



CANADIAN BASIC AMATEUR RADIO EXAM PREPARATION

SECTION 4 **B** CIRCUIT COMPONENTS





**THIS COURSE IS BEING TAUGHT TO THE JULY 15, 2025 UPDATE
OF THE CANADIAN BASIC AMATEUR RADIO EXAM QUESTIONS.**

SECTION 4 QUESTION CATEGORIES:

B-004-001: AMPLIFIERS IN AMATEUR RADIO

B-004-002: SEMICONDUCTOR DIODES

B-004-003: BIPOLAR TRANSISTORS (BJTS)

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

B-004-005: VACUUM TUBES (SPECIFICALLY TRIODES)

B-004-006: RESISTORS



QUESTION SECTION B-004-001:

AMPLIFIERS IN AMATEUR RADIO

WHAT IS AN AMPLIFIER?

- AN AMPLIFIER IS A CIRCUIT DESIGNED TO INCREASE THE **AMPLITUDE (STRENGTH) OF A SIGNAL** WITHOUT CHANGING ITS BASIC SHAPE OR INFORMATION CONTENT.
- KEY TERM: A CIRCUIT THAT **BOOSTS SIGNAL LEVEL** →
AMPLIFIER.



WHY AMPLIFIERS MATTER IN HAM RADIO

- WEAK SIGNALS NEED BOOSTING AT DIFFERENT STAGES:

VERY WEAK **RADIO FREQUENCY (RF) SIGNALS** FROM THE ANTENNA → USE AN **RF AMPLIFIER (PREAMP)** TO INCREASE THEM BEFORE FURTHER PROCESSING.



WHY AMPLIFIERS MATTER IN HAM RADIO

- **WEAK SIGNALS NEED BOOSTING AT DIFFERENT STAGES:**

VERY WEAK AUDIO SIGNALS FROM A MICROPHONE → USE AN AUDIO AMPLIFIER TO RAISE THEM TO A USABLE LEVEL FOR MODULATION/TRANSMISSION.



WHY AMPLIFIERS MATTER IN HAM RADIO

- IN A TRANSCEIVER, THE **SPEECH AMPLIFIER (AUDIO STAGE)** TYPICALLY PROCESSES HUMAN VOICE FREQUENCIES IN THE RANGE OF 300Hz TO 3,000Hz — THIS COVERS THE ESSENTIAL RANGE FOR CLEAR SPEECH WHILE FILTERING OUT UNNECESSARY LOWS/HIGHS.



WHAT AMPLIFIERS CAN INCREASE

- AMPLIFIERS BOOST DIFFERENT **SIGNAL PROPERTIES** DEPENDING ON DESIGN:
 - MOST COMMONLY: **VOLTAGE** (ESPECIALLY IN VOLTAGE AMPLIFIERS).
 - ALSO POSSIBLE: CURRENT OR POWER.



KEY PERFORMANCE TERMS

- THE INCREASE IN SIGNAL LEVEL PRODUCED BY AN AMPLIFIER IS CALLED **GAIN**.
- EXAMPLE: A DEVICE LABELLED “GAIN = 10 dB” IS ALMOST CERTAINLY AN AMPLIFIER
- GAIN IS A HALLMARK OF AMPLIFICATION



KEY PERFORMANCE TERMS

- **EFFICIENCY** MEASURES HOW WELL THE AMPLIFIER CONVERTS DC INPUT POWER INTO USEFUL **OUTPUT SIGNAL POWER** (RATIO OF OUTPUT POWER TO DC INPUT POWER).



PROBLEMS WITH AMPLIFIERS

- IF AN AMPLIFIER BECOMES **NON-LINEAR** (DOESN'T RESPOND PROPORTIONALLY TO THE INPUT OVER ITS FULL RANGE), THE OUTPUT SIGNAL BECOMES **DISTORTED** — THIS CAN CREATE UNWANTED HARMONICS, SPLATTER, OR POOR AUDIO QUALITY.



PROBLEMS WITH AMPLIFIERS

- EXCESSIVE POSITIVE FEEDBACK IN AN AMPLIFIER STAGE CAUSES **OSCILLATIONS** (UNWANTED SELF-GENERATED SIGNALS, LIKE HOWLING OR SQUEALING) — THE CIRCUIT STARTS BEHAVING LIKE AN **OSCILLATOR** INSTEAD OF A CLEAN AMPLIFIER.





QUESTION SECTION B-004-002:

SEMICONDUCTOR DIODES

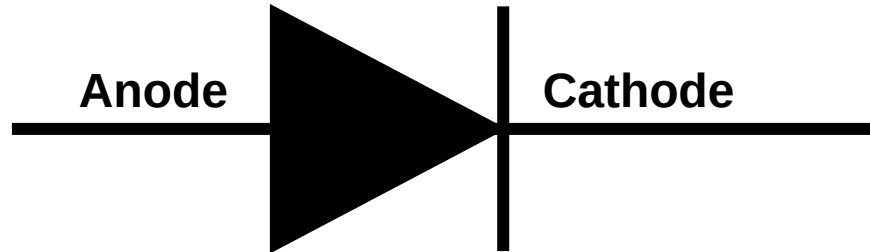
WHAT IS A DIODE?

