INSTRUCTOR GUIDE

PRINCIPLES
OF
MODERN COMMUNICATIONS TECHNOLOGY

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Overview

The book *Principles of Modern Communications Technology* published by Artech House (Norwood, MA 2001) has been used at the Annenberg School for Communication at the University of Southern California as the prime text for a one-semester, upper-level course for undergraduates majoring in communication. The text could also be used for a graduate-level course for non-engineering students in communication, business, law, or any other field for which a knowledge of the basic technological principles of communication technologies is required.

This Instructor Guide is intended to assist the instructor by suggesting a weekly outline of the material to be covered in a course on the principles of communication technologies.

The book and course are organized into four major modules or sections, each dealing with an aspect of human communication: sound, vision, speech, and writing. Each module begins with a description of the physiology or history of that aspect of communication. Sound begins with a description of human hearing, vision with the human eye, speech with the articulatory mechanism, and writing with human written communication. Key inventors and business people are integrated into each module to present a historical perspective of the role of these people in inventing the technology and developing the businesses of communication.

OVERVIEW

PRINCIPLES OF MODERN COMMUNICATIONS TECHNOLOGY

The guide is organized into a series of suggested lectures. Each lecture would normally be about 1.5 hours in duration. Hence, a class meeting once per week for 3 hours would cover two lectures each week. The lectures are in outline form as a suggested aid to the instructor.

Detailed Course Schedule

This is a suggested weekly schedule for a one-semester course. The material for the individual lectures is presented in outline form in following pages.

Week	Lecture	MODULE	TOPIC
1	1	INTRODUCTION	
2	2 3	I. AUDIO	• human hearing • phonograph • sound
3	4 5		• signals • electricity
4	5 (cont'd) 6		• electronics • digital
5	6 (cont'd) Review		• digital (cont'd)
6	7	II. VIDEO	EXAM 1 • human vision
7	8 9		• TV basics • radio
8	10 11		• modulation • color theory
9	12 Review		• color TV • video media
10	13	III. SPEECH	EXAM 2 • speech
11	14 15 16		• telephone • networks • transmission
12	17 18		• switching • fax & wireless
13	19 20 21	IV. WRITTEN	• written • telegraph • computers
14	21 (cont'd) 22		• software • data com
15	23 Review	EPILOGUE	• future
16			FINAL EXAM

Study Guides and Outline

The course has been graded with three exams: two short exams at the end of the first and second modules and a final exam. Study guides to assist students in preparing for these exams are presented in the following pages. The guides are then followed by a detailed outline of the various lectures that comprise the course. These lectures follow the material of the book.

Study Guide #1

Definitions:
diffraction, refraction, & reflection
resonance
frequency
period
fundamental frequency
phase
wavelength
longitudinal & transverse waves
harmonic
nodes & antinodes
neuron
binaural & stereophonic
bandwidth
resistance
reactance
impedance
root mean square (rms)
sine wave
waveform
amplitude
spectrum
spectrograph
signal
periodic signal
dc & ac
transducer
diode
triode
anode & cathode
grid
amplification
noise & distortion
decibel
quantization
sampling

Abbreviations:
Hz
cps
rms
V, A, Ω
W
LPF, HPF, BPF
bit, bps
MOSFET
DIP
VLSI

Equations/Mathematics:
F = 1 / T (frequency & period)
E = I R (Ohm's Law)
Nyquist sampling theorem
binary/decimal conversion
determine period

Facts:
properties of a sine wave
frequency response
powers of 10
bandwidths
complete circuit
symbols
ac vs dc (transformers)
analog-digital conversion
human ear parts
cochlea & basilar membrane
hammer, anvil, & stapes
neural signals
properties of laser light

People:
Edison
Boyle
von Helmholtz
von Békésy
Pfleumer
Tesla
Westinghouse
Berliner
Fourier
Fleming
de Forest
Nyquist
Bardeen, Shockley, & Brattain

NOTE:
This study guide is not necessarily the only material that will appear on an examination. The guide is an outline of only the major material covered in the lectures.

Study Guide #2

Definitions:
etheric force
radio waves
color
chrominance & luminance
quadraplex
Nickelodeon

Abbreviations:
AM
FM
SSB
DSB
SC
FDM
CATV
DBS
HDTV
DVD
NTSC
VCR
MPEG
RCA
CRT
LCD
TV
LPTV
SMATV

Equations/Mathematics:
AM BW = 2 x F_{max}

Facts:
camera/eye analogy
portions of eye
rods & cones
color theory
psychophysics of human vision
luminance/chrominance signals
stereoscopic vision
color TV waveform
movie rates
TV specs
scanning
Nipkow disk
blanking pulse
synchronization pulse
sidebands
frequency shifting
frequency division multiplexing
AM waveform
color TV waveform
spectrum of TV channel
aspect ratio
frequency interleaving
video tape recording
shadow mask
backwards compatability
field-sequential color TV
vestigial AM
selenium
flicker fusion

People:
Thomas Alva Edison
Louis & Auguste Lumiére
Eadweard Muybridge
Paul Nipkow
Leland Stanford
Vladimir Zworykin
Howard Armstrong
David Sarnoff
Philo T. Farnsworth
James Clerk Maxwell
Heinrich Hertz
Frank Conrad
Reginald Fessenden
L. E. Parsons
Mertz & Gray
Sir Oliver Lodge
Nikola Tesla
Guglielmo Marconi
Boris Rosing
Joseph May

NOTE:
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Study Guide #3

Definitions:
plosives/fricatives/nasals
vocoder
central office
vocoder
simplex/duplex (full & half)
bit/byte/nibble
bit rate & baud rate
trunk

Abbreviations:
LATA
LEC
CLEC
IXC
PSTN
POP
SS7
CCIS
FDM
TDM
WDM
SONET
TASI
BORSCHT
CCS
AMPS
GSM
CDMA
DSL
ADSL
LEO
ISDN
PCS
ASCII
RAM
ROM
ROM
CDROM
WORM
WWW
HTML
CPU
ARPA
FORTRAN
BASIC
DOS
ASK/FSK
QAM
LAN
URL
GUI

Equations/Mathematics:
T1 = 1.54 Mbps

Facts:
human-speech production
telephone components
transmission media
geostationary satellite orbit delay
optical fiber basics
laser light properties
circuit switching
packet switching
types of switches
switching stages
blocking
wireless cellular principles
history of writing
pictograms
semaphore
elements of computer system
directionalities
Boolean logic gates
machine language
history of writing

People:
Wolfgang von Klempelen
Christian Gottlieb Kratzenstein
John J. Carty
Elisha Gray
Alexander G. Bell
Thomas Watson
Charles Vernon Boys
Almon B. Strowger
A. K. Erlang
Alexander Bain
Johann Gutenberg
Samuel F. B. Morse
Alfred Vail
Herman Hollerith
Charles Wheatstone
Cyrus W. Field
Jean-Maurice-Émile Baudot
Claude E. Shannon
Norbert Wiener
Grorge Boole
Tim Berners-Lee
Marc Andreessen

NOTES:
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INTRODUCTION

Lecture 1 GENERAL OVERVIEW OF COURSE

- General introduction to course:
    - ◊ importance of technology literacy
    - ◊ structured for non-engineers
- Readings:
    - ◊ main: Artech book by Noll
    - ◊ ancillary: *Signals* by Pierce & Noll
- Grading
- Course overview:
    - ◊ four modules:
        1. audio technology
        2. video systems
        3. speech communication systems
        4. written communication systems
    - ◊ human physiology of communication senses:
        - sound (hearing, ear)
        - vision (sight, eye)
        - speech (articulatory mechanism)
        - writing
    - ◊ key inventors & business people
        - who really invented what
        - radio = Edison & Hertz
        - telephone = Bell & Elisha Gray
        - Marconi did first trans-Atlantic radio telegraph
        - people motivation:
            . knowledge -- Nikola Tesla
            . wealth -- Lee de Forest & Guglielmo Marconi
            . power -- David Sarnoff
            . credit -- Howard Armstrong
    - ◊ basic principles are emphasized

