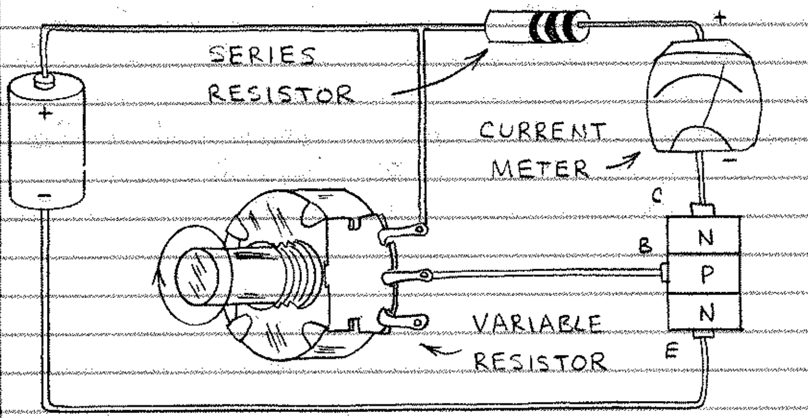
☐ A BIPOLAR TRANSISTOR DC AMPLIFIER — THE VARIABLE RESISTOR FORWARD BIASES THE TRANSISTOR AND CONTROLS THE INPUT (BASE-EMITTER) CURRENT. THE METER INDICATES THE OUTPUT (COLLECTOR - EMITTER) CURRENT. THE SERIES RESISTOR PROTECTS THE METER FROM EXCESSIVE CURRENT.



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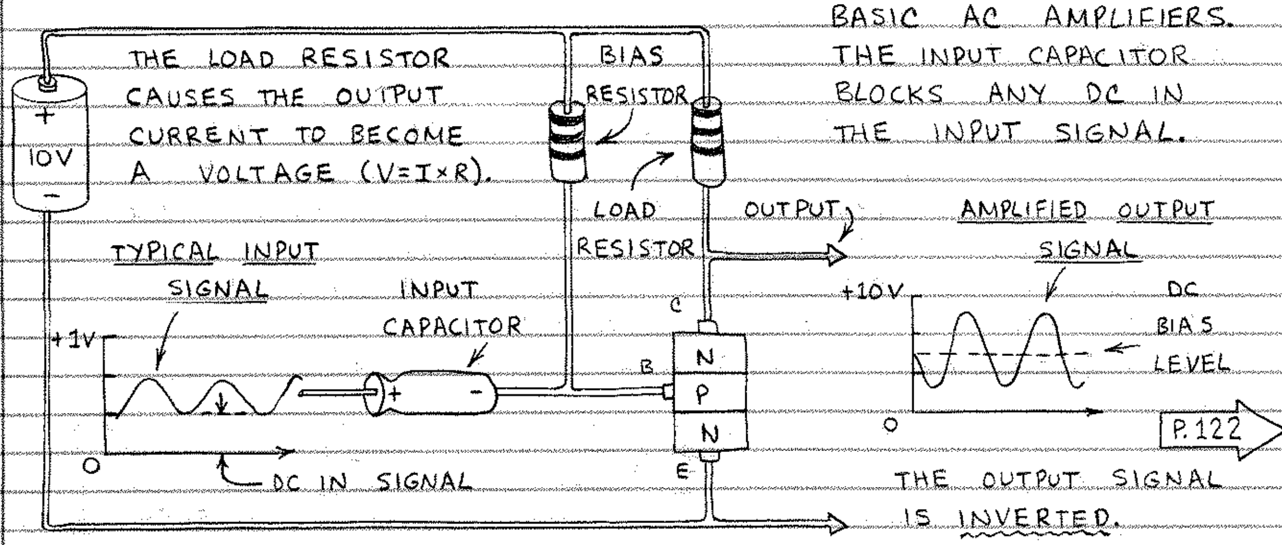
IN A WORKING CIRCUIT, THE VARIABLE RESISTOR MAY BE IN SERIES WITH A SECOND COMPONENT HAVING A RESISTANCE THAT VARIES WITH TEMPERATURE, LIGHT, MOISTURE, ETC. (WATER IS THE VARIABLE RESISTANCE IN THE MOISTURE METER ON P. 104.) WHEN THE INPUT SIGNAL CHANGES RAPIDLY, AN AC AMPLIFIER SUCH AS THE ONE BELOW IS USED.