- A SEMICONDUCTOR DIODE IS A ONE-WAY VALVE FOR ELECTRIC CURRENT.
- IT HAS TWO ELECTRODES: **ANODE** (POSITIVE SIDE) AND **CATHODE** (NEGATIVE SIDE).



WHAT IS A DIODE?

- **STANDARD SYMBOL: ARROW POINTING TOWARD THE CATHODE (DIRECTION OF CONVENTIONAL CURRENT FLOW), WITH A BAR AT THE CATHODE END.**



WHAT IS A DIODE?

- **KEY PROPERTY: IT CONDUCTS IN ONE DIRECTION ONLY (WHEN FORWARD BIASED — ANODE POSITIVE RELATIVE TO CATHODE) AND BLOCKS CURRENT IN THE REVERSE DIRECTION.**
- **FOR A DIODE TO CONDUCT: IT MUST BE FORWARD BIASED.**

B-004-002: SEMICONDUCTOR DIODES

CONVENTIONAL CURRENT VS ELECTRON FLOW

CONV-CURRENT: POSITIVE TO NEGATIVE 

ELECTRON FLOW: NEGATIVE TO POSITIVE 

IN REALITY, THE ACTUAL CHARGE CARRIERS ARE ELECTRONS, WHICH ARE NEGATIVELY CHARGED. ELECTRONS MOVE TOWARD THE POSITIVE TERMINAL — SO THEIR DIRECTION OF MOTION IS OPPOSITE TO THE DIRECTION OF CONVENTIONAL CURRENT.

CONV-CURRENT VS ELECTRON FLOW

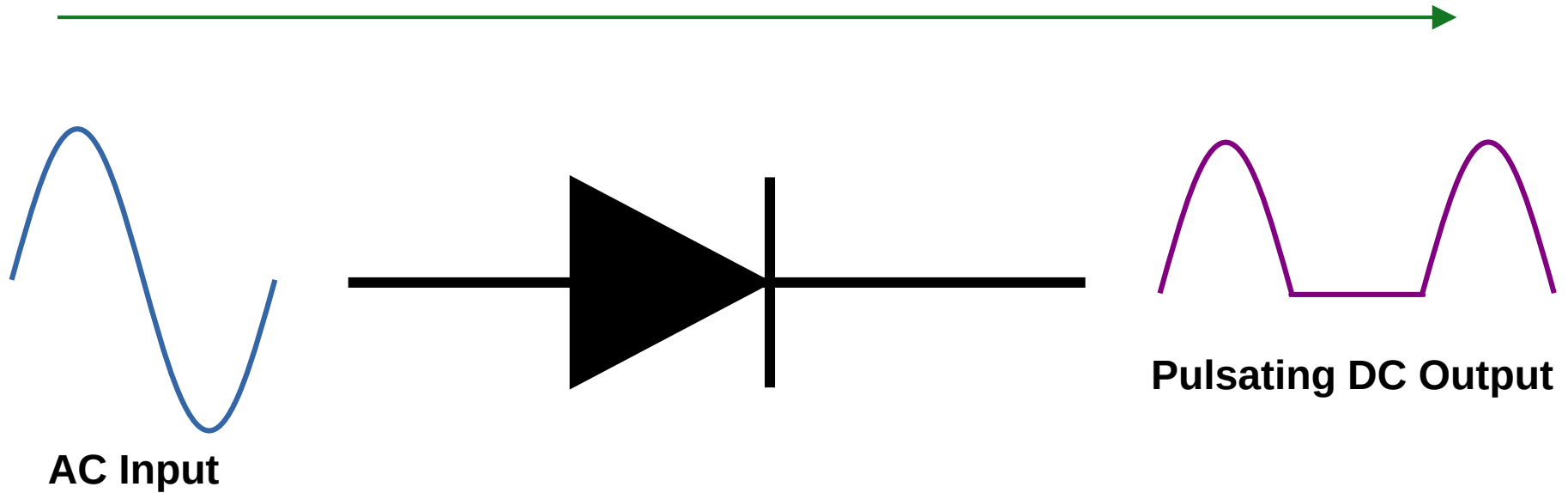
- THINK OF A A SALMON SWIMMING UPSTREAM AGAINST THE CURRENT
- ELECTRONS FLOW AGAINST THE CURRENT



CURRENT FLOW IN A DIODE

- IN A SEMICONDUCTOR DIODE, **ELECTRONS** FLOW FROM **CATHODE TO ANODE** (CONVENTIONAL CURRENT IS OPPOSITE: ANODE TO CATHODE).
- IF ALTERNATING CURRENT (AC) IS APPLIED TO THE **ANODE**, THE OUTPUT AT THE **CATHODE** IS PULSATING DIRECT CURRENT — ONLY THE POSITIVE HALF-CYCLES PASS THROUGH.