I. AUDIO TECHNOLOGY

Lecture 2 SOUND

- sound waves:
  - ◊ what is sound?
    - air particles moving against each other
    - travels as series of increases (compressions) & decreases (rarefractions)
  - ◊ needs medium for transmission:
    - travels through air at 1,133 ft/sec at 0° C (345 m/s)
  - ◊ radiate spherically -- like water waves -- decreasing in intensity with distance
  - ◊ DEMO:
    - “Slinky” toy -- wave motion (longitudinal)
    - rope -- reflections (transverse)
    - radio waves are transverse (perpendicular to direction of travel)
  - ◊ wavelength -- distance between crests in wave
  - ◊ frequency:
    - one full cycle between crests
    - frequency = number of cycles per second
- propagation effects:
  - ◊ diffraction:
    - bending around objects
    - depends on wavelength of sound -- frequency dependent
  - ◊ refraction:
    - air temperature affects speed
    - speed increases with air temperature
    - causes sound waves to bend as they travel
  - ◊ reflection
- musical acoustics:
  - ◊ octave = doubling in frequency
  - ◊ harmonic:
    - integer multiple of fundamental
    - in music, known as partials
  - ◊ musical instruments
- architectural acoustics

Lecture 3 & THE PHYSIOLOGY OF HUMAN HEARING & THE PHONOGRAPH

- three parts of ear:
  - ◊ outer ear:
    - external ear > ear canal > ear drum
    - forms resonant chamber @ about 3,000 Hertz
    - directionality shaped by external ear (pinna)
  - ◊ middle ear:
    - hammer (malleus) > anvil (incus) > stirrup (stapes)
    - oval window and fluid of cochlear are very stiff
    - in a cavity in skull -- pressure equalized by eustachian tubes
  - ◊ inner ear:
    - the cochlea -- size of tip of small finger -- 2 1/2 turns -- snail like
    - input is oval window -- pressure relieved by round window at end
    - basilar membrane -- hair cells -- spatial filter
    - basal end responds to higher frequencies
    - basilar membrane and tectorial membrane connected by organ of Corti
- neural signals:
  - ◊ auditory nerve to brain
  - ◊ 30,000 neurons
  - ◊ neuron:
    - axon = length
    - dendrites = nerve endings (tentacle like) at each end
    - touch at synapses (junctions)
    - terminal arbor of dendrites
  - ◊ cells:
    - receptor cells initiate signals (as in organ of Corti)
    - effector cells respond (as in muscles)
  - ◊ activity:
    - threshold before nerve impulse is generated (fires)
    - size of impulse is not important -- rate is -- on/off analogy
- the phonograph:
  - ◊ Thomas Alva Edison (“wizard of Menlo Park”)
  - ◊ invented device for recording telegraph signals as indentation in paper
  - ◊ 1877 invention:
    - tinfoil cylinder
    - stylus up & down indentations
    - patent granted February 19, 1878
  - ◊ phonautograph invented by Leo Scott in 1856:
    - tracing of sound wave left along blackened cylinder
  - ◊ Edison saw phonograph as a tool for education & business dictation
- enhancements:
  - ◊ graphaphone -- waxed paper cylinder -- invented 1885
  - ◊ disc -- invented 1887 by German-born American Emile Berliner
  - ◊ magnetic tape recording -- invented 1927 by German Fritz Pfleumer
  - ◊ long-playing (LP) record at 33 1/3 rpm -- invented 1948 by Peter Goldmark
  - ◊ stereophonic disc -- 1958
  - ◊ digital compact disc (CD) -- 1982

THOMAS ALVA EDISON

- born February 11, 1847 in Milan, Ohio
- died October 18, 1931 at home in Llewellyan, NJ
- started working as telegrapher for Western Union in 1862
- 1868--
    - ◊ working at Western Union office in Boston
    - ◊ invented way to transmit both ways on single wire
    - ◊ applied for his first patent on vote recording device
    - ◊ invented stock ticker
- 1870--
    - ◊ moved to Newark, NJ -- founded Newark Telegraph
    - ◊ working on printing telegraph, multiplexing, manufacturing
- Menlo Park, NJ research lab
    - ◊ started in 1875 as “invention factory”
    - ◊ 1877 invented carbon transmitter for telephone
    - ◊ 1879 invented carbonized thread for high-resistance light bulb
- 1882 -- Pearl Street power plant in NYC
- developed corporate empire to commercialize electricity
- 1889 -- Edison companies merged to form Edison General Electric Company (GE today)
- 1891 -- applied for patent on peep-show viewer of movies
- constructed first motion picture studio at West Orange, NJ lab
- added sound to motion pictures
- observed etheric force -- radio

Lecture 4 SIGNALS

- definition:
  "A signal is an event that changes with time and can be used to convey information as a means to facilitate communication."
- representation:
  (1) time domain
    - shows shape of signal (waveform) as function of time
  (2) frequency domain
    - shows frequency components that comprise signal
- waveforms:
  ◊ x-axis -- time (abscissa)
  ◊ y-axis -- instantaneous amplitude (ordinate)
  ◊ shape is called "waveshape" or "waveform"
  ◊ types:
    - periodic--
      . square wave
      . triangular wave
      . sawtooth wave
      . pulse train
    - aperiodic -- noise, impulse
- periodicity:
  ◊ basic shape that keeps repeating itself
  ◊ period = length in time of shortest basic shape
  ◊ 1 period = 1 full cycle
  ◊ frequency = rate at which it repeats (cycles/sec = Hertz)
  ◊ wavelength:
    - $\lambda = v/F$
    - velocity of light = 186,000 miles/sec (3×10^8 meter/sec)
- engineering notation:

	NUMBER	ABBREVIATION
BIG	$1,000,000,000,000 = 10^{12}$	tera (T)
	$1,000,000,000 = 10^9$	giga (G)
	$1,000,000 = 10^6$	mega (M)
	$1,000 = 10^3$	kilo (k)
	$1 = 10^0$	
SMALL	$0.001 = 10^{-3}$	milli (m)
	$0.000001 = 10^{-6}$	micro (μ)
	$0.000000001 = 10^{-9}$	nano (n)
	$0.000000000001 = 10^{-12}$	pico (p)

- the sine wave:
    - ◊ pure tone
    - ◊ properties:
        - maximum amplitude -- positive & negative polarity
        - period or frequency
        - phase (where it starts)
- Fourier analysis:
    - ◊ French physicist Jean Baptiste Joseph Fourier
    - ◊ any periodic waveform can be represented as finite sum of sine waves
    - ◊ any waveform can be decomposed into sum of infinite number of sine waves
- spectrum -- called the frequency domain
- bandwidth:
    - ◊ finite (or near finite) range of frequencies
    - ◊ width of range = bandwidth
    - ◊ signal & channel bandwidth
    - ◊ bandwidth examples:

SIGNAL/CHANNEL	BANDWIDTH
telephone speech	4 kHz
AM radio station	10 kHz
hi-fi amplifier	20 kHz
FM radio station	200 kHz
AM radio band	1.2 MHz
TV channel	6 MHz
FM radio band	20 MHz

- filters:
    - ◊ shape frequency spectrum of signal or channel
    - ◊ types:
        - high pass (HPF)
        - low pass (LPF)
        - band pass (BPF)
        - band stop
        - equalizers
- spectrogram

