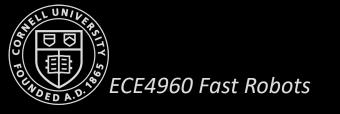
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Fast Robots



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(Rechargeable) Batteries

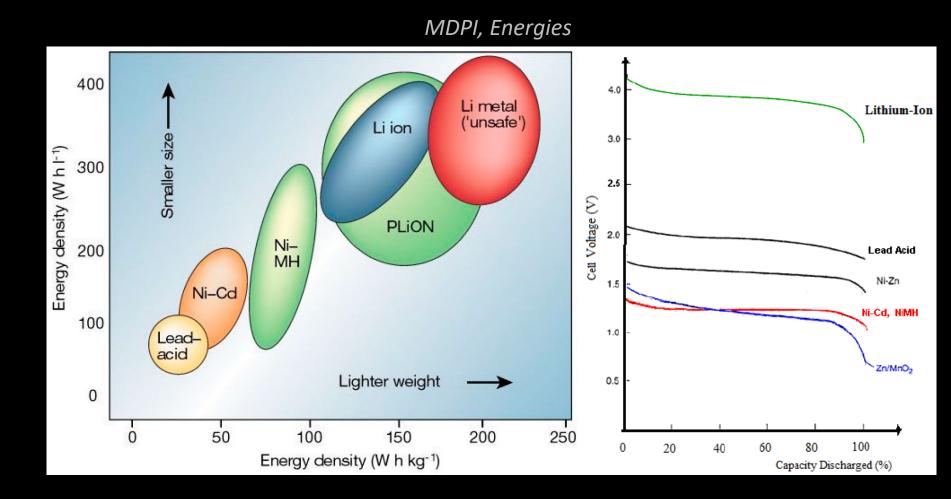


https://batteryuniversity.com/article/whats-the-best-battery

Important properties

What do you look for when choosing a battery?

- Battery capacity
- Cell voltage
- Discharge curve
- Discharge rate (C)
- Charge rate
- Cycle times
- Aging
- Safety
- Form factor/weight
- Cost



Rechargeable Batteries

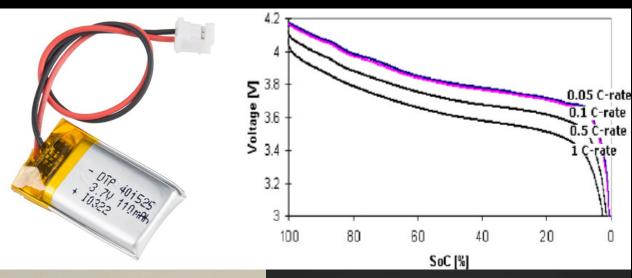
- Nickel Cadmium (NiCd)
 - Mature tech, affordable
 - Pretty low in energy density
 - High discharge rate
 - Long cycle life
 - Better in rigorous working conditions
 - Periodic full discharge/charge is critical
 - Contains toxic metals
- Nickel-Metal Hydride (NiMH)
 - Higher capacity than NiCd
 - Higher discharge rate than NiCd
 - More robust
 - No toxic metals
 - Reduced cycle life
 - More expensive than NiCd
- Lead Acid (SLA)
 - Cheap
 - Large power applications
 - Low energy density

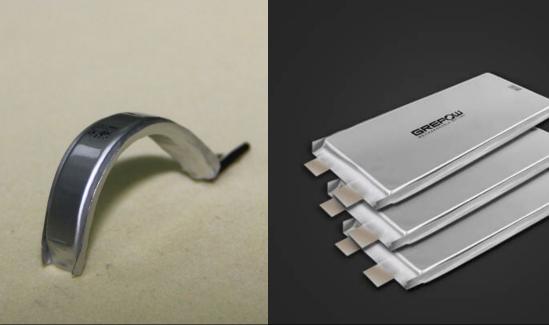




Rechargeable Batteries

- Lithium Ion (Li-Ion)
 - High energy density
 - Light weight
 - Low maintenance battery
 - Max discharge rate: 1-2C 🗲
 - High cell voltage (single cell batteries)
 - Low self-discharge
 - Form factor: Prismatic and cylindrical
 - Protection circuits for charge/discharge
 - Aging
- Lithium Polymer (Li-Po)
 - Light weight
 - Free form-factor
 - More robust
 - Max discharge rate: 3-60C
 - Lower energy density than Li-Ion
 - Cost more than Li-Ion