CURRENT FLOW IN A DIODE



CHANGING AC TO DC: RECTIFICATION

- THE PROCESS OF CONVERTING **ALTERNATING CURRENT (AC)** TO **DIRECT CURRENT (DC)** IS CALLED RECTIFICATION.
- A SINGLE DIODE PERFORMS HALF-WAVE RECTIFICATION, ALLOWING ONLY ONE POLARITY OF THE AC WAVEFORM TO PASS (RESULTS IN PULSATING DC).
- THIS IS COMMON IN SIMPLE POWER SUPPLIES FOR HAM GEAR.

IMPORTANT APPLICATIONS IN HAM RADIO

- **REVERSE POLARITY PROTECTION:** A DIODE PLACED IN SERIES IN THE POSITIVE POWER LEAD TO A TRANSCEIVER PROTECTS AGAINST ACCIDENTAL REVERSE BATTERY OR POWER SUPPLY CONNECTION.
- **PURPOSE:** REVERSE POLARITY PROTECTION.

IMPORTANT APPLICATIONS IN HAM RADIO

- **HOW IT WORKS: THE DIODE CONDUCTS NORMALLY IF POLARITY IS CORRECT BUT BLOCKS CURRENT (AND MAY BLOW A FUSE) IF REVERSED — BECAUSE IT CONDUCTS IN ONE DIRECTION ONLY.**



IMPORTANT APPLICATIONS IN HAM RADIO

- **DETECTION (DEMODULATION)**: ONE KEY USE OF DIODES IS **RECOVERING INFORMATION** (LIKE AUDIO) FROM TRANSMITTED RADIO SIGNALS — THIS IS CALLED DETECTION.
- **EXAMPLE: IN SIMPLE AM RECEIVERS OR PRODUCT DETECTORS.**

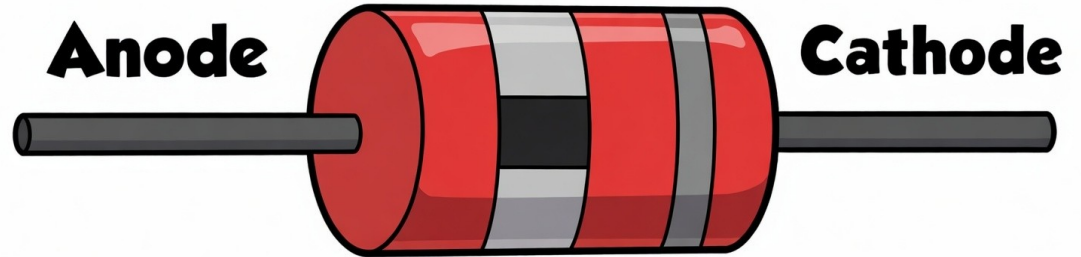
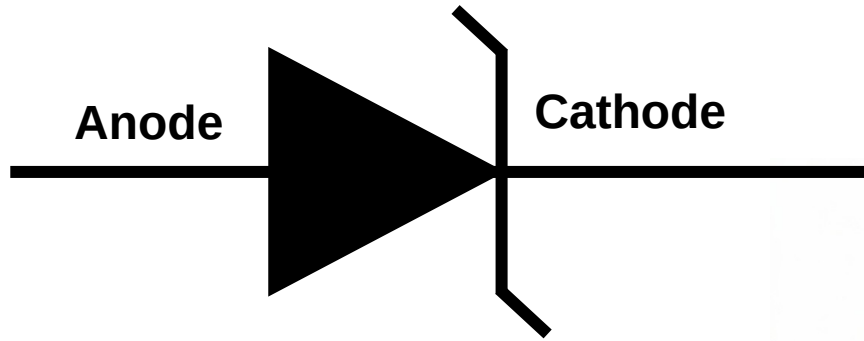


IMPORTANT APPLICATIONS IN HAM RADIO

- **VOLTAGE REGULATION:** THE PRIMARY PURPOSE OF A **ZENER DIODE** IS TO REGULATE OR MAINTAIN A CONSTANT VOLTAGE ACROSS A LOAD, EVEN WHEN INPUT VOLTAGE OR LOAD CURRENT VARIES.
- **ZENER DIODES OPERATE IN THE REVERSE-BIAS BREAKDOWN REGION TO HOLD A STABLE REFERENCE VOLTAGE.**