Lecture 5 ELECTRICITY

- electricity = flow of electrons
    - ◊ electrons = negatively-charged particles
    - ◊ need medium to conduct flow (copper wire usually)
    - ◊ conductor -- insulator -- semiconductor
- electric circuit:
    - ◊ bicycle chain analogy
    - ◊ marbles in pipe analogy
        - marble moving force
        - marble current = # of marbles per second
        - opposition to flow of marbles
- symbols:
    - ◊ conductor = straight lines
    - ◊ electromotive force (EMF) -- volts (V)
    - ◊ current (I) -- amperes (A)
    - ◊ opposition (R) -- ohms (Ω)
    - ◊ switch -- on/off
- kinds:
    - ◊ direct current (dc)
        - flows in one direction
        - polarity
    - ◊ alternating current (ac)
        - flows to and fro
- Ohm's Law:
    - ◊ I = E/R
    - ◊ E = I x R
- circuits:
    - ◊ series -- voltage divider
    - ◊ parallel -- current divider
- electromagnetism:
    - ◊ flow of electrons generates magnetic field
    - ◊ coil of wire concentrates field -- effects like a magnet
    - ◊ transformer:
        - primary & secondary
        - coupled coils
        - works only with alternating current
        - can change ac voltage
- power distribution:
    - ◊ 110 V @ 60 Hz
    - ◊ hot & ground wires
    - ◊ higher voltages in distribution network -- step-down transformers

NIKOLA TESLA

- born at midnight July 9-10, 1856 in Smiljan, Croatia, Yugoslavia
- died in New York City on January 7, 1943
- 1881 -- invented principle of rotating magnetic fields for ac motor
- 1882:
  - ◊ moved to Paris to work at Continental Edison Company
  - ◊ met Charles (Edison assistant) there & encouraged to work for Edison
- 1884:
  - ◊ Tesla to New York
  - ◊ worked for Edison on shipboard lighting system
  - ◊ Edison not interested in ac motor
- 1886:
  - ◊ Tesla working a common laborer
  - ◊ foreman takes him to president of Western Union
  - ◊ helps Tesla form Tesla Electric Company
  - ◊ starting in 1887, Tesla applies for patents on ac motors
- George Westinghouse obtains rights to Tesla inventions
- other inventions:
  - ◊ fluorescent tubes
  - ◊ electric clock synchronized to an oscillator
  - ◊ high-frequency air-core transformers (Tesla coil)
- 1893:
  - ◊ demo of spark-gap radio system
  - ◊ used tuned transmission and reception
  - ◊ applied for patent in 1897
  - ◊ US Supreme Court in 1943 ruled for Tesla over Marconi
- 1904 article visioned radio as broadcast medium for “enlightening the masses”
- reference: Margaret Cheney *Tesla: Man Out of Time* (1981)

- root mean square (rms):
  - ◊ measure of effective (work) value of ac
  - ◊ for a sine wave -- rms = peak/(square root of 2) = 0.707 x peak
  - ◊ 110 V is rms value
- power:
  - ◊ measure of work --useful energy expenditure
  - ◊ P = E x I in watts
- amplification
- transducers
  - ◊ loudspeakers
  - ◊ microphones
- frequency-dependent effects:
  - ◊ resistance does not depend on frequency
  - ◊ reactance depends on frequency:
    - - capacitive reactance -- decreases with frequency
    - - inductive reactance -- increases with frequency
  - ◊ used to create filters:
    - - capacitor blocks dc and low frequencies
    - - inductor passes dc but blocks high frequencies
  - ◊ impedance = measure of combined effect of resistance and reactance

LECTURE 5 (cont'd) ELECTRONICS

- electronics deal with the control of electricity for useful purposes
- transducers:
    - ◊ electric <> modality conversion
    - ◊ phonograph cartridge
    - ◊ loudspeakers:
        - - woofer
        - - tweeter
        - - stereo (left & right channels)
    - ◊ microphones:
        - - electromagnetic
        - - piezoelectric
        - - electret (electrostatic charge)
- ac to dc:
    - ◊ vacuum tube diode:
        - - invented by Britisher John Ambrose Fleming in 1904
        - - two electrodes-
            - . cathode (heated to emit electrons)
            - . anode (made positive to attract)
            - . heater heats cathode
        - - "Edison effect" = current flowing in a vacuum
    - ◊ diodes used for rectifiers (ac to dc conversion)
- amplification:
    - ◊ vacuum tube triode -- invented by Lee de Forest in 1906:
        - - three electrodes-
            - . cathode
            - . anode
            - . grid (controls flow) also called screen
            - . heater
        - - makes small ac signal voltage very large

LEE DE FOREST

- born August 26, 1873 -- died June 30, 1961 -- penniless
- motivated by search for financial wealth
- stole other people's ideas
- married three times -- a womanizer
- shady deals

    - ◊ transistors:
        - - invented at Bell Labs in 1947 -
            - . John Bardeen, William Shockley, & Walter H. Brattain
        - - semiconductors
        - - types: point contact, junction, & field effect (MOSFET)
    - ◊ integrated circuits:
        - - chips
        - - dual in-line package (DIP)
        - - very large scale integration (VLSI)

- decibels:
  - ◊ logarithmic response of human perception to physical stimuli
  - ◊ definition:
    $db = 10 \log (P_1 / P_2)$
  - ◊ review logarithms
  - ◊ note: 0 db means what is measured is same as reference
  - ◊ also used to measure sound pressure levels -- table:

SOUND PRESSURE LEVELS		
DECIBELS	SOUND	INTENSITY in watts per square meter
130	initial pain	10
120	amplified rock music	1
110	initial discomfort	10^{-1}
90	NYC subway train	10^{-3}
70	speech @ 1 ft.	10^{-5}
50	average home	10^{-7}
30	quiet whisper	10^{-9}
0	threshold of hearing	10^{-12}

  - ◊ loudness control on hi-fi
  - ◊ 3 db = doubling in power
- corruption of signals:
  - ◊ noise:
    - hum
    - buzz
    - clicks & pops
    - white noise
  - ◊ distortion
- magnetic tape recording:
  - ◊ patented in 1928 by German Fritz Pfleumer
  - ◊ principles:
    - tape with ferrous coating
    - record/playback head
    - high-frequency bias sine wave added to signal to overcome non-linearities

LECTURE 6 DIGITAL SIGNALS

- intro:
  - ◊ draw waveform & ask all to copy
  - ◊ now make table of numbers & ask all to copy
  - ◊ digits (digital) are more powerful than actual waveform (analog)
- sampling (Harry Nyquist):
  - ◊ sampling rate = 2 x maximum frequency
  - ◊ under sampling & aliasing:
    - - anti-aliasing filter (LPF at 1/2 sampling frequency)
- analog to digital conversion:
  1. anti-alias filter
  2. sample
  3. quantize
  4. encode as binary
- quantization:
  - ◊ number of levels = 2^n
  - ◊ n = number of bits in encoding
  - ◊ 256 levels -- 8 bits (telephone circuit)
  - ◊ 65,536 levels -- 16 bits (CD)
- bandwidth ≈ bit rate ÷ 2
- noise immunity:
  - ◊ threshold decision
  - ◊ regenerative repeaters
- compact disc:
  - ◊ 4.75 inches in diameter
  - ◊ read by laser
  - ◊ laser light:
    - - monochromatic (single frequency)
    - - coherent (in phase)
    - - collimated (parallel rays)
  - ◊ 200-500 rpm -- inside to outside
  - ◊ beam focused through disc
  - ◊ depth of pit = 1/4 wavelength -- reflection cancels
  - ◊ 1.4 Mbps data rate + error correction = 4.32 Mbps
  - ◊ CD-ROM technology