☐ A BIPOLAR TRANSISTOR AC AMPLIFIER — THIS IS THE SIMPLEST OF SEVERAL BASIC AC AMPLIFIERS. THE INPUT CAPACITOR BLOCKS ANY DC IN THE INPUT SIGNAL.



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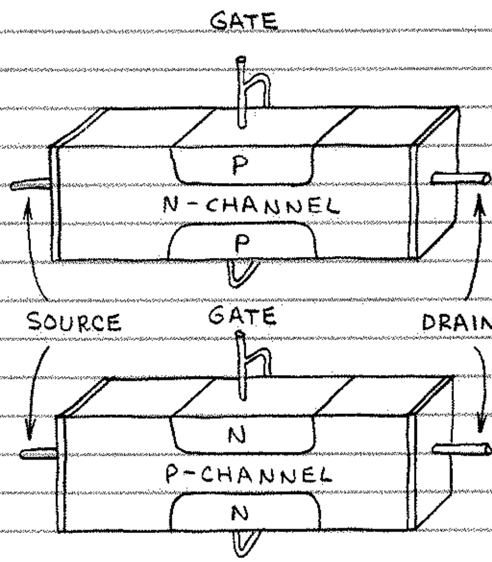
THE OUTPUT SIGNAL IS INVERTED.

THE BIAS RESISTOR IS SELECTED TO GIVE AN OUTPUT VOLTAGE OF ABOUT HALF THE BATTERY VOLTAGE. THE AMPLIFIED SIGNAL "RIDES" ON THIS STEADY OUTPUT VOLTAGE AND VARIES ABOVE AND BELOW IT. (WITHOUT THE BIAS RESISTOR, ONLY THE POSITIVE HALF OF THE INPUT SIGNAL ABOVE 0.6 VOLT (SEE P. 45) WILL BE AMPLIFIED. THIS WILL CAUSE SEVERE DISTORTION.) TO SEE ONE WAY A WORKING VERSION OF THIS AMPLIFIER IS USED, TURN NOW TO P. 122 AND LOOK AT THE OUTPUT SECTION OF THE LIGHTWAVE TRANSMITTER.

FIELD-EFFECT TRANSISTORS

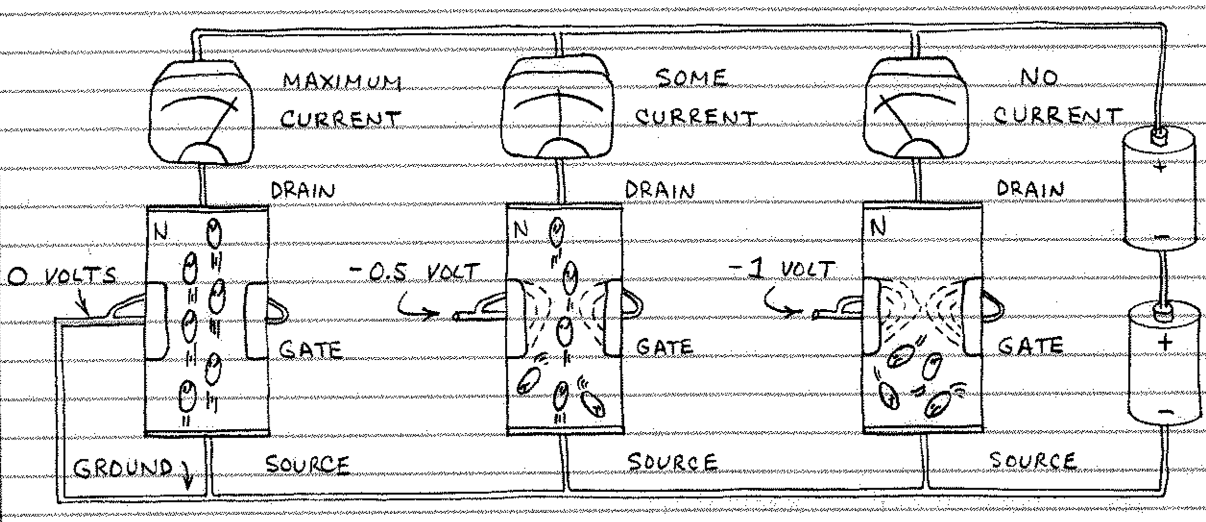
FIELD-EFFECT TRANSISTORS (OR FETs) HAVE BECOME MORE IMPORTANT THAN BIPOLAR TRANSISTORS. THEY ARE EASY TO MAKE AND REQUIRE LESS SILICON. THERE ARE TWO MAJOR FET FAMILIES, JUNCTION AND METAL-OXIDE-SEMICONDUCTOR. IN BOTH KINDS AN OUTPUT CURRENT IS CONTROLLED BY A SMALL INPUT VOLTAGE AND PRACTICALLY NO INPUT CURRENT!

