM) and Pulse-Amplitude modulation (PAM) are covered next. After a discussion of digital signals, binary arithmetic and data formats, Analog/Digital and Digital/Analog conversion is covered. Building on this knowledge, the instructor then presents Pulse-Code modulation (PCM), including sub- and super-commutation techniques.

Next comes a discussion of Data Bus standards such as ARINC-429, MIL-STD-1553 and SCADA, followed by a section on bit encoding, including Viterbi, Reed-Solomon and convolution.

Special PCM formatting such as embedded asynchronous and embedded video techniques are discussed before covering time codes. The instructor then discusses Range Telecommunications issues such as multi-sourced data and architecture.

Next comes an overview of available computer systems, interfaces, networking options and parameter databases. Data compression and storage are considered next, including analog and digital tape recording and multiplexers. The course concludes with discussions of RF transmission theory, CCSDS and packet telemetry, an overview of telemetry vendors and recommendations for further reading.

**CERTIFICATE PROGRAMS** This course is an elective for TTI's [Instrumentation Test Specialist Certificate Program](#) and may be used as an elective for any other [TTI Certificate Program](#).

**PREREQUISITES** There are no definite prerequisites, but TTI's courses "[Instrumentation for Electrical Test and Measurement](#)," and "[Digital Signal Processing](#)" would be helpful.

**TEXT** Each student will receive a [course workbook](#) including most of the viewgraphs used in the presentation, also a CD-ROM with copies of the various standards discussed in the class.

**COURSE HOURS, CERTIFICATE AND CEUs** Open courses meet seven hours per day. Upcoming presentation dates can be found on our current [open course schedule](#). Class hours/days for on-site courses can vary from 14–35 hours over 2–5 days as requested by our clients. At successful course completion, each participant receives a certificate of completion and one Continuing Education Unit (CEU) for every ten class hours.

For [schedules](#), [general information](#) and [registration forms](#), see TTI's web site.

### Course Outline

#### Introduction to Telemetry Systems

- Types of telemetry systems, Basic radio telemetry system, RF Link
- Components of telemetry system, Antennas, Signal Modulation
- Near-Earth and Deep Space Applications, Telemetry standards
- Understanding dB: Decibels, Power Ratio, Voltage Ratio, dB Conversions
- Signal Waveforms and Sources of Inaccuracy, Decisions
  - General Categories: Self Generating, Piezoelectric, Externally Excited
  - Piezoresistive (PR), Internally Excited • Transducer Calibration
  - Filtering: Analog vs. Digital filtering, Bandpass filters, Filter characteristics
- Signal Waveforms and Fourier Analysis: Square Wave, Pulse shape
  - Complex Waveform • Addition of Sine Waves, Time and Frequency Domain
- Signal Sampling: Acquisition, Shannon's Theorem, Critical component, Aliasing
- Frequency Modulation (FM) and Pulse Amplitude Modulation (PAM):
  - Carrier Modulation • Amplitude and Frequency Modulation (AM and FM)
  - FM: Ground Station, Frequencies, Techniques, IRIG Channels, Modulation
  - Guard Bands, Signal Sampling • PAM Ground Station, Miscellaneous Encoding
- Digital Signals, Binary Arithmetic and Analog/Digital Conversion
  - Analog and Digital Waveforms, Signals • Numbering Systems
  - Signed Magnitude • 2s Compliment • Comparisons, Summing
  - Data formats: Fixed vs. Floating Point • Analog/Digital, Digital/Analog Conversion
  - Output Waveform of DAC • % Resolution • Number of Bits and LSB • Endians
- Pulse Code Modulation (PCM): PCM Encoder • Airborne Instrumentation
  - CAIS Sources • PCM Ground Station • Bit Sync • Decommutator
  - Optimal Frame Sync Pattern • Sample Rates vs. Bit Rates • Sub-Commutation
  - Frame Encoding • Formats • Super-Commutation • Super-Sub-Commutation
  - Sub-Sub Commutation • Discrete Inputs • Receiving System Setup Issues
  - Receiver Settings • Bit Sync Settings • Decom Settings
- Data Bus: ARINC-429 • MIL-STD-1553 • IRIG-106, Chapter 8 • SCADA
- Bit Encoding: Digital Data Formats, Common Codes, Eye Patterns, Bit Syncs
  - Noise in the Data Stream, Viterbi and Reed-Solomon Encoding
  - Convolution Encoding Examples: 1/3 Rate, 1/2 Rate • Interleaving
- Special PCM Formatting: Embedded Asynchronous, Embedded Video, Data Class 1 & 2, Fragmented Words, Independent Subframes, Sample/Hold, Tagged Data
- Time Codes: System Timing Info • Internal vs. External Time • Typical Time Codes, Resolution • IRIG-B, Embedded Time • IRIG 106 Standard • Desktop time
- Range Telecommunications: Problem • Multi-Sourced Data • Architecture • Carrier Strengths and Weaknesses • IP Data Transfer • Merging File (Data) Sets
- The Computer and the Telemetry System: Data Words • Data Transfer Mechanisms
  - Programmed, DMA I/O • Double-Buffering • Chaining • Data Storage • PCs
  - Data Acquisition to Disk ..Speed • Getting Data to Disk • Interrupts • FIFO Memory
  - Transfers, Scans, and Buffers • Interface, Bus Standards • PC Clones
  - Portability and Ruggedness • Fibre Channel • RAID and Networked Storage
  - Ethernet Architecture • Software Protocols • Data Flow Down • Display Devices
  - Parameter Databases • "Hard" Programming • Strip charts
- System Processing, Testing, and Specifying: Needs for a Processing Engine
  - IRIG Time Testing • Data Driven vs CVT Testing • System Specifications
- Data Compression and Storage: ZFN, In Limits, N<sup>th</sup> Sample, Bit Level Compression
  - Storage: Analog & Digital Recorders, Issues, Multiplexers
- RF Transmission: RF Standards for Telemetry • UHF Bands
  - Digital Signal Transmission • Standard vs. Wide Bandwidth Channels
  - Output Power • Modulation Techniques • FM vs. PSK • Antennas • System Test
- Mission Planning and Data Mining: Work Breakdown Structure • Mission Support
  - Process • Data Mining, Tool Requirements • Three Solutions
- CCSDS: Packet Telemetry • Layering of Telemetry Data • Data Flow Chart
  - Conceptual Ground Station • Hierarchy • CCSDS Overhead
- Telemetry Vendors • Recommended Reading
- Summary, Final Quiz, Award of Certificates for Successful Completion



## Technology Training, Inc.

(a tti group company)

Toll-free telephone: 866-884-4338 (866-TTI-4edu)  
805/715-2638 Fax: 805/715-2650

E-mail: [Training@ttiedu.com](mailto:Training@ttiedu.com)  
<http://www.ttiedu.com>