B-004-002: SEMICONDUCTOR DIODES

IMPORTANT APPLICATIONS IN HAM RADIO

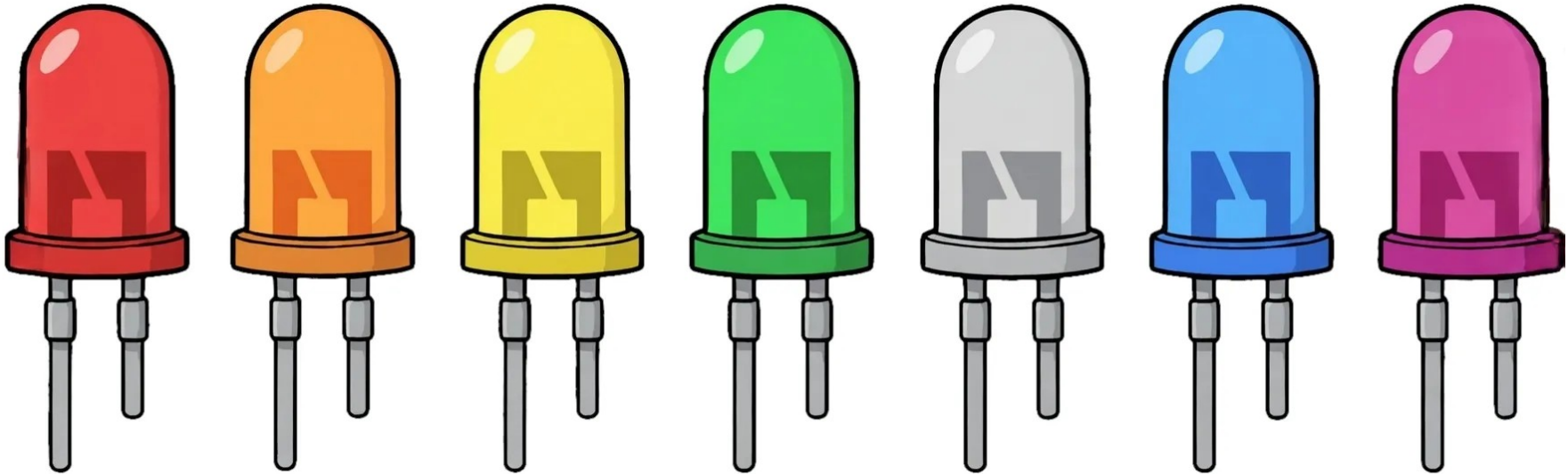


ZENER DIODE

IMPORTANT APPLICATIONS IN HAM RADIO

- **LIGHT INDICATION: A LIGHT-EMITTING DIODE (LED) GLOWS IN DIFFERENT COLOURS DEPENDING ON ITS CHEMICAL COMPOSITION (EX: RED, GREEN, BLUE, YELLOW).**
- **LEDs ARE DIODES TOO — THEY EMIT LIGHT WHEN FORWARD BIASED AND ARE EVERYWHERE IN HAM RADIOS FOR POWER INDICATORS, MODE LIGHTS, ETC.**

IMPORTANT APPLICATIONS IN HAM RADIO



LIGHT EMITTING DIODES

IMPORTANT APPLICATIONS IN HAM RADIO



**DIODES ARE THE GATEKEEPERS OF
CURRENT FLOW IN HAM RADIO.**



**THEY RECTIFY, PROTECT, REGULATE,
DETECT AND LIGHT UP!**





QUESTION SECTION B-004-003:

BIPOLAR TRANSISTORS (BJTS)

B-004-003: BIPOLAR TRANSISTORS (BJTS)

BIPOLAR TRANSISTORS:

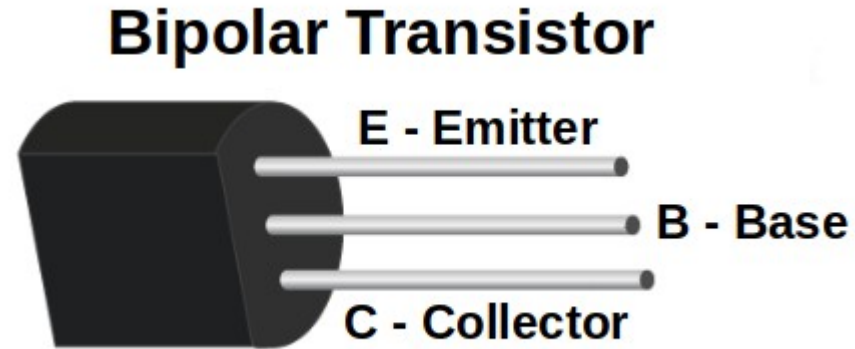
- **ONE OF THE MOST IMPORTANT SEMICONDUCTOR DEVICES IN AMATEUR RADIO. THEY CAN TAKE A TINY SIGNAL (LIKE FROM A MICROPHONE OR RECEIVER STAGE) AND MAKE IT MUCH LARGER USING ONLY LOW VOLTAGES — SOMETHING VACUUM TUBES STRUGGLE WITH AT LOW POWER. THIS MAKES THEM IDEAL FOR PORTABLE RIGS, QRP TRANSMITTERS, AUDIO STAGES, AND MANY OTHER HAM APPLICATIONS.**

WHAT IS A TRANSISTOR AND WHY IS IT USEFUL?:

- THE MOST BASIC SEMICONDUCTOR COMPONENT USED TO **AMPLIFY** A SIGNAL IS A **TRANSISTOR**. IT CAN AMPLIFY A SMALL SIGNAL USING LOW VOLTAGES.
- THE COMPONENT THAT DOES THIS BEST IS THE BIPOLAR TRANSISTOR.