JUNCTION FETs



THE TWO MAIN KINDS OF FETs ARE N-CHANNEL AND P-CHANNEL. THE CHANNEL IS LIKE A SILICON RESISTOR THAT CONDUCTS CURRENT MOVING FROM THE SOURCE TO THE DRAIN. A VOLTAGE AT THE GATE INCREASES THE CHANNEL RESISTANCE AND REDUCES THE DRAIN-SOURCE CURRENT. THEREFORE THE FET CAN BE USED AS AN AMPLIFIER OR A SWITCH.

☐ JUNCTION FET OPERATION— THE ARRANGEMENT BELOW SHOWS HOW AN N-CHANNEL FET WORKS. A NEGATIVE GATE VOLTAGE CREATES TWO HIGH RESISTANCE REGIONS (THE FIELD) IN THE CHANNEL ADJACENT TO THE P-TYPE SILICON. MORE GATE VOLTAGE WILL CAUSE THE FIELDS TO MERGE TOGETHER AND COMPLETELY BLOCK THE CURRENT. THE GATE-CHANNEL RESISTANCE IS VERY HIGH.



☐ MORE ABOUT JUNCTION FETs — SINCE THEY ARE VOLTAGE CONTROLLED, JUNCTION FETs (OR JFETs) HAVE IMPORTANT ADVANTAGES OVER CURRENT-CONTROLLED BIPOLAR TRANSISTORS:

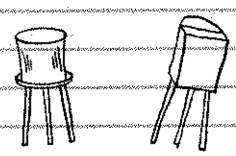
1. THE GATE-CHANNEL RESISTANCE OF A JFET IS VERY HIGH (MILLIONS OF OHMS). THEREFORE THE JFET HAS LITTLE OR NO EFFECT ON EXTERNAL COMPONENTS OR CIRCUITS CONNECTED TO ITS GATE.

2. THE VERY HIGH GATE-CHANNEL RESISTANCE MEANS PRACTICALLY NO CURRENT FLOWS IN THE GATE CIRCUIT. (WHY IS THE RESISTANCE SO HIGH? THE GATE AND CHANNEL FORM A DIODE. SO LONG AS THE INPUT SIGNAL <u>REVERSE</u> BIASES THIS DIODE, THE GATE HAS VERY HIGH INPUT RESISTANCE.)

3. LIKE BIPOLAR TRANSISTORS, JFETs CAN BE DAMAGED OR DESTROYED BY EXCESSIVE CURRENT OR VOLTAGE.

☐ KINDS OF JUNCTION FETs — JFETs ARE USED IN MANY DIFFERENT APPLICATIONS. SINCE THEY CANNOT BE USED FOR HIGH POWER ROLES, MOST ARE INSTALLED IN SMALL PLASTIC OR METAL PACKAGES. HERE ARE THE MAIN CATEGORIES:

SMALL SIGNAL AND SWITCHING.