***** EXAM #1 *****

II. VIDEO SYSTEMS

Lecture 7 HUMAN VISION

- human eye:
  - ◊ about 1 inch in diameter -- spherical shaped
  - ◊ filled with semi-viscous, jelly-like fluid -- vitreous humor
  - ◊ physical structure:
    - **sclera** = outer white material gives shape
    - **cornea** = transparent section at front
    - eyelid = sweeps away dirt
    - lacrimal glands = tears to lubricate and wash
    - conjunctiva = transparent membrane protecting eye and cavity
    - choroid
      - . supplies blood
      - . black to prevent reflection
  - ◊ optical mechanism:
    - spherical **lens** focuses light passing through cornea
    - muscles control shape of lens and its focusing (called accommodation)
    - iris controls amount of light
      - . pigment of iris gives color of the eye
      - . opening in iris is called the **pupil**
    - focused at rear onto retina
  - ◊ light conversion:
    - occurs at **retina**
    - rods and cones
    - **fovea**
      - . central area
      - . cones only which respond to primary colors
    - rods are at periphery for dim light and night vision
    - neural pulses are created in response to light
      - . optic nerve = one million ganglion cells
      - . blind spot -- off-center area
  - ◊ camera analogy:
    - sclera = camera body
    - eyelid = camera shutter
    - iris = camera aperture
    - lens = camera lens
    - retina = film
- psychophysics of human vision:
  - ◊ resolution:
    - 2 minutes of arc (1/30th of a degree)
  - ◊ motion:
    - continuous at >20 pictures per second
    - flicker fusion at >40/sec at fovea
    - peripheral fusion at a faster rate
  - ◊ movies:
    - 24 frames/sec
    - shutter rate at 48 flashes/sec

◊ stereoscopic:
- two eyes = two different images
- also perspectives and motion clues (monocular depth)

◊ resolution depends on color:
- most resolution for black/white brightness changes
- cyan and orange intermediately
- lowest resolution for large areas of color

• color theory:

◊ light spectrum:
- 7.4 X 10^{14} Hz = violet
- 4.3 x 10^{14} Hz = red

◊ additive tristimulus theory:
- red + green + blue = primary colors

◊color wheel arrangement
- color = hue = angle on wheel
- pastel = saturation = radius distance (center = white)
- complementary colors are opposite each other-
  . red >>> cyan
  . blue >>> yellow
  . green >>> magenta
- brightness = light energy
- all arranged = cone

◊ terminology:
- hue + saturation = chrominance
- brightness = luminance

◊ physical/psychophysical:
- dominant wavelength >>> hue
- purity >>> saturation
- luminous flux >>> brightness

MOTION PICTURES

- Eadweard Muybridge:
  - Leland Stanford bet regarding horse's hooves while running
  - string-tripped cameras -- June 19, 1878
  - shows results to Edison in February, 1888
- Thomas Alva Edison:
  - caveat dated October 17, 1888
  - kinetoscope viewer & kinetograph camera
  - August 24, 1891 patent application
  - long strip of film:
    - . George Eastman's Eastman Company manufactured film
    - . 70 mm wide split to create 35 mm width
    - . sprocket holes at sides to control motion
  - early film = "The Sneeze"
  - April 14, 1894 first peep showparlor opened in NYC
- Louis and Auguste Lumiére:
  - invented triangular eccentric device to pull-down film
  - kept image stationary when projected
  - first movie projector constructed in 1894 in Lyons, France
    - . patent issued February 13, 1895
    - . December 28, 1895 -- first movie theater
- Movie history:
  - Edwin S. Porter:
    - . telling a story by movie
    - . "The Great Train Robbery" -- 1903
  - first movie theater in U.S. opened in June 1905
    - . charged 5¢, thus called "Nickelodeon"
  - to Southern California in search of good light in 1908

Lecture 8 TELEVISION BASICS

- early television;
  - ◊ light into electricity:
    - selenium resistance varied when exposed to light
    - observed Joseph May in Ireland in 1872
    - Willoughby Smith conducts experiments on photoconductivity
  - ◊ scanning:
    - Paul Nipkow
    - disk with concentric holes
    - invented 1883 and patented 1884
  - ◊ cathode ray tube:
    - cold CRT invented in 1906 by Max Diekman
  - ◊ early TV:
    - Boris Rosing applied for patent in 1907
      - . cold CRT
      - . mechanical scanner
    - student Vladimir Zworykin came to U.S. to pursue ideas
    - Philo T. Farnsworth
    - Charles Francis Jenkins
    - John Logie Baird (in London)
    - electronic standards adopted 1941 for U.S.
      - . National Television Standards Committee (NTSC)
    - allocation of 13 channels -- 1945
    - by 1953, 50% penetration!

VLADIMIR KOSMA ZWORYKIN

- born 1889 in Russia
- graduated from St. Petersburg Technological Institute in 1912
- emigrated to U.S. in 1919 in disgust of Russian revolution of 1917
- worked at Westinghouse Research Laboratory in Pittsburgh
- December 29, 1923 patent application for all-electronic TV system
- work then supported by David Sarnoff of RCA
- invented Iconoscope tube in 1931 as result of seeing Farnsworth's work

PHILO T. FARNSWORTH

- born 1907
- went to California from Utah
- invented Image Dissector tube in 1927

- scanning:
  - ◊ Nipkow disk:
    - invented 1883 by Paul Nipkow
    - one at transmitter and at receiver
  - ◊ two-dimensional image >>> series of scan lines = serial signal
  - ◊ electronic scanning:
    - camera
    - cathode ray tube

- ◊ scan lines:
  - - vertical retrace & blanking (VBI)
  - - horizontal retrace & blanking
- synchronization:
  - ◊ receiver with camera
  - ◊ synch pulses
- specifications:
  - ◊ scan lines:
    - - 525
    - - 483 usable
    - - chosen to match resolution of human eye
    - - viewing distance ≥ 4 times height of screen
  - ◊ aspect ratio = 4 wide to 3 high
  - ◊ rate:
    - - 30 frames/sec
    - - 60 fields/sec
    - - interlacing
  - ◊ horizontal frequency:
    - - 30 x 525 = 15,750 Hz
    - - color uses 15,734.264 Hz

Lecture 9 RADIO

- history:
  - ◊ James Clerk Maxwell:
    - 1864
    - theoretical equations for electromagnetic waves
  - ◊ Thomas Alva Edison:
    - 1875
    - “etheric force” observed
  - ◊ Heinrich Rudolf Hertz:
    - 1887
    - radio waves observed
  - ◊ Nikola Tesla:
    - 1893 -- tuned spark-gap transmitter & receiver
    - 1904 -- envisioned radio broadcasting as mass medium
  - ◊ Guglielmo Marconi:
    - born in Italy in 1874
    - mother took him to England in 1896 to pursue radio
    - discovered grounded antenna and ground wave
    - in 1899 to U.S.
    - America’s Cup race in NY harbor
    - 1901 transmitted radio telegraph signal across Atlantic
  - ◊ radio on ships:
    - 1907 *Titanic* disaster
    - Radio Act of 1912
  - ◊ tuned radio:
    - Sir Oliver Lodge in 1894 discovered coherer
    - H. H. Dunwoody & G. W. Pickard
      - . quartz crystal detector
      - . “cat’s whisker”
  - ◊ detection:
    - J. Ambrose Fleming:
      - . University College London
      - . invented vacuum tube diode in 1904
  - ◊ continuous waves:
    - Reginald Aubrey Fessenden
      - . EE prof at Purdue University
      - . GE support
      - . made alternator to generate radio waves
    - GE used Fessenden alternator to transmit human voice
      - . 1906
      - . first voice transmission
  - ◊ Radio Corporation of America (RCA):
    - 1919 formed by GE, Westinghouse, & AT&T
  - ◊ broadcast radio:
    - 1920
      - . Frank Conrad
      - . Westinghouse employee
      - . Pittsburgh
    - 1932 -- 60% penetration of radio receivers

- radio waves:
    - ◊ magnetic field created by electric current flowing
    - ◊ electrostatic field created by flow of electricity
    - ◊ combined effects = electromagnetic field
    - ◊ travels through space:
    - ◊ transverse wave
    - ◊ frequencies:
        - 500 kHz commercial AM band
        - 30 GHz for satellites