Societal Perspective on Lithium and Cobalt...

- Lithium prices are up 280% in the last year
 - Green transport / EV, phones, etc.
 - 80% is mined in Australia, Chile, and China
 - China controls ~50% of Lithium processing and refining
 - US mines and processes 1%
- Cobalt is used for the electrolytes
 - Congo sits on ~50% of the Cobalt
 - 2016-2020: China Molybdenum took ownership of two of the largest US-owned Cobalt mines in Congo



Cobalt electrolytic and 1cm3 cube



Lithium production in Chile



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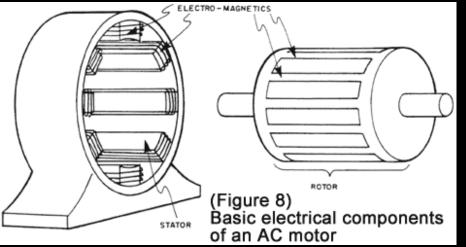
ELECTRIC MOTORS

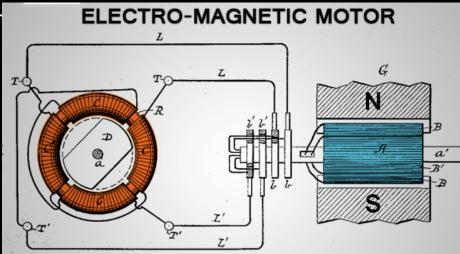


AC Motors

https://www.explainthatstuff.com induction-motors.html

- High power/torque
- Access to a mains/wall outlet
- Synchronous AC motors
 - Rotor turns as fast as the magnetic field fluctuates
- Asynchronous AC motors / Induction motors
 - Rotor turns slower than the field
 - Coil, frequency, and load dependent
- Simple, low cost, long lasting
- You'll need a variable frequency drive to change their speed





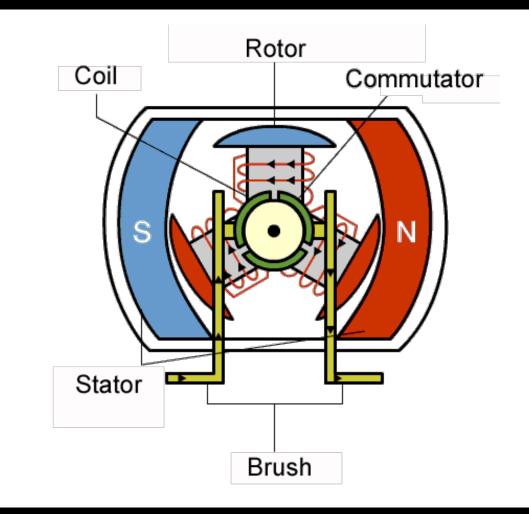
(CRITICAL FEATURES - MODE AND PLAN OF OPERATING ELECTRIC MOTORS BY PROGRESSIVE SHIFTING; FIELD MAGNET; ARMATURE; ELECTRICAL CONVERSION; ECONOMICAL; TRANSMISSION OF ENERGY; SIMPLE CONSTRUCTION; EASIER CONSTRUCTION; ROTATING MAGNETIC FIELD PRINCIPLES)