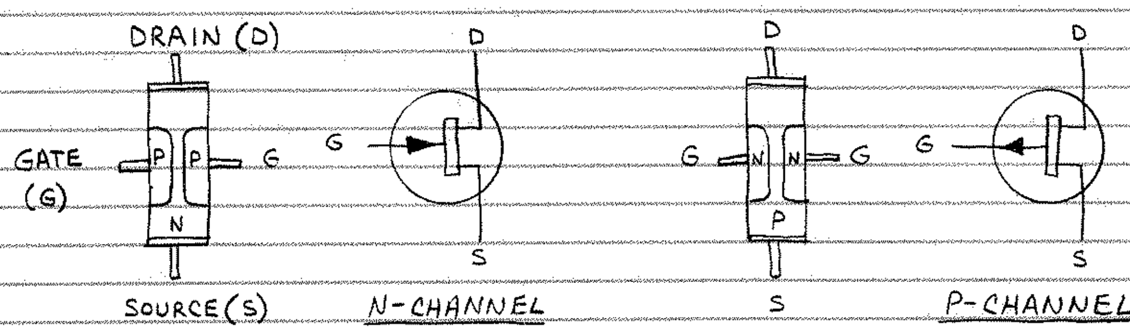


SMALL SIGNAL JFETs ARE USED AT THE INPUT STAGE OF AMPLIFIERS TO PROVIDE A HIGH RESISTANCE INPUT. THEY ARE ALSO USED AS SWITCHES.

HIGH FREQUENCY.

HIGH FREQUENCY JFETS ARE USED TO AMPLIFY OR PRODUCE HIGH FREQUENCY SIGNALS.

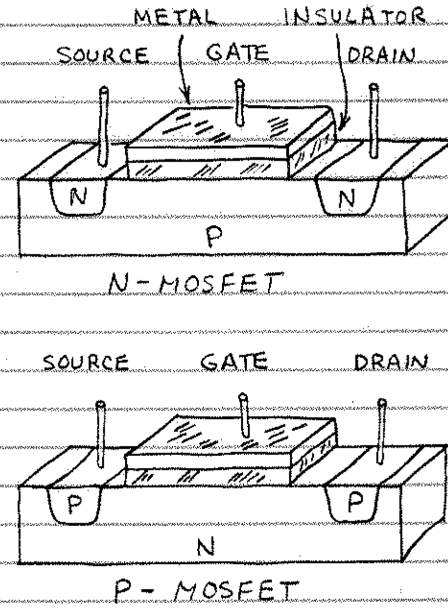
☐ JUNCTION FET SYMBOLS — GATES INTERNALLY CONNECTED.



