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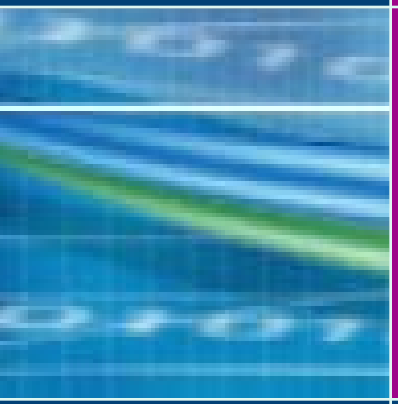

How Wire Fails

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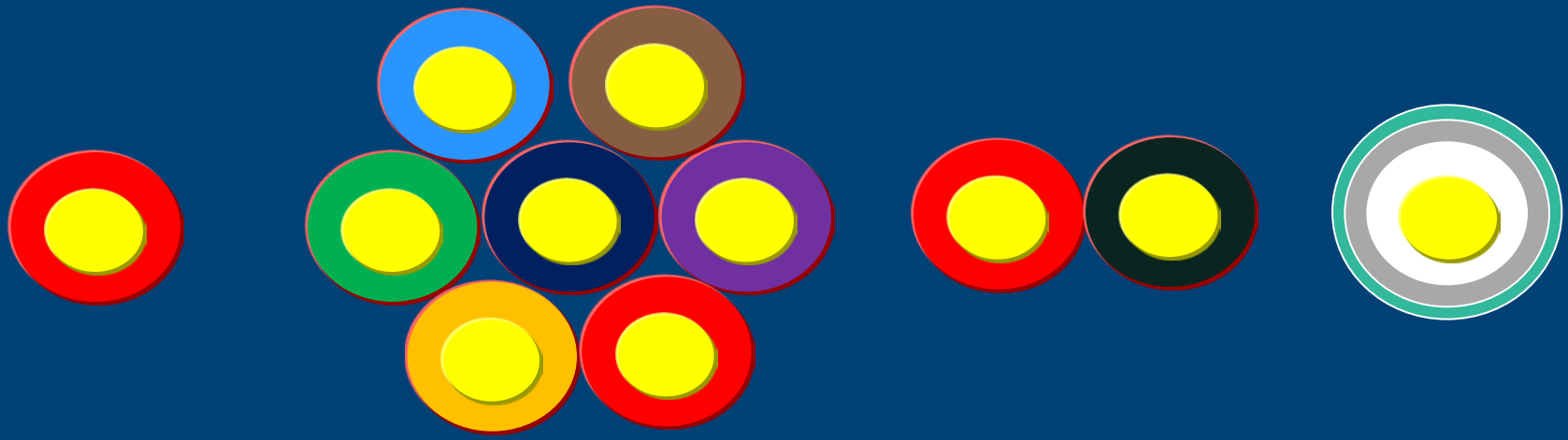
Wire & Cable

- Really should be “How Wire & Cable Fail”
- Difference between wire and cable
- We’ll start with wire and “build” cables



Single Conductor

Multiconductor

Twisted Pair

Coaxial Cable

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Wire & Cable Failure

- Two kinds of failure:
  - Electrical failure
    - "Catastrophic failure"
      - Wire breaks
  - Performance failure
    - Works but it doesn't work right
      - Wire is to small or too long
      - Signal is reduced in level

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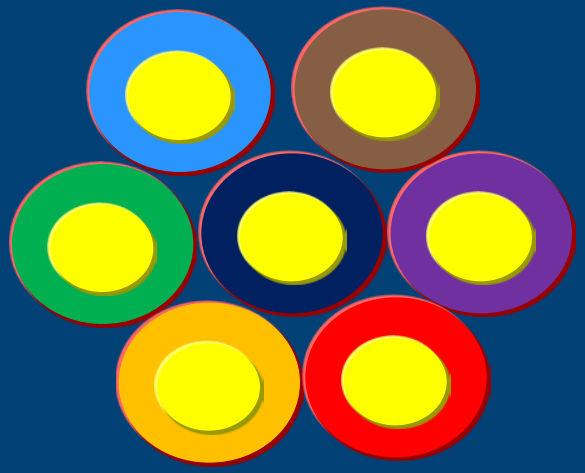
Single Conductor Failure

American Wire Gage	Breaking Strength	Pull Strength
24 AWG	10 lbs. 5kg	4 lbs. 2kg
22 AWG	18 lbs. 8kg	7 lbs. 3kg
20 AWG	30 lbs. 14kg	12 lbs. 6kg
18 AWG	48 lbs. 22kg	19 lbs. 9 kg
16 AWG	75 lbs. 34 kg	30 lbs. 14kg
14 AWG	120 lbs. 55kg	48 lbs. 22kg
12 AWG	193 lbs. 88kg	77 lbs. 35kg