STRUCTURE OF A BIPOLAR TRANSISTOR:

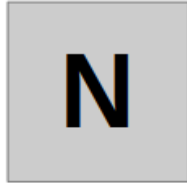
- A BIPOLAR TRANSISTOR HAS THREE ELECTRODES (LEADS/TERMINALS):
 - COLLECTOR
 - EMITTER
 - BASE



B-004-003: BIPOLAR TRANSISTORS (BJTS)

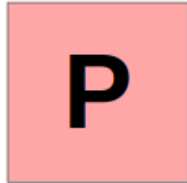
THERE ARE TWO BASIC TYPES:

- **NPN**



Has extra valence electron in the dopant
Electron is the primary voltage carrier
N is for Negative (extra electron)

- **PNP**

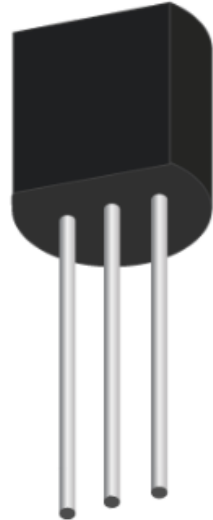


Missing valence electron in the dopant
The hole is the primary voltage carrier
P is for Positive (missing electron)
Mnemonic: you P in the hole!



This makes a **Diode**
Can be forward or reverse depending
on positive current source

Semiconductor Fun



Transistors can be
configured either way

B-004-003: BIPOLAR TRANSISTORS (BJTS)

HOW BIPOLAR TRANSISTORS WORK – AMPLIFICATION:

- A SMALL INPUT SIGNAL APPLIED TO THE BASE CONTROLS A MUCH LARGER CURRENT FLOWING FROM **COLLECTOR** TO **EMITTER** (IN AN NPN; REVERSE FOR PNP).
- THIS RESULTS IN AMPLIFICATION — A LOW-LEVEL INPUT SIGNAL PRODUCES A HIGHER-LEVEL OUTPUT SIGNAL.
- THE BASE IS THE CONTROL ELECTRODE: IT DIRECTLY CONTROLS THE OUTPUT CURRENT.

B-004-003: BIPOLAR TRANSISTORS (BJTS)

BIPOLAR TRANSISTORS AS SWITCHES:

- TRANSISTORS AREN'T JUST FOR AMPLIFICATION — THEY'RE ALSO EXCELLENT ELECTRONIC SWITCHES, COMMON IN KEYING CIRCUITS, TX/RX SWITCHING, DIGITAL MODES, AND MICRO-CONTROLLERS IN MODERN HAM GEAR.
- THE BASE CONTROLS WHETHER THE TRANSISTOR IS **ON** (CONDUCTING/SATURATED) OR **OFF** (CUT-OFF).
- WHEN DRIVEN ALTERNATELY INTO **SATURATION** (FULLY ON) AND **CUT-OFF** (FULLY OFF), IT BEHAVES LIKE A SWITCH.

B-004-003: BIPOLAR TRANSISTORS (BJTS)

PRACTICAL TIP – AVOIDING FAILURE:

- TRANSISTORS ARE RUGGED BUT SENSITIVE TO **EXCESSIVE HEAT** — ONE OF THE MOST COMMON CAUSES OF FAILURE IN HAM PROJECTS (EX: OVERDRIVING A FINAL, POOR HEATSINKING, OR HIGH DUTY CYCLE MODES LIKE FT8 WITHOUT COOLING).
- ALWAYS USE HEAT-SINKS WHEN NEEDED AND MONITOR TEMPERATURES.





QUESTION SECTION B-004-004:

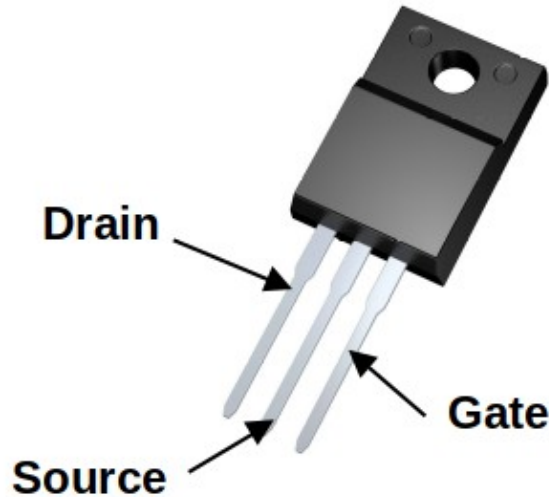
FIELD-EFFECT TRANSISTORS (FETS)

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

WHAT IS A FIELD-EFFECT TRANSISTOR?