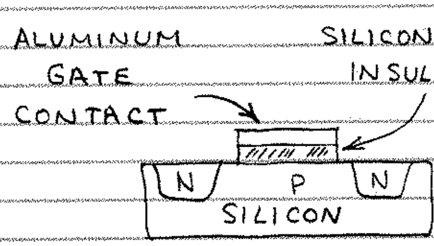
N-CHANNEL P-CHANNEL

METAL-OXIDE-SEMICONDUCTOR FETs

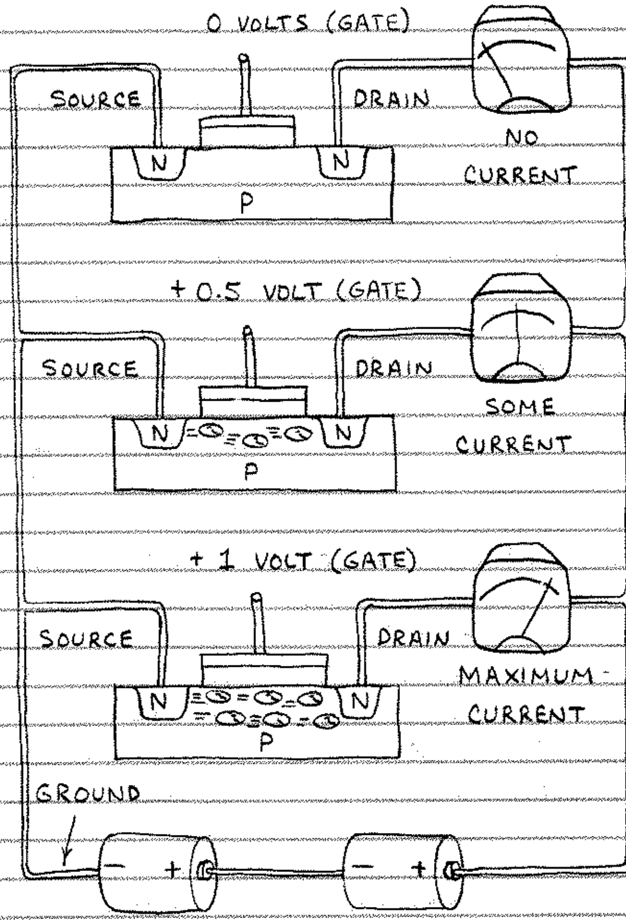
THE METAL-OXIDE-SEMICONDUCTOR FET (OR MOSFET) HAS BECOME THE MOST IMPORTANT TRANSISTOR. MOST MICROCOMPUTER AND MEMORY INTEGRATED CIRCUITS ARE ARRAYS OF THOUSANDS OF MOSFETs ON A SMALL SLIVER OF SILICON. WHY? MOSFETs ARE EASY TO MAKE, THEY CAN BE VERY SMALL, AND SOME MOSFET CIRCUITS CONSUME NEGLIGIBLE POWER. NEW KINDS OF POWER MOSFETS ARE ALSO VERY USEFUL.



☐ MOSFET OPERATION— ALL MOSFETs ARE N-TYPE OR P-TYPE. UNLIKE THE JUNCTION FET, THE GATE OF A MOSFET HAS NO ELECTRICAL CONTACT WITH THE SOURCE AND DRAIN. A GLASS-LIKE LAYER OF SILICON-DIOXIDE (AN INSULATOR) SEPARATES THE GATE'S METAL CONTACT FROM THE REST OF THE TRANSISTOR.



A POSITIVE GATE VOLTAGE ATTRACTS ELECTRONS TO THE REGION BELOW THE GATE. THIS CREATES A THIN N-TYPE CHANNEL IN THE P-TYPE SILICON BETWEEN THE SOURCE AND DRAIN. CURRENT CAN THEN FLOW THROUGH THE CHANNEL. THE GATE VOLTAGE DETERMINES THE RESISTANCE OF THE CHANNEL.



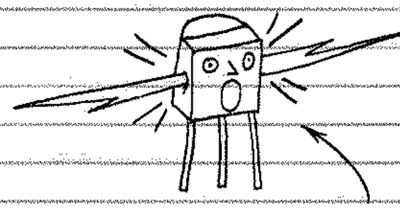
☐ MORE ABOUT MOSFETs — THE INPUT RESISTANCE OF THE MOSFET IS THE HIGHEST OF ANY TRANSISTOR. THIS AND OTHER FACTORS GIVE MOSFETs IMPORTANT ADVANTAGES:

1. THE GATE-CHANNEL RESISTANCE IS ALMOST INFINITE (TYPICALLY 1,000,000,000,000,000-OHMS). THIS MEANS THE GATE PULLS <u>NO</u> CURRENT FROM EXTERNAL CIRCUITS. (WELL, IT MAY BORROW A FEW TRILLIONTHS OF AN AMPERE.)