Cable Pulling Strength



- Multiply by number of conductors
- Different combined gages
- Coax cable
  - Ask manufacturer, web page, catalog

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Coax Pulling Strength

COAX	PULL
179DT	15 lbs. 7kg
1855A	36 lbs. 16kg
1505A	47 lbs. 21kg
1694A	69 lbs. 31kg
1794A	111 lbs. 51kg
7731A	145 lbs. 66kg

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Pull Strength

- Also called “Pull Tension”
- Wire does not break instantly
  - –Elongates
  - –Wire changes its size or gage
  - –Affects performance
    - Affects resistance

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Resistance

- For 1,000 ft. (305m) of *solid* copper at 20˚ C/68˚ F

AWG	Resistance	Circular Mil Area
30	103.2 Ω	100.5
24	25.67 Ω	404
22	16.14 Ω	640.4
20	10.15 Ω	1020
18	6.385 Ω	1620
16	4.016 Ω	2583
14	2.525 Ω	4107
12	1.588 Ω	6530
10	0.999 Ω	10,380

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Resistance

- Resistance turns electric flow into heat
- The bigger the wire, the lower the resistance
- The smaller the wire, the higher the resistance
  - Excessive pull tension elongates the wire
  - Thinner wire = higher resistance
  - Higher resistance = more heat produced
  - Higher resistance increases “voltage drop”
- Cables that combine signals with power conductors
  - Often the power conductors that limit distance
  - Go and learn “Ohm’s Law”
    - Relationship between voltage, amperage and resistance

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Flexibility and Flex Life

- No way to measure flexibility
  - Your chance to become famous
- Flex-life : flexes to failure
  - Solid wire: “work-hardening”
    - Some solid wire = 2,000 flexes
  - All wire is “annealed” to improve flex life
  - Stranded wire has better flex life than solid
    - Some stranded wire = millions of flexes
    - Belden “Infinity” line of cables
      - Up to 9,000,000 flexes
      - ***Predictable*** failure

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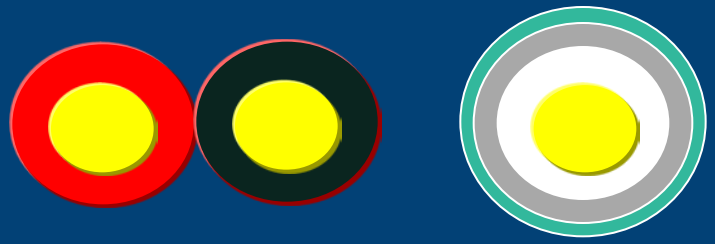
Capacitance

- Two pieces of metal with a nonconductor in-between



  - A “capacitor”
- Twisted pair or coax cable are two pieces of metal
  - They have “capacitance”
  - Capacitance is measured in Farads
  - Cables have a tiny amount of capacitance: picofarad
- Capacitance holds an electrical charge
  - Especially noticeable at higher frequencies
  - Can affect audio and how it sounds
    - Audio cables with too much capacitance sound “dull” or “boomy”

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Capacitance

- Capacitance adds with the length of the cable.
  - Longer cable has more capacitance than a short cable.
- We can make cable with high or low capacitance
  - High is 50 pF/ft. (164 pF/m)
    - Cheap plastic, easy to make
  - Low is 13 pF/ft. (43 pF/m)
    - ….even down to 8.5 pF/ft. (28 pF/m)
    - Expensive plastic, difficult to make
- Low capacitance works better at high frequencies
    - Sometimes capacitance is “locked in” by construction