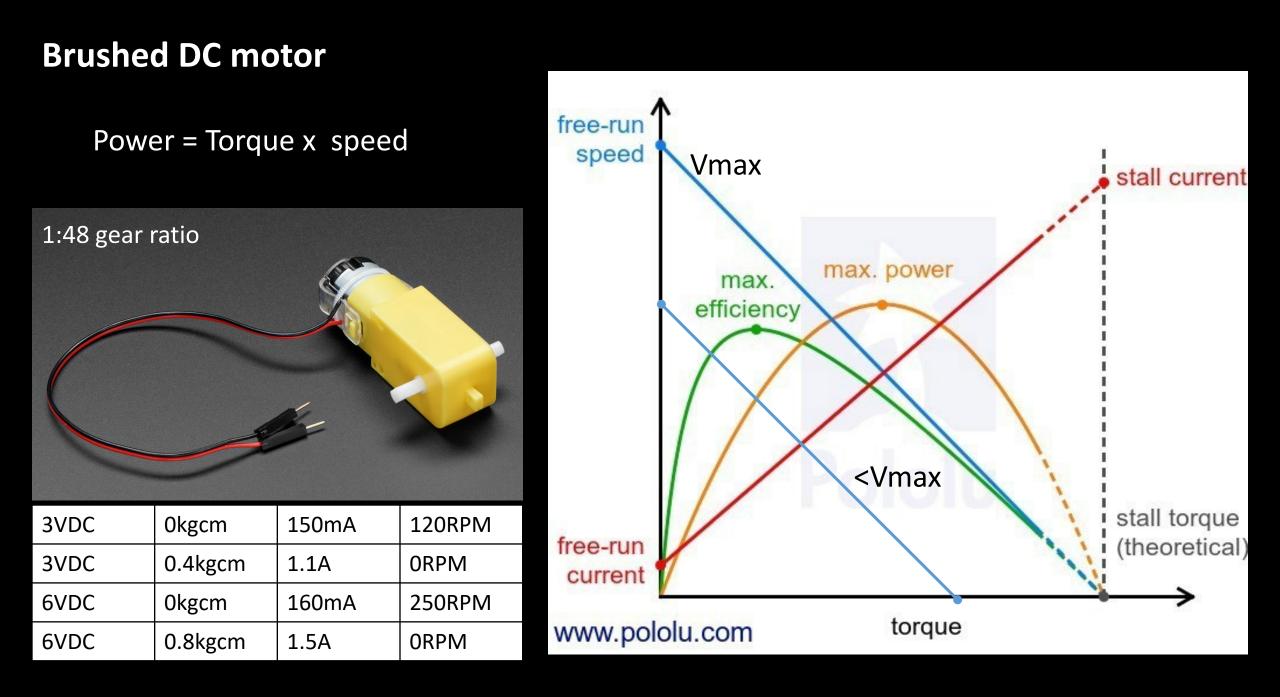
#8 TESLA PATENT US 381968 A



Brushed DC motor

- Brushes conduct current from source to armature
- Most commonly Permanent Magnet DC motors (PMDC)
- Pros
 - Inexpensive
 - Easy speed control (DC voltage)
 - Light weight
 - Reasonably efficient
 - Great for low power, low form factor applications
- Cons
 - Mechanical wear
 - Electrical noise



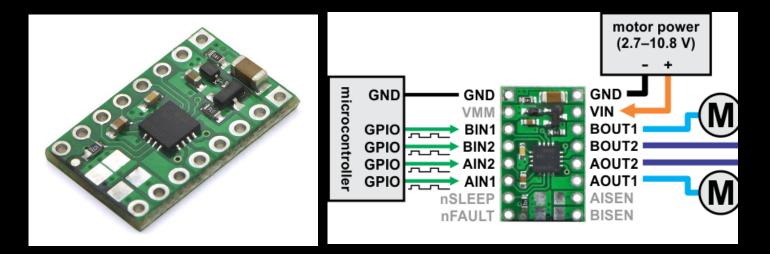


https://www.pololu.com/product-info-merged/2130

Brushed DC motor Controllers

DRV8833 Dual Motor Driver Carrier

- V_{IN} = 2.7-10.8V
- 3 and 5V compatible inputs
- I_{con} = 1.2A (per channel)
- I_{peak} = 2A (per channel)
- ...with active cooling