2. MOSFETs CAN FUNCTION AS VOLTAGE-CONTROLLED VARIABLE RESISTORS. THE GATE VOLTAGE CONTROLS CHANNEL RESISTANCE.

3. NEW KINDS OF MOSFETs CAN SWITCH VERY HIGH CURRENTS IN A FEW BILLIONTHS OF A SECOND.

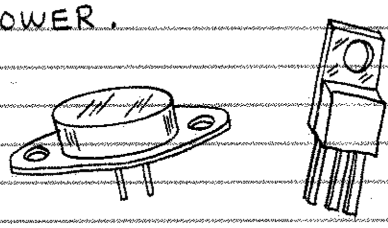
☐ CAUTION — BECAUSE THE GLASS-LIKE SILICON OXIDE LAYER BELOW THE GATE IS SO THIN, IT CAN BE PIERCED BY TOO MUCH VOLTAGE OR EVEN STATIC ELECTRICITY. EVEN THE STATIC CHARGE GENERATED BY CLOTHING OR A CELLOPHANE WRAPPER CAN ZAP THE GATE OF A MOSFET!


ZAPPED MOSFET


CAUTION SYMBOL

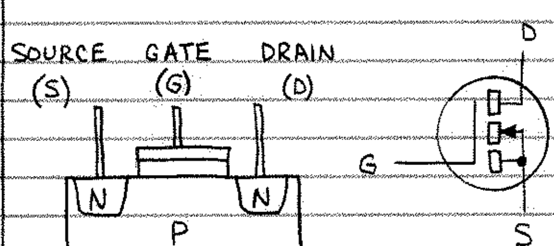
☐ KINDS OF MOSFETS — LIKE JFETs, MOSFETs INSTALLED IN SMALL METAL OR PLASTIC PACKAGES ARE USED TO GIVE AMPLIFIERS AN ULTRA-HIGH INPUT RESISTANCE. THEY ARE ALSO USED AS VOLTAGE CONTROLLED RESISTORS AND SWITCHES. THE MOST IMPORTANT CATEGORY HAS BECOME:

POWER.

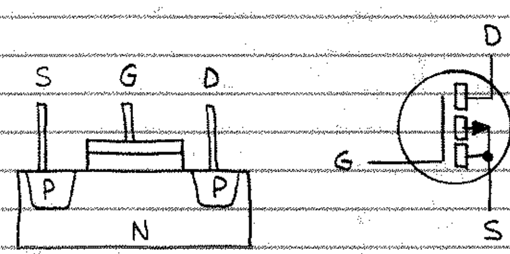


POWER MOSFETs ALLOW A FEW VOLTS TO SWITCH OR AMPLIFY MANY AMPERES AT VERY FAST SPEEDS.

☐ MOSFET SYMBOLS — THESE ARE THE MOST COMMON.