Lecture 10 MODULATION THEORY

- frequency shifting:
    - ◊ frequency-division multiplexing (FDM)
    - ◊ baseband signal shifted to a new range
    - ◊ accomplished by:
        - amplitude modulation
        - frequency modulation
- amplitude modulation (AM):
    - ◊ sine wave carries signal to a new range of frequencies
    - ◊ sine wave is called the carrier
    - ◊ envelope of modulated carrier
    - ◊ modulation steps:
        - add dc to signal
        - multiply signal by carrier
        - amplify and apply to antenna
    - ◊ demodulation steps:
        - discard negative portion
        - track envelope through LPF
    - ◊ spectrum effects:
        - sidebands
        - bandwidth = 2B
        - transmissions
            - . double sideband (DSB)
            - . suppressed carrier (SC)
            - . single sideband (SSB)
            - . vestigial AM
- frequency modulation (FM):
    - ◊ invented in 1930s by Major Howard Armstrong
    - ◊ wideband FM achieves noise immunity
    - ◊ FM stereo:
        - L + R = mono sum signal
        - L - R = stereo difference signal
        - L - R SC modulates a 38 kHz subcarrier
- quadrature modulation:
    - ◊ phase and amplitude modulation

EDWIN HOWARD ARMSTRONG

- born December 18, 1890 in NYC
- graduated Columbia University in 1913
- 1912 discovered regenerative feedback for high-frequencies
- World War I:
    - ◊ went to Europe in 1917 as Captain in Signal Corps in U.S. Army
    - ◊ promoted to Major in 1919
    - ◊ invented superheterodyne circuit while in Paris in 1918
- 1921 invented superregenerative circuit
- 1933 patents issued to him for wideband FM
- 1945 -- FCC moved FM band to where it is today
- battled with David Sarnoff over patent royalties
- January 31, 1954 committed suicide

DAVID R. SARNOFF

- born in Russia on February 27, 1891
- emigrated to NYC in 1900
- 1919 became commercial manager of newly formed RCA
- EVP of RCA at age 31
- created NBC
- 1947 became Chairman of the Board
- financed Zworykin and early TV
- bet future of RCA on color TV
- died on December 12, 1971

Lecture 11 BROADCAST TELEVISION

- television channel:
  - ◊ bandwidth = 6 MHz
    - TV signal upper sideband = 4.5 MHz
    - lower vestigial sideband = 1.25 MHz
  - ◊ audio sent as FM of carrier 4.5 MHz above video carrier
- VHF/UHF broadcast television:
  - ◊ VHF band:
    - channels 2-4: 54-72 MHz
    - channels 5 & 6: 76-88 MHz
    - channels 7-13: 174-216 MHz
  - ◊ UHF band:
    starts at 216 MHz and every 6 MHz after
- cable television (CATV):
  - ◊ 1949:
    - L. E. Parsons in Astoria, Oregon
    - coaxial cable distribution
  - ◊ 1950:
    - Robert J. Tarlton in Lansford, PA
    - pull-in Philadelphia stations
  - ◊ acronym:
    - CATV = community antenna TV
    - CATV = coaxial cable TV
  - ◊ purposes:
    - distant stations
    - better picture in big cities
    - more channels
  - ◊ programming from:
    - rebroadcast of VHF/UHF local stations
    - newer satellite networks
    - local origination
  - ◊ penetration in U.S.:
    - 95% TV/HH
    - about 2/3 subscribe
- satellite TV:
  - ◊ direct broadcast satellite TV (DBS)
    - DirectTV & others
  - ◊ satellite master antenna TV (SMATV)
  - ◊ low-power TV (LPTV)
  - ◊ large dish antennas
  - ◊ multichannel multipoint distribution service (MMDS) microwave

Lecture 11 (cont'd) COLOR TELEVISION

- history:
  - ◊ 1950:
    - FCC approval
    - CBS field-sequential system
    - rotating transparent color wheel
    - one primary color per field
    - three fields = complete image
    - incompatible with NTSC older monochrome system
  - ◊ December 1953:
    - FCC reversal
    - new color NTSC system adopted
    - backwards compatible with monochrome
  - ◊ international standards:
    - French *séquentiel couleur avec mémoire* (SECAM) system
    - German & British *phase alternation line* (PAL) system
- the challenge:
  - ◊ backwards compatibility
  - ◊ high quality
- time domain:
  - ◊ camera creates three primary signals
    - red
    - green
    - blue
  - ◊ luminance signal created as Y = 0.30R + 0.59G + 0.11B
    - Y is sent in full 4.2 MHz bandwidth
  - ◊ color difference signals calculated: (R - Y) & (B - Y)
    - then I & Q calculated
    - I given 1.5 MHz
    - Q given only 0.5 MHz
  - ◊ chrominance signal created:
    - phase = hue
    - amplitude = saturation (0 = no color)
    - sent along with Y but in less bandwidth
  - ◊ chrominance quadrature modulates subcarrier and is added to luminance signal
  - ◊ color burst as phase reference on back porch of blanking signal
- frequency domain:
  - ◊ 1934 paper by Pierre Mertz and Frank Gray of Bell Labs
  - ◊ frequency spectrum of TV looks like teeth of a comb
  - ◊ harmonic multiples of scanning frequency
  - ◊ standards:
    - frequency of color subcarrier = 3.579545 MHz exactly
    - 15,734.264 horizontal scan lines/sec
    - 525 lines
    - 59.94 Hz field rate
- TV receivers:
  - ◊ color picture tube:
    - three guns
    - shadow mask
    - pixels of color dots

Lecture 12 VIDEO MEDIA

- video recording:
  - ◊ magnetic recording:
    - base material
    - ferrous oxide coating
    - record/playback head
  - ◊ the challenge:
    - number of octaves to be recorded
    - speed of head to record bandwidth
    - writing speed ≈ 1 meter/sec
    - amount of tape
  - ◊ video tape recorder:
    - 1956 Ampex engineers
    - quadraplex recorder (4 heads)
    - spinning head across width of 2-inch tape at 15 ips
  - ◊ video cassette recorder:
    - helical scanning
    - JVC in early 1960s
    - initially 1-inch tape
    - now 1/2-inch tape for home
    - Sony Betamax failed -- VHS succeeded
    - technique:
      - . luminance signal is bias for chrominance
  - ◊ camcorder:
    - RCA and Matsushita in 1980
    - use 8 mm tape
- video disk:
  - ◊ RCA:
    - mechanical 12-inch disk
    - began 1964
    - introduced in 1981 and withdrew in 1984 as flop
  - ◊ laser disk:
    - Phillips innovation
    - still around today as 12-inch format
  - ◊ digital video disk (DVD):
    - smaller disk size of CD
    - digital TV compressed
  - ◊ dis**k** vs dis**c**
- HDTV (high-definition television):
  - ◊ 1000 scan lines
  - ◊ 16:9 aspect ratio
- digital TV:
  - ◊ HDTV quality:
    - 1080 scan lines
    - 1920 pixels/line
    - 16 bits/pixel
    - 1 Gbps — BW ≈ 500 MHz
    - ??? how to transmit the tremendous bandwidth

◊ home quality:
- 115 Mbps
- lowest is 84 Mbps — BW ≈ 40 MHz
- ??? still requires much bandwidth to transmit
- solution is compression using processing

• compression:
◊ MPEG (Moving Pictures Experts Group)
◊ home quality compressed:
- 4 Mbps MPEG
- intra and inter frame compression
◊ digital TV broadcasting:
- an additional 6 MHz channel to broadcasters
- HDTV
- multicasting of 4 normal digital programs
◊ compression is compromise with quality:
- artifacts
- loss of resolution

• future of television

***** EXAM #2 *****

III. SPEECH COMMUNICATION SYSTEMS

INTRODUCTION

- telegraph required knowledge of Morse code
- Bell realized that speech was most natural form of communication—not Morse code
- telephone system:
    - ◊ instrument
    - ◊ transmission media
    - ◊ switching systems
    - ◊ signaling control