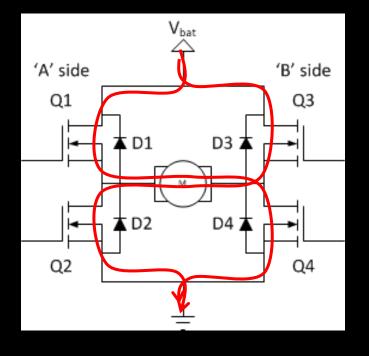
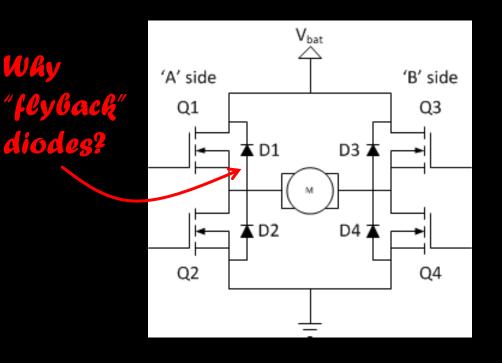


Table 1. H-Bridge Logic								
	xIN1	xIN2	xOUT1	xOUT2	FUNCTION			
	0	0	Z	Z	Coast/fast decay			
	0	1	L	Н	Reverse			
	1	0	Н	L	Forward			
	1	1	L	L	Brake/slow decay			

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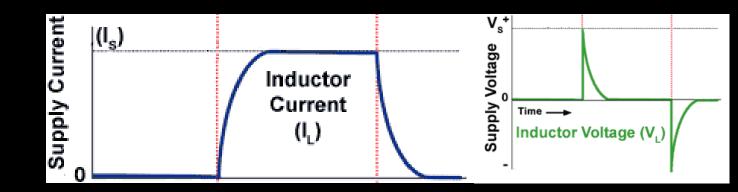


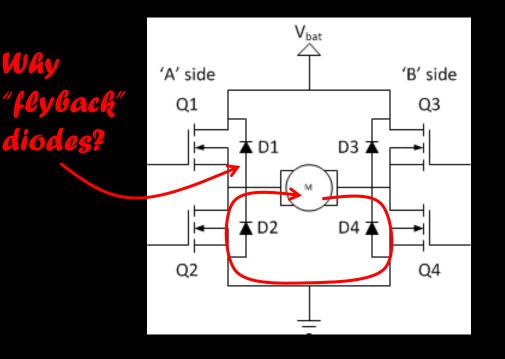
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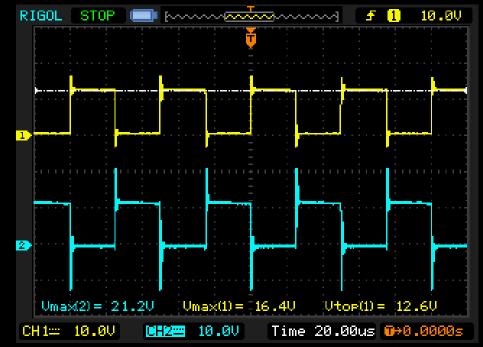