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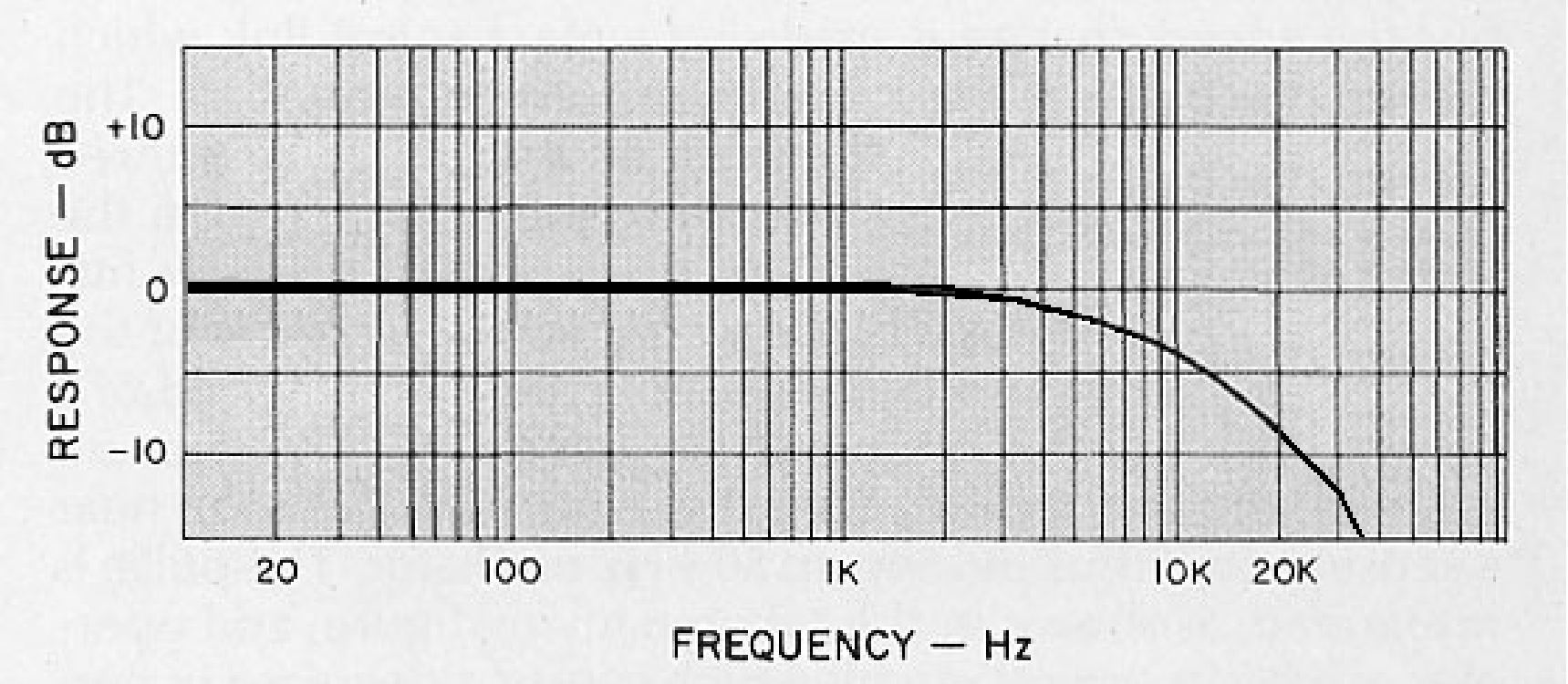
“Slope” “Tilt” “EQ Curve”



- Happens in every cable.
- Lower capacitance means it starts at a higher frequency.
- You can compensate…
  - Better cable, lower capacitance
  - Insert an “equalizer”

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Inductance

- Very tiny effect on a cable
  - So tiny we don’t list it in the catalog or web page
- Inductance & Capacitance cancel each other
  - Capacitance wins.
- Resistance, Capacitance, Inductance
  - This is everything that affects a signal on a cable.

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Impedance

- On a cable, applies to high frequencies
  - Higher than 100,000 Hz (100 kHz)
    - Digital audio
    - Analog video
    - Digital Video
    - CATV/broadband
    - RS-422 data
    - RS-485 data
    - Ethernet
  - Impedance doesn’t apply to low frequencies
    - Analog audio (microphone, line, speaker cable)
    - Slow-speed data (RS-232)

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Impedance Failure

- Signal is looking for a specific impedance
  - 75 ohm coax for video
  - 50 ohm for transmission coax
  - 100 ohm twisted pairs for data
    - Many other impedances
- Wrong impedance, or changed impedance
  - Causes signals to reflect (go backwards)
  - “Return Loss”
  - “Structural Return Loss”
- Anything that deforms the cable
  - Anything that changes its shape
    - Rough installation

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Failure by Distance

- DC resistance
- Capacitance (EQ)
- Digital Cliff
  - Signal level drops
  - Hard to recover signal
  - Perfect to “gone” in 10 ft. (3m)
    - Major problem with professional HD video
    - Ethernet maximum distance 100 meters (328 ft.)

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Failure by Fire

- Not related to cable performance
- Specific to cable construction
- Avoid being the fuel to feed a fire
- Fire ratings
  - Cables will still melt
  - Won’t be “fuel for the fire”
    - US Standards set in the NEC, National Electrical Code
    - Most US communities use the NEC as their “law”
    - Some do not…
      - Las Vegas, Chicago, Los Angeles
- Cables that won’t burn exist but are VERY expensive

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Ruggedized Cable

- Cables intended to withstand abuse
- “Tactical” cable
  - Double jackets
  - Special conductors (alloy)
  - Kevlar with conductors
  - Armored
    - Aluminum armor
    - Steel armor
- More expensive, but NOT better performance

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www.belden.com

9,000 page online

1,000,000 hits per week

steve.lampen@belden.com

8,000 employees

3,500 in the USA

37 factories

13 in the USA