Lecture 13 HUMAN SPEECH

- speech production:
    - ◊ trumpet analogy:
        - player's lips >>> vocal cords vibrate
        - metal pipe >>> vocal tract of mouth/tongue
        - bell >>> lips
    - ◊ steady stream of air:
        - lungs
        - trachea
        - larynx (wind pipe)
        - also esophagus (food pipe) -- larynx closed by epiglottis
    - ◊ vocal cords:
        - two lips of ligament and muscle
        - opening = glottis
        - mass, length, tension determine pitch of vibration
    - ◊ vocal tract:
        - cavity of mouth
        - jaw and tongue determine shape (articulators)
        - cavity resonates in response to puffs of air
        - soft palate opens for nasals
    - ◊ speech types:
        - voiced
            - . vowels
            - . nasals
        - unvoiced (voiceless)
            - . plosives [p] [k]
            - . fricatives [s] [sh]
            - . whispered speech
    - ◊ spectrum:
        - voiced -- resonances (formats)
        - unvoiced -- noise & sudden plosives
- mechanical speaking machines:
    - ◊ 1779:
        - Christian Gottlieb Kratzenstein
        - won prize offered by Imperial Academy of St. Petersburg
        - mechanical speaking machine

◊ 1769: Wolfgang von Kempelen's earlier machine
◊ Bell influence:
- von Kempelen machine copied by Wheatstone
- Wheatstone machine seen by A. G. Bell and his brother

• vocoders:
◊ Voder: Bell Labs demo at 1939 World's fair in New York
◊ pitch detection
◊ parameters to specify filter
◊ usually digital filters
◊ linear predictive coding (LPC) -- B. S. Atal of Bell Labs in 1960s

• speech processing:
◊ HAL in 1968 Stanley Kubrick movie *2001: A Space Odyssey*
◊ automatic speech recognition:
- speech >>> text
- voice typewriter
- spoken digits
- context problems [meat] vs [meet]
◊ automatic speech production:
- text >>> speech
- "Speak & Spell" toy
- Mac computer demo
◊ speaker identification
◊ speaker authentication

Lecture 14 THE TELEPHONE

- beginnings:
    - ◊ early growth:
        - 1876 -- 3,000 telephones in U.S.
        - 1900 -- 1,356,000 telephones in U.S.
    - ◊ early invention:
        - tuned forks -- like music box -- on-off signals
        - 1876 Alexander Graham Bell invention
        - but also Elisha Gray
    - ◊ early telephone transmitters:
        - Bell's variable resistance liquid transmitter
        - Edison's carbon granules in 1886
        - Thomas Watson—ringer
    - ◊ 1881 -- John J. Carty -- twisted pair of wires
    - ◊ automated switching:
        - 1892
        - Almon B. Strowger
- telephone: (known as "station apparatus")
    - ◊ major components:
        - transmitter (microphone)
        - receiver
        - switch-hook
        - ringer
        - dialer
        - anti-sidetone circuit (2-4 wire conversion)
    - ◊ sidetone = hearing one's own speech
        - electrical leakage
        - reduced
        - some gives liveliness
    - ◊ switchhook:
        - flow of dc
        - 48 volts from central offfice
    - ◊ dialers:
        - dial pulse at 10 pulses/sec
        - touchtone
            - . introduced 1963
            - . two tones simultaneously

ALEXANDER GRAHAM BELL

- born March 3, 1847 in Scotland
- father (Alexander Melville Bell) was teacher of elocution
- A. G. Bell known as “Aleck”
- 1863:
    - ◊ Aleck met Charles Wheatstone
    - ◊ saw speaking machine
    - ◊ Aleck and brother attempt their copy
- 1870—father Melville takes wife and Aleck to Ontario, Canada
- Aleck goes to Boston to teach deaf on his own
- 1873—student is Mabel Hubbard
    - ◊ daughter of Bell backer
    - ◊ Bell marries her in 1877
- harmonic telegraph craze attracts Bell
- Bell using phonautograph to trace speech signals to help teach deaf students
- February 14, 1876:
    - ◊ patent application filed by Bell’s attorney in DC
    - ◊ caveat filed by Elisha Gray
- March 10, 1876:
    - ◊ Bell produces working model of telephone
    - ◊ uses liquid transmitter
- other work:
    - ◊ 1880—photophone using light
    - ◊ 1907—tetrahedral kites and other structures
    - ◊ invented hydrofoil
    - ◊ invented iron lung
- died August 2, 1922 in Nova Scotia
- though wealthy and financially secure—no family dynasty in telephone

ELISHA GRAY

- born August 1835 in Ohio
- Gray and Enos Barton founded Western Electric Company in 1872
- experimenting with sound over telegraph wires as early as 1867
- observed “undulatory currents” in 1874
- Phillip Reis (German) first used term “telephon”
- in 1874, term “telephone” used by Elisha Gray
- Gray invented teleautograph machine
- died January 21, 1901 in drowning accident

Lecture 15 NETWORKS

- a "network of networks:"
    - ◊ local access & transport area (LATA)
    - ◊ inter-LATA
        - long distance -- toll calls
        - inter exchange
        - IXC (inter exchange carrier)
    - ◊ intra-LATA
        - local exchange
        - LEC (local exchange carrier)
    - ◊ public switched telephone network (PSTN)
    - ◊ data networks
- local networks:
    - ◊ telephone >>> modular plug >>> telephone jack
    - ◊ intrapremises wiring >>> protector block
    - ◊ drop >>> connector >>> pole
    - ◊ local loop -- twisted pair of copper wire
    - ◊ cables >>> cross connects
    - ◊ central office:
        - cable vault
        - risers (vertical)
        - distribution frame
        - protector frame
        - switching machine
        - trunks
        - battery backup (48 volts)
- long-distance networks:
    - ◊ point-of-presence (POP)
    - ◊ bypass (competitive access provider) CAP
    - ◊ aspects:
        - transport of traffic
        - control
            - . signaling
            - . SS7
            - . common channel interoffice signaling (CCIS)
- traffic:
    - ◊ 1.6 billion calls/day (1995)
    - ◊ AT&T 230 million calls/day (1998)
    - ◊ busiest days:
        - Mother's Day
        - Christmas Day
        - Father's Day

Lecture 16 TRANSMISSION TECHNOLOGIES

- multiplexing:
  - ◊ frequency division multiplexing (FDM):
    - unique band of frequencies per signal
    - frequency shifting of baseband signal
  - ◊ time division multiplexing (TDM):
    - unique time slot for each signal
    - T1
      - . introduced in 1962
      - . used twisted pair with regenerative repeaters every mile
      - . 24 digitized signals combined = DS-1
      - . overall rate = 1.544 Mbps
    - many DS signals multiplexed at higher rates
  - ◊ space division multiplexing:
    - twisted pairs in a cable
- copper wire media:
  - ◊ twisted pair:
    - 110-2700 pairs in a cable
    - loading coils used to boast signal on long loops
  - ◊ coaxial cable:
    - bandwidth = 1 GHz
    - first used in 1946 across continent (L1 system)
- terrestrial microwave radio:
  - ◊ microwaves:
    - f = 3 GHz
  - ◊ antenna towers every 26 miles across continent
  - ◊ first system in 1950
  - ◊ last systems in 1980s
- communication satellites:
  - ◊ circular geostationary orbit @ 22,300 miles above equator
  - ◊ radio communication:
    - uplink -- earth to sattelite
    - downlink -- satellite to earth
  - ◊ bands:
    - C band -- @ 4 GHz & 6 GHz
    - Ku band -- @ 12 GHz & 14 GHz
  - ◊ delay problem:
    - 270 ms to travel up and down from satellite
    - 540 ms round trip delay
    - bad for speech & disaster for computer
- optical fiber
  - ◊ invention:
    - mirrored light pipes patented in 1881 by William Wheeler
    - thin glass fibers described in 1887 by Charles Vernon Boys
  - ◊ principles:
    - Snell's law:
      - . light passing through boundary
      - . different indices of refraction
      - . light rays bent

- types:
    - . multi-mode -- stepped & graded index
    - . single mode (5 micrometer diameter)

◊ fiber system:
- source is solid-state laser
- detector is a photo-diode

◊ laser light:
- monochromatic (single frequency)
- coherent (in phase)
- collimated (parallel rays)