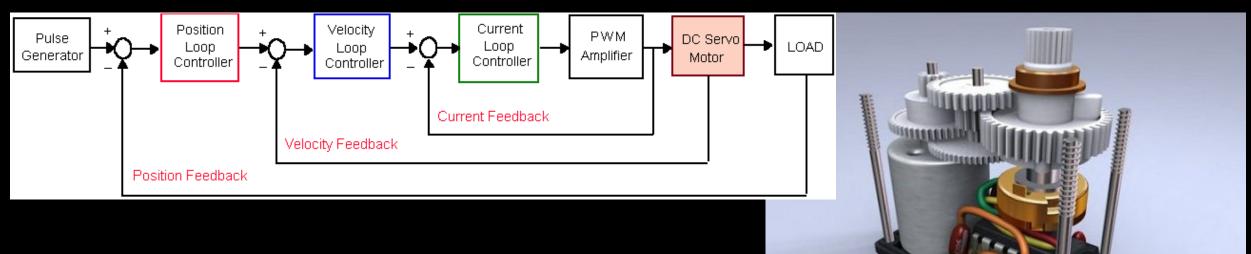
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Servo motor

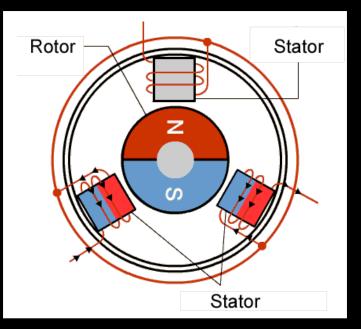
- Duty cycle of a 50Hz 0-5V signal
- Continuous rotation servo
- Position controlled servo



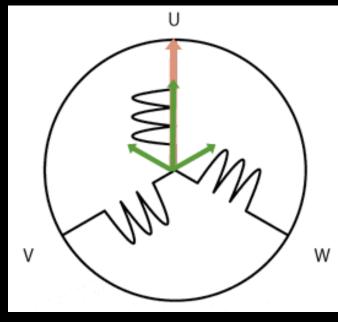


Brushless DC motor (BLDC)

- Inside-out PMDC
- Higher efficiency (85-90% compared to 74-780% brushed motors)
- No wear, easier cooling, low EMI
- Higher power, high starting torque
- Precise control of torque and speed
 - Discrete control (easy, but jerky)
 - Sinusoidal control
- Position sensing
 - Sensors (hall effect, etc.)
 - Sensor less (back-EMF)
 - Lower speeds
 - Initialization