A FIELD-EFFECT TRANSISTOR (FET) HAS THREE ELECTRODES:

- **GATE**
- **DRAIN**
- **SOURCE**



FET Transistor

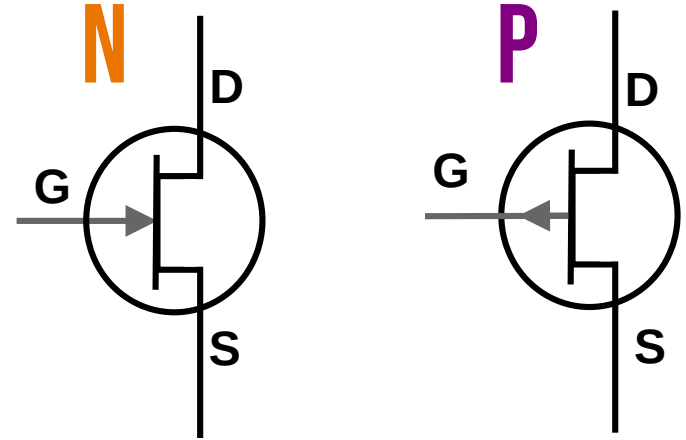
WHAT IS A FIELD-EFFECT TRANSISTOR?

- THE **GATE** CONTROLS THE RESISTANCE OF THE **CHANNEL** BETWEEN SOURCE AND DRAIN.
- CHARGE CARRIERS ENTER THE CHANNEL FROM THE **SOURCE** AND LEAVE THROUGH THE **DRAIN**.
- THE TWO ENDS OF THE CHANNEL ARE THE **SOURCE** AND **DRAIN**

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

TWO BASIC TYPES OF FETS:

- **N CHANNEL** (ELECTRONS AS CARRIERS)
- **P CHANNEL** (HOLES AS CARRIERS)



THE ARROW IN THE SCHEMATIC SYMBOL POINTS INWARD FOR N-CHANNEL (LIKE AN NPN BASE ARROW) AND OUTWARD FOR P-CHANNEL.

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

WHY FETS ARE HIGH-IMPEDANCE DEVICES

- THE GATE IS INSULATED (IN JFETS BY A REVERSE-BIASED JUNCTION; IN MOSFETS BY AN OXIDE LAYER), SO IT **NEVER CONDUCTS CURRENT** UNDER NORMAL OPERATION.
- THIS GIVES FETS EXTREMELY HIGH INPUT IMPEDANCE — OFTEN MILLIONS OR BILLIONS OF OHMS — PERFECT FOR NOT LOADING DOWN WEAK SIGNALS IN RECEIVERS OR ANTENNAS.

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

HOW FETS OPERATE (SIMPLIFIED)

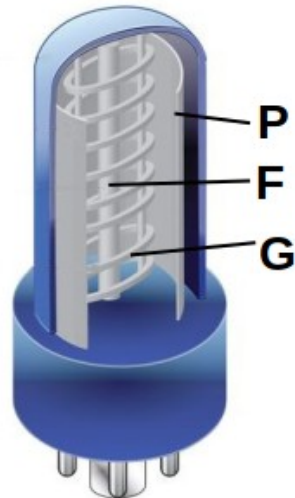
- **IN A TYPICAL JFET: THE GATE IS REVERSE-BIASED RELATIVE TO THE SOURCE.**
- **INCREASING THE REVERSE BIAS PINCHES OFF THE CHANNEL MORE
→ LESS CURRENT FLOWS FROM DRAIN TO SOURCE.**
- **DECREASING THE REVERSE BIAS (MAKING IT LESS NEGATIVE) WIDENS THE CHANNEL → CURRENT INCREASES.**
- **THIS VOLTAGE CONTROL IS WHY FETS ARE GREAT FOR VARIABLE GAIN OR SWITCHING WITH ALMOST NO POWER DRAW ON THE CONTROL LINE.**

COMPARING FETS TO BIPOLAR TRANSISTORS

- **FETS AND BIPOLARS DO SIMILAR JOBS (AMPLIFICATION, SWITCHING) BUT DIFFER IN CONTROL AND CHARACTERISTICS.**
- **THE NEXT SLIDE SHOWS THE DIRECT ELECTRODE CORRESPONDENCE (INCLUDING A VACUUM TUBE WHICH IS COVERED IN THE NEXT SECTION).**

B-004-004: FIELD-EFFECT TRANSISTORS (FETS)

Bipolar Transistor



Vacuum Tube

	Transistor	FET	Triode
Input	Emitter	Source	Fill/Cathode
Output	Collector	Drain	Plate/Anode
Control	Base	Gate	Control Grid

FET Transistor



Comparable
Connections



QUESTION SECTION B-004-005:

VACUUM TUBES (SPECIFICALLY TRIODES)

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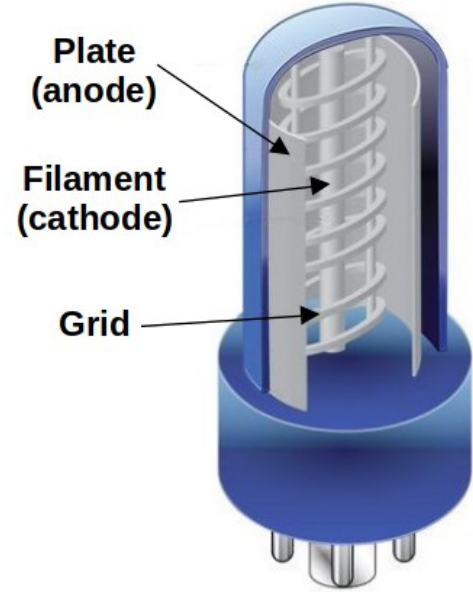
WHAT IS A TRIODE VACUUM TUBE?