◊ capacities:
- single frequency theoretical = 200 Gbps
- wave-division multiplexing
    - . entire light spectrum = 50,000 Gbps (50 Tbps)
    - . could be as much as 300,000 GHz (300 Tbps) = entire light spectrum

◊ erbium doped fiber amplifiers

◊ synchronous optical network (SONET)
- rings
- OC-1 signal = 51.84 Mbps

• undersea cable:

◊ TAT-1:
- completed 1958
- amplifiers every 44 statute miles
- two coaxials in cable
- 36 two-way voice circuits
- TASI (time-assignment speech interpolation) = 72

◊ TAT-8:
- 1988 service date
- optical fiber -- 3 pairs in cable (2 in service)
- repeaters every 41 statute miles
- 40,000 two-way voice circuits

◊ TAT-12/13:
- installed 1996
- 5 Gbps/pair

◊ TAT-14:
- expected in 2001
- 160 Gbps/pair

◊ Others:
- Global Crossings, Ltd. — Atlantic Crossing 1 — AC-1
    - . 4 fiber pairs
    - . 10 Gbps/pair for total capacity of 40 Gbps
- Global Crossings, Ltd. — AC-2
    - . 2.5 Tbps under Atlantic
    - . wave division multiplexing
    - . planned for 2001

• echo:

◊ two-wire to four-wire problem

◊ echo suppressor
- opened the return path
- no full duplex

◊ echo canceler -- allows full duplex

Lecture 17 SWITCHING SYSTEMS

- switching machines:
  - ◊ aspects of switching:
    - (1) switching network
    - (2) control
  - ◊ technology:
    - electromechanical
    - electronic
  - ◊ switching approaches:
    - space-division (space switch)
    - time-division (time switch)
  - ◊ types:
    - circuit switching
    - packet switching
  - ◊ blocking = denial of service
- space division:
  - ◊ a physical connection
  - ◊ switches:
    - rotary
    - on-off
    - matrix -- connects at crosspoints
  - ◊ stages:
    - (1) concentration
    - (2) distribution
    - (3) expansion
- time division:
  - ◊ digital based
  - ◊ time slots rearranged
  - ◊ time-slot interchange (TSI)
  - ◊ buffer memory
  - ◊ space switch usually used
- specific systems:
  - ◊ Strowger:
    - step-by-step
    - invented by Almon B. Strowger in 1892
    - rotary dial invented by his associates in 1896
    - basic Strowger switch
      - . rotary switch
      - . connects 1 to 100
    - control is distributed in each switch
  - ◊ crossbar:
    - matrix switch
      - . connects 20 to 10
      - . can maintain 10 simultaneous connections
    - control in centralized (common control)
  - ◊ electronic:
    - AT&T No.1 ESS™

◊ digital:
- AT&T No.4 ESS™
- Northern Telecom (Nortel) DMS™ series
- Lucent Technologies 5ESS® series

• ancillary topics [OPTIONAL]:
◊ BORSCHT:
- Battery
- Over-voltage protection
- Ringing
- Supervision of the loop
- Coding and decoding
- Hybrid function (4 wire to 2 wire)
- Testing

◊ traffic:
- A. K. Erlang (Danish mathematician)
- 1 Erlang = 100% occupancy
- CCS = 100 call seconds

Lecture 18 SERVICES

• wireless (cellular):
◊ basic concepts:
- low power
- frequency reuse
- channel hand-offs

◊ systems:
- advanced mobile phone service (AMPS)
. analog
. 30 kHz channels
. 830 two-way radio channels
. operates in 800-900 MHz band
. frequency-division multiple access (FDMA)
- digital AMPS (DAMPS)
. digital
. 3 encoded speech signals per 30-kHz channel
. time division multiple access (TDMA)
- Gropue Spéciale Mobile (GSM)
. Europe at 800-900 MHz band
. 8 digital encoded speech signals per channel
. channel = 200 kHz
. U.S. at 1700-1900 MHz band = PCS
- code-division multiple access (CDMA)
. pattern of bits
. 64 digital speech signals per 1250 kHz channel

• data over local loop:
◊ asymmetric digital subscriber line (ADSL)
- 16 to 640 kbps up-stream
- 1.5 to 6 Mbps down-stream

◊ ISDN (integrated services digital network)

IV. WRITTEN COMMUNICATION SYSTEMS

INTRODUCTION

- cave drawings
- commerce & records
- telegraph >>> today's e-mail >>> written language

Lecture 19 WRITTEN COMMUNICATION

- history of writing:
    - ◊ cuneiform writing & clay tablet:
        - reed stylus
            - . wedge-shaped impressions in clay
            - . wedge = "cuneus" in Latin
            - . thus ... **cuneiform**
        - developed as early as 3500 B.C. by Sumerians
        - deciphered
            - . began by Georg Grotefend in Göttingen, Germany
            - . completed in 1847 by Sir Henry Creswicke Rawlinson
    - ◊ hieroglyphics:
        - used from 3100 B.C. to A.D. 400
        - Rosetta Stone
            - . same text in Greek, demotic, and hieroglyphics
            - . decoded by Frenchman Jean-Francois Champollion in 1823
        - pictograms
            - . entire word (logogram)
            - . phonetic sounds (phonogram)
            - . determinatives (indicate categories of pictograms)
            - . cartouche (royal kings and queens) is a phonetic word
    - ◊ papyrus:
        - Egyptian invention from 3000 B.C.
        - slivers of papyrus plant
- Chinese:
    - ◊ 2000 B.C. to today
    - ◊ stylized pictograms
    - ◊ invented paper around second century A.D.
    - ◊ Japanese adopted Chinese characters -- system called Kanji
- the alphabet:
    - ◊ Phoenicians:
        - around 11th century B.C.
        - 22 letters
        - no vowels
    - ◊ Aramaic >>> Hebrew letters and Arabic
    - ◊ Greeks adopted Phoenician system around 900 B.C.
    - ◊ Romans adopted Greek system around 150 B.C.
    - ◊ Phoenicians >>> Greeks >>> Romans >>> today's alphabet
- printing [OPTIONAL]:
    - ◊ basic idea = movable type
    - ◊ earliest was Chinese (around 11th century)

◊ Johann Gutenberg of Mainz, Germany
- movable/reusable letters cast in metal
- bible in 1450

◊ first daily newspaper:
- *Daily Universal Register* founded 1785 by Englishman John Walter
- became *The Times* in about 1790

◊ evolution:
- spool of paper in 1807
- cylinder and reciprocating bed in 1812
- lithography in 1796
- linotype machine in 1886 by Ottmar Mergenthaler

Lecture 19 (cont'd) THE TELEGRAPH

• signaling over distance:
◊ sound -- drum
◊ smoke signals -- fire
◊ visual:
- arm waving
- flags
- semaphore

• telegraph invention:
◊ earliest:
- Harrison Gray Dyer in 1826
- 8 miles of wire
- dc produced bubbles in chemical liquid

◊ electromagnetism:
- discovered by Hans Christian Oersted in 1820
- Joseph Henry at Princeton built electromagnets
. built electric telegraph in 1831
. electromagnet striking bell as sounder
. but no efficient code

◊ Samuel F. B. Morse:
- 1837 filed caveat in Patent Office
- Morse + Alfred Vail
. Morse code
. 1844 Baltimore-Washington telegraph line

◊ first commercial system:
- Sir William Fotherhill Cooke & Sir Charles Wheatstone
- patented 1837 & installed 1839
- five rotating needles to indicate letters
- used six wires to operate

◊ early commercial use:
- news reporting

• development:
◊ trans-Atlantic cable:
- 1858 completed and failed
- 1866 success!
. financed by Cyrus W. Field
. laid down by ship *Great Eastern*
. took 3 seconds for signal to reach maximum value

. very slow

◊ trans-continental telegraph:
- completed in 1861
- obsoleted the Pony Express
- 200,000 miles of telegraph wire installed by 1865