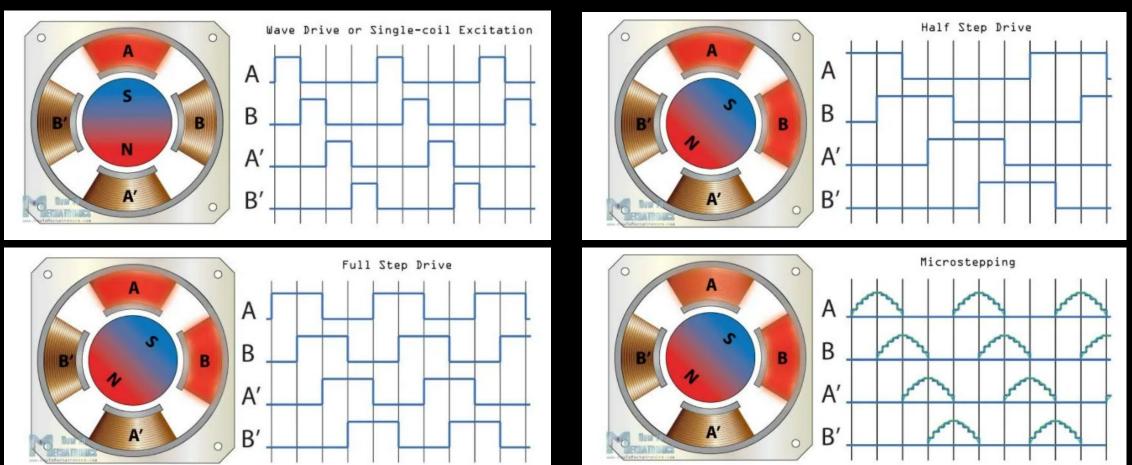






Stepper motor

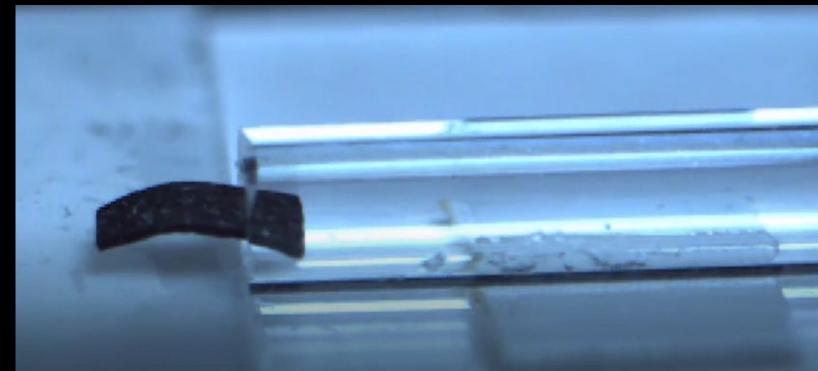
- Good Choice when low speed and high precision is needed
- Advantages: High torque compared to servos, constant holding torque, frictionless
- Disadvantages: Low efficiency, torque declines rapidly with speed, low torque to inertia



Actuators...

- A device that converts energy into mechanical motion
 - Electric
 - Mechanical
 - Hydraulic
 - Pneumatic
 - Pneumatic
 - Bio-hybrid
 - Magnetic
 - Light-driven
 - Thermal







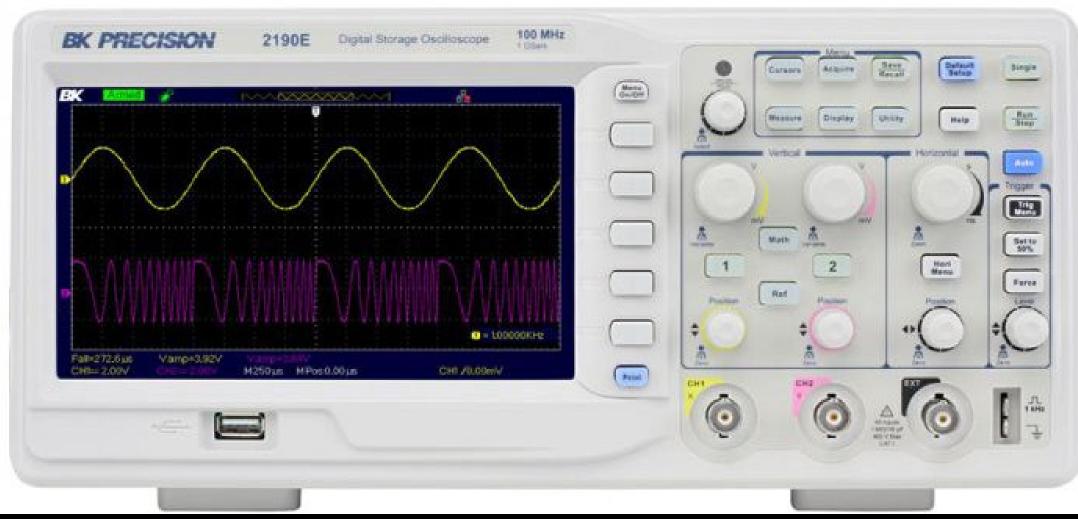
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Oscilloscopes