<u>N-MOSFET</u>

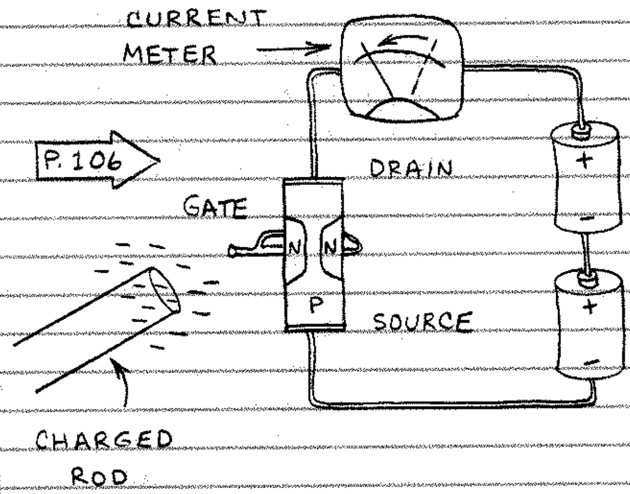


<u>P-MOSFET</u>

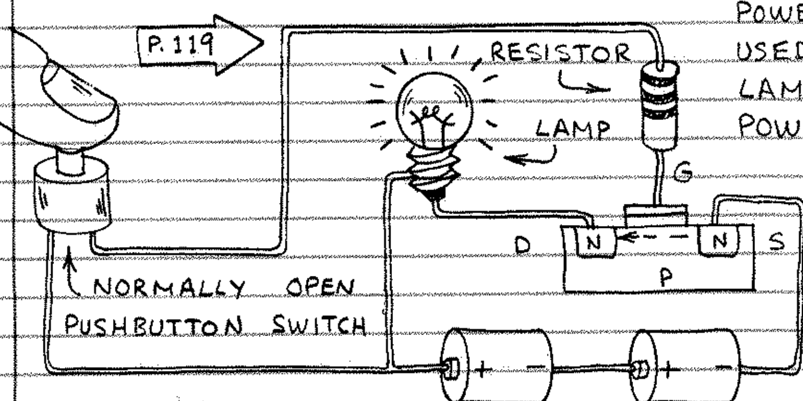
HOW FETs ARE USED

FIELD-EFFECT TRANSISTORS ARE USED AS AMPLIFIERS, SWITCHES AND VOLTAGE-CONTROLLED RESISTORS. HERE ARE SOME TYPICAL CIRCUIT ARRANGEMENTS.

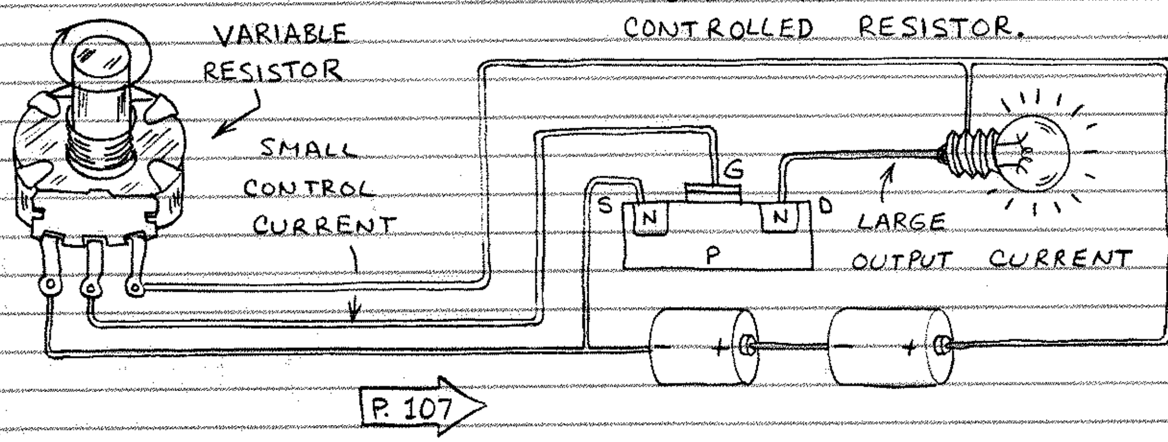
☐ A JFET ELECTROMETER — THIS ULTRA-SIMPLE CIRCUIT IS THE ELECTRONIC VERSION OF THE ELECTROSCOPE. THE GATE LEAD OF AN N-CHANNEL JFET IS LEFT DISCONNECTED. NORMALLY A CURRENT FLOWS FROM SOURCE TO DRAIN. WHEN A NEGATIVELY CHARGED OBJECT (LIKE A PLASTIC COMB THAT'S BEEN STROKED THROUGH YOUR HAIR) IS PLACED NEAR THE GATE, THE CURRENT FLOW IS REDUCED OR STOPPED.



☐ A MOSFET LAMP DRIVER — THIS CIRCUIT SHOWS HOW A POWER MOSFET CAN BE USED TO SWITCH ON A LAMP OR OTHER DC POWERED DEVICE. SINCE THE POWER MOSFET HAS AN ALMOST INFINITE INPUT RESISTANCE, THE SWITCH CAN BE REPLACED BY A TINY INPUT SIGNAL.

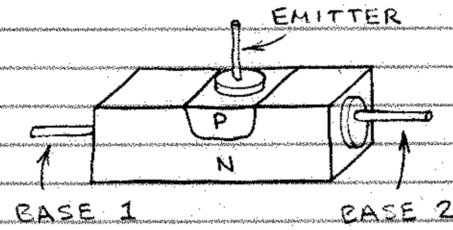


☐ A MOSFET LAMP DIMMER — THIS CIRCUIT USES A POWER MOSFET AS A VOLTAGE CONTROLLED RESISTOR.