◊ Jean-Maurice-Émile Baudot:
- six signals on one wire
- invented character code
. fixed five bits/character
. Baudot code
. used in teletypewriter machines to this day

• telegraph's legacy:
◊ harmonic telegraph >>> telephone
◊ wireless telegraphy >>> radio
◊ teletypewriter >>> Telex >>> e-mail of today

• communication theory [OPTIONAL]:
◊ theoretical maximum capacity:
- Harry Nyquist & R. V. L. Hartley of Bell Labs
- measures of information in bits

◊ Claude E. Shannon:
- Bell Labs
- 1948 paper
- "A Mathematical Theory of Information"
- $C = W [\log_2 (1 + S/N)]$ bps

◊ Norbert Wiener:
- prediction theory
- filters and signal detection

SAMUEL FINLEY BREESE MORSE
• born April 27, 1791 in Massachusetts
• died April 2, 1872 in New York City
• studied painting and was accomplished portrait painter
• interested in electricity
• affiliated with University of the City of New York (NYU today)
• got Congress to fund $30,000 for telegraph installation

ALFRED VAIL
• born September 25, 1807 in Morristown, NJ
• died January 18, 1859 in New York City
• Speedwell Iron Works in Morristown
• Prof. Leonard Gale introduced Vail to help Morse on telegraph
• Vail invented telegraph key and code
• contract gave all credit to Morse!

Lecture 20 THE COMPUTER

- history:
  - ◊ abacus:
    - beads on narrow metal rods
    - 500 BC earliest use
  - ◊ slide rule:
    - invented 1630s by Englishman William Oughtred
    - based on addition of logarithms
  - ◊ analog computers:
    - added voltages
    - not programmable
  - ◊ digital computer:
    - Englishman Charles Babbage
      - . built Difference Engine in 1822
      - . conceived Analytic Engine in 1834
    - Boolean algebra
      - . George Boole
      - . paper published in 1847
      - . math of logic & decisions
    - Herman Hollerith (American)
      - . 1880 paper cards
      - . used in 1890 census
      - . company became IBM
    - electromechanical relay machines
      - . MIT 1930
      - . Harvard 1939-1944
      - . Bell Labs 1939
    - general-purpose electronic machines
      - . ENIAC at University of Pennsylvania in 1945
      - . UNIVAC-I in 1951 for census
    - personal computer
      - . Altair in 1975
      - . Apple I in 1976
      - . Apple Macintosh in 1984
- computer system:
  - ◊ definition:

    "A computer is an electronic machine that performs various mathematical operations on data under the control of a stored set of instructions."
  - ◊ system:
    - hardware
    - software

Lecture 20 (cont'd) COMPUTER HARDWARE

- major system elements:
  - ◊ input
  - ◊ output
  - ◊ central processor
  - ◊ main memory
  - ◊ peripheral memory
- central processor unit (CPU):
  - ◊ microprocessor today
  - ◊ various arithmetic/logic operations performed
  - ◊ instructions decoded and issued
  - ◊ elements
    - - arithmetic and logic unit (ALU)
    - - control unit (CU)
- Boolean logic gates:
  - ◊ AND gate
    - - output = 1 only if A and B = 1
    - - out = AB
  - ◊ OR gate
    - - output = 1 if either A or B = 1
    - - out = A + B
  - ◊ NOT gate
    - - negates or changes
- memory:
  - ◊ types:
    - - ROM & RAM
    - - PROM & EPROM
    - - VRAM
    - - buffer
  - ◊ technology:
    - - solid state
    - - magnetic
    - - optical -- CD-ROM -- WORM (write once / read many)
  - ◊ size:
    - - kilo = 2^{10} = 1024 bits
    - - b = bits
    - - B = bytes
    - - 8 bits = 1 byte
- internal communication -- buses:
  - ◊ serial
  - ◊ parallel
- input & output:
  - ◊ mouse
  - ◊ cathode ray tube
  - ◊ liquid crystal display
  - ◊ loudspeaker
  - ◊ printer
  - ◊ peripheral memory: floppies & removable hard drives

Lecture 21 COMPUTER SOFTWARE

- computer program:
  - ◊ definition:
    - a set of instructions
    - specifies sequence of operations to be performed
  - ◊ types:
    - operating system
    - application
    - languages
- information structure:
  - ◊ byte = 8 bits
  - ◊ coding of information:
    - American Standard Code for Information Interchange (ASCII)
    - 7 data bits + parity bit
    - binary coded decimal (BCD)
  - ◊ words:
    - data word
    - instruction word
- programming languages:
  - ◊ language = rules
  - ◊ code = program
  - ◊ compiler:
    source code >>> machine code (object program)
  - ◊ interpreter:
    one line at a time
  - ◊ assembly language
  - ◊ higher-level languages:
    - FORTRAN (FORmula TRANslator)
    - BASIC (Beginners All-purpose Symbolic Instruction Code)
    - COBOL (Common Business Oriented Language)
    - C (developed at Bell Labs -- cross platform application)
  - ◊ application programs:
    - word processing (Word & WordPerfect
    - spread sheets (Lotus 1-2-3 & Excel)
    - database (FileMaker)
    - contact managers
    - home finance
  - ◊ operating systems:
    - Macintosh
    - DOS
    - Windows
    - UNIX
- user interface

Lecture 22 DATA COMMUNICATION

- modems:
  - ◊ modulator/demodulator = modem
- modulation schemes:
  - ◊ on-off keying (OOK)
  - ◊ amplitude- shift keying (ASK)
  - ◊ frequency-shift keying (FSK)
  - ◊ phase-shift keying (PSK)
  - ◊ quadrature amplitude modulation (QAM):
- bit/baud rate:
  - ◊ bits per second
  - ◊ baud = signaling element
- directionality:
  - ◊ simplex =one-way
  - ◊ duplex = two-way:
    - - full (FDX) = all the time
    - - half (HDX) = reverse channel
- topologies of local area networks:
  - ◊ mesh
  - ◊ star
  - ◊ bus
  - ◊ ring
  - ◊ LANs:
    - - Ethernet
    - - token ring
    - - collision detection & avoidance
- packet switching:
  - ◊ header -- address
  - ◊ routers
- the Internet:
  - ◊ ARPANET:
    - - late 1960s
    - - transmission control protocol/Internet protocol (TCP/IP)
      - . first described in 1974 by Vinton Cerf & Bob Kahn
      - . adopted for ARPANET in 1982
  - ◊ NSFNET:
    - - created in 1986
    - - assumed ARPANET
    - - became the Internet
  - ◊ the Web (World Wide Web -- WWW):
    - - hypertext markup language (HTML)
      - . proposed by Tim Berners-Lee in 1989
      - . use for common storage and retrieval from databases
    - - world wide web
      - . term first used in 1994
    - - browsers
      - . Gopher -- 1991
      - . Mosaic -- 1993 by Marc Andreessen (Netscape founder)

- ◊ address protocol:
  - - domain name server (.com, etc)
  - - uniform resource locator (URL)
    - . protocol [http]
    - . name of host
    - . file to be addressed

• local access:
- ◊ modems over:
  - - analog phone lines
  - - coaxial cable (cable modems)
- ◊ ISDN
- ◊ ADSL

EPILOGUE—THE FUTURE OF COMMUNICATION

Lecture 23 THE FUTURE OF COMMUNICATION

- factors affecting future:
    - ◊ technology
    - ◊ business
    - ◊ consumers
    - ◊ finance
    - ◊ policy
- progress: revolutionary *vs* evolutionary
- lessons for the future:
    - ◊ backwards compatibility essential
        - cbs color tv system *vs* ntsc
    - ◊ decentralization & distributed processing
        - time-shared computing *vs* personal computers
    - ◊ the "wow factor"
        - IMAC
        - cd
    - ◊ ease of use
        - Internet protocol
        - browsers
    - ◊ need to make $$$
- a glimpse forward

***** FINAL EXAM *****