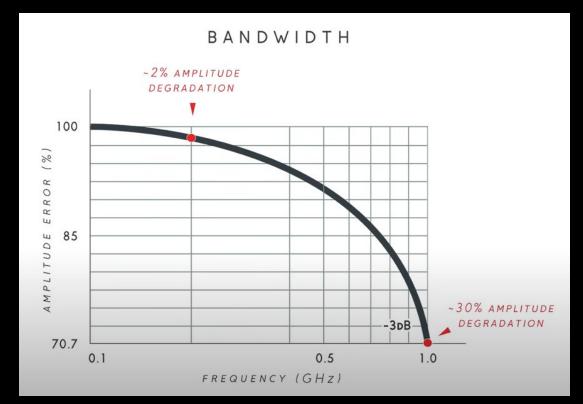
Oscilloscope Setup

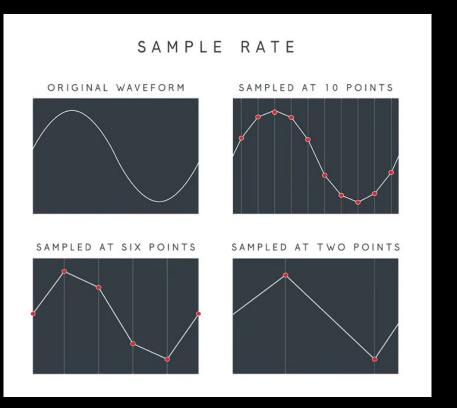




Oscilloscope Characteristics

- Bandwidth
- Sample rate
- Resolution



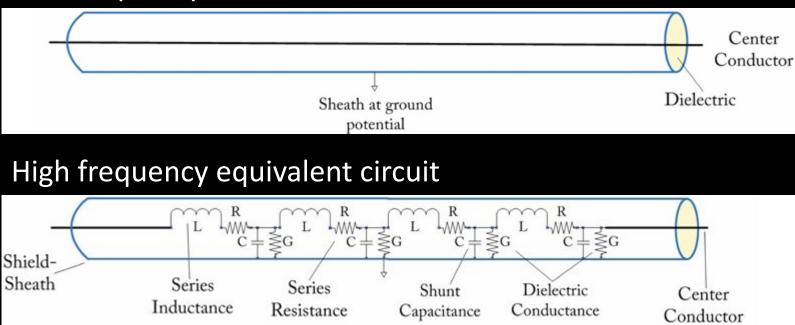


Oscilloscope Probes

- Scope inputs resemble a 16pF capacitor in parallel with a 1MOhm resistor
- At high frequencies the coax cable acts as a low pass filter
- 1x attenuation for low amplitude, low frequency signals
- 10x attenuation for load-sensitive circuits, high frequency- or high amplitude signals