- A TRIODE IS A VACUUM TUBE CONTAINING A **CATHODE**, A SINGLE **GRID**, AND A PLATE, ALL SEALED INSIDE AN **ENVELOPE** FILLED WITH A **VACUUM** (TO ALLOW FREE ELECTRON FLOW WITHOUT AIR INTERFERENCE).
- THE **CATHODE** (HEATED BY A FILAMENT) **EMITS ELECTRONS**.
- THE **GRID** (A WIRE MESH) ACTS AS THE **CONTROL ELEMENT** — A SMALL VOLTAGE CHANGE ON THE GRID CONTROLS A LARGE ELECTRON FLOW.
- THE **PLATE** (ALSO CALLED ANODE) COLLECTS THE ELECTRONS AND IS OPERATED AT THE **HIGHEST POSITIVE VOLTAGE** IN THE CIRCUIT.

B-004-005: VACUUM TUBES (SPECIFICALLY TRIODES)

WHAT IS A TRIODE VACUUM TUBE?

- THE TWO ELEMENTS THAT CARRY THE MAIN OUTPUT CURRENT (ELECTRON FLOW) ARE THE **CATHODE** AND **PLATE**.



Vacuum Tube

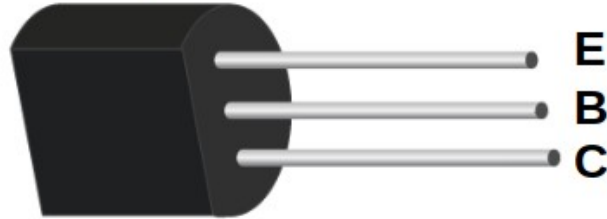
B-004-005: VACUUM TUBES (SPECIFICALLY TRIODES)

TRIODES VS. TRANSISTORS – SIMILARITIES AND DIFFERENCES

- BOTH TRIODES AND TRANSISTORS **CAN AMPLIFY SIGNALS** — THAT'S THE KEY SHARED FEATURE.
- A TRIODE'S CHARACTERISTICS (VOLTAGE CONTROL OF CURRENT, HIGH INPUT IMPEDANCE ON THE CONTROL ELEMENT) ARE MOST SIMILAR TO **A FIELD-EFFECT TRANSISTOR (FET)**, NOT A BIPOLAR TRANSISTOR.
- ONE BIG REASON HAMS STILL CHOOSE A TRIODE OVER A TRANSISTOR: **IT MAY BE ABLE TO HANDLE HIGHER POWER** (EX: TUBES LIKE THE 811A, 572B, OR 3-500Z CAN DISSIPATE HUNDREDS OR THOUSANDS OF WATTS IN RF SERVICE, FAR BEYOND MOST SOLID-STATE DEVICES WITHOUT COMPLEX COMBINING).

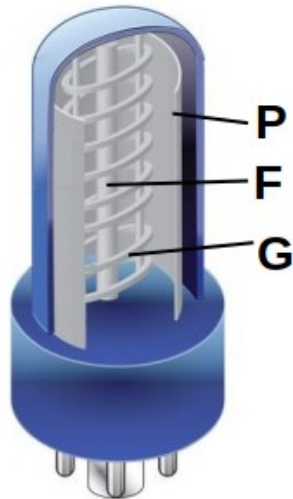
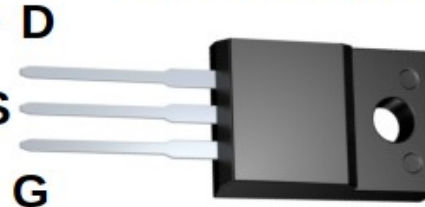
B-004-005: VACUUM TUBES (SPECIFICALLY TRIODES)

Bipolar Transistor



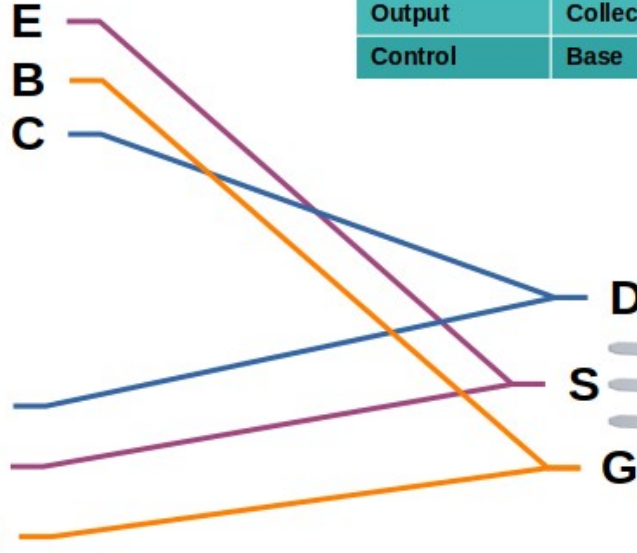
	Transistor	FET	Triode
Input	Emitter	Source	Fill/Cathode
Output	Collector	Drain	Plate/Anode
Control	Base	Gate	Control Grid

FET Transistor



Vacuum Tube

**Comparable
Connections**



B-004-005: VACUUM TUBES (SPECIFICALLY TRIODES)

HAM RADIO CONTEXT

- **TRIODES SHINE IN:**
 - **HIGH-POWER RF FINALS/LINEAR AMPS (EX: GROUNDED-GRID DESIGNS).**
 - **VINTAGE RECEIVER/TRANSMITTER RESTORATION.**
 - **AUDIO STAGES WHERE "TUBE WARMTH" IS DESIRED (THOUGH DEBATED).**
 - **MODERN HAMS OFTEN MIX: SOLID-STATE FOR LOW-POWER/QRP, TUBES FOR HIGH-POWER SSB/CW.**



QUESTION SECTION B-004-006:

RESISTORS

FOUR-BAND RESISTOR COLOUR CODE BASICS

- STANDARD FOUR-BAND RESISTORS ARE READ FROM LEFT TO RIGHT (TOLERANCE BAND IS USUALLY SEPARATED OR GOLD/SILVER).
- **FIRST BAND:** FIRST SIGNIFICANT DIGIT
- **SECOND BAND:** SECOND SIGNIFICANT DIGIT
- **THIRD BAND:** MULTIPLIER (POWER OF 10)
- **FOURTH BAND:** TOLERANCE (% ACCURACY)

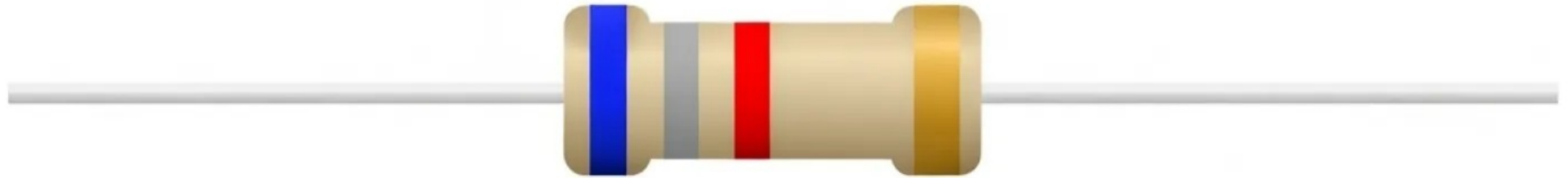


B-004-006: RESISTORS

TOLERANCE – PRECISION AND ACCEPTABLE RANGE

- **TOLERANCE TELLS YOU THE GUARANTEED ACCURACY. COMMON VALUES:
GOLD = $\pm 5\%$, SILVER = $\pm 10\%$, NO BAND = $\pm 20\%$.**
- **HIGHER PRECISION = LOWER % TOLERANCE.**
- **EXAMPLE: 0.1% IS VERY PRECISE, USED IN MEASUREMENT GEAR.**
- **LOWEST PRECISION = 20% (OLD CARBON RESISTORS).**
- **EXAMPLE: A 100Ω RESISTOR WITH 10% TOLERANCE CAN ACTUALLY BE ANYWHERE FROM 90 OHMS TO 110 OHMS.**

Resistor Colour Code Guide



Colour Value:	1	2	3	4	5	6	7	8	9	0
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±Tolerance:	1%	2%		0.5%	0.25%	0.1%				
			Silver 10%	Gold 5%						

B-004-006: RESISTORS

EXAMPLE CALCULATION

- **COLORS: RED (2), VIOLET (7), YELLOW ($\times 10,000$ OR 10^4), TOLERANCE GOLD ($\pm 5\%$).**
- **VALUE = $27 \times 10,000 = 270,000$ OHMS = 270 KILOHMS (OR 270 K Ω).**

Colour Value:	1	2	3	4	5	6	7	8	9	0
$\pm$ Tolerance:	1%	2%			0.5%	0.25%	0.1%			
								Silver 10%		Gold 5%

TEMPERATURE EFFECTS

- RESISTANCE ISN'T FIXED — IT CHANGES WITH TEMPERATURE. THE CHANGE DEPENDS ON THE **TEMPERATURE COEFFICIENT** (HOW MUCH RESISTANCE VARIES PER DEGREE CELSIUS, OFTEN IN PPM/°C).
- POSITIVE COEFFICIENT: RESISTANCE INCREASES WITH HEAT (MOST METALS).
- NEGATIVE COEFFICIENT: RESISTANCE DECREASES (SOME TYPES LIKE THERMISTORS, BUT NOT TYPICAL FIXED RESISTORS).
- IN HAM GEAR, HEAT FROM TRANSMITTERS OR POOR VENTILATION CAN SHIFT BIAS OR TUNING — USE **LOW-TC** RESISTORS IN CRITICAL SPOTS (EX: OSCILLATORS).



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