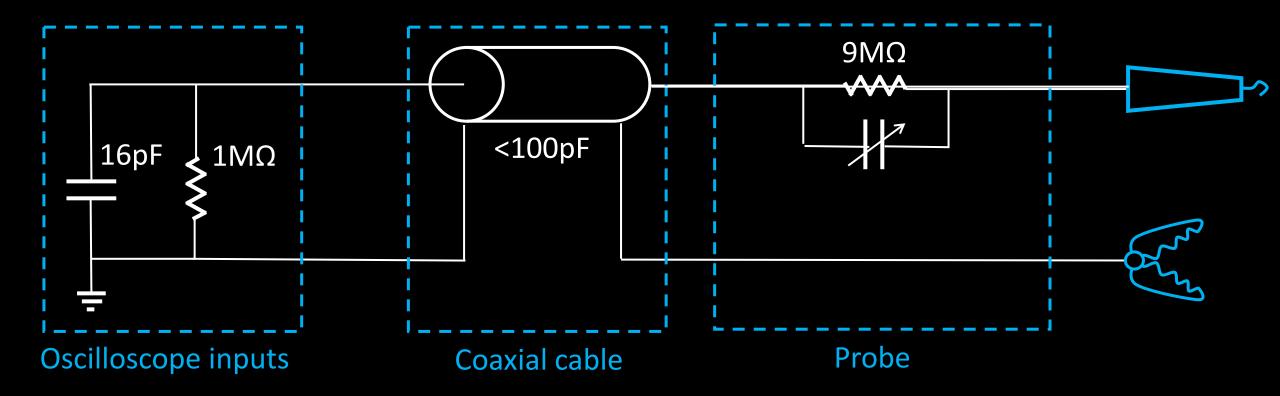


Low frequency coax cable



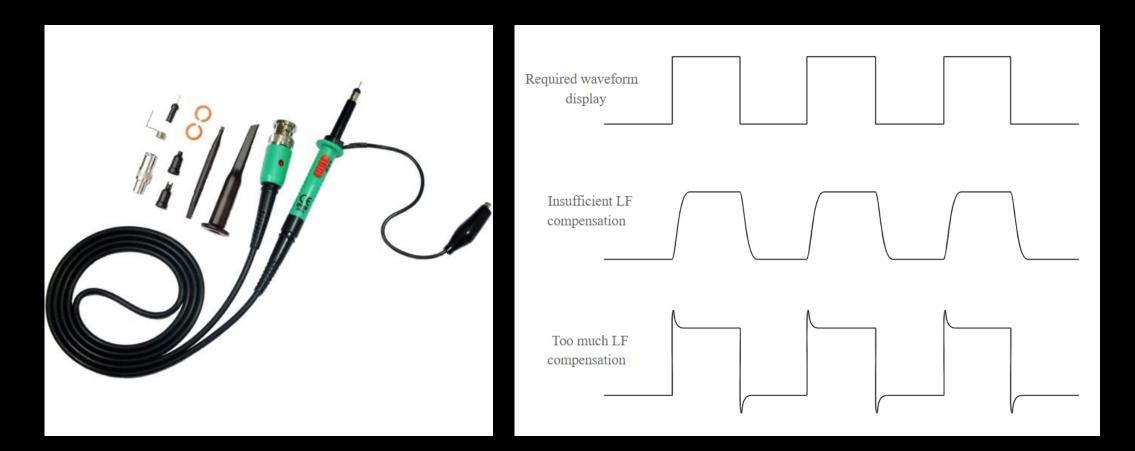
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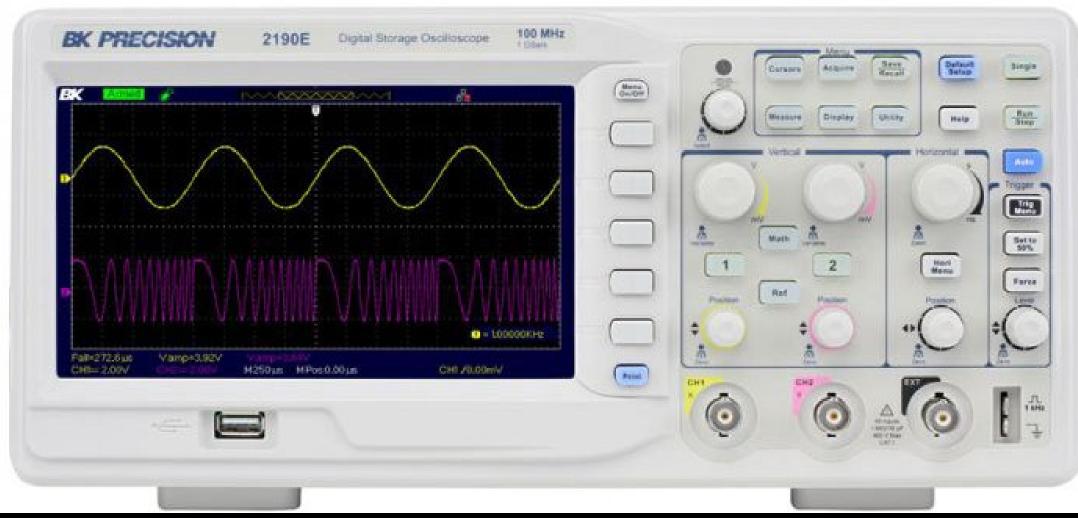


Oscilloscope Probes

- 10x probe calibration
 - Use the built-in square wave generator
 - Adjust capacitor until the square wave looks square!



Oscilloscope Setup





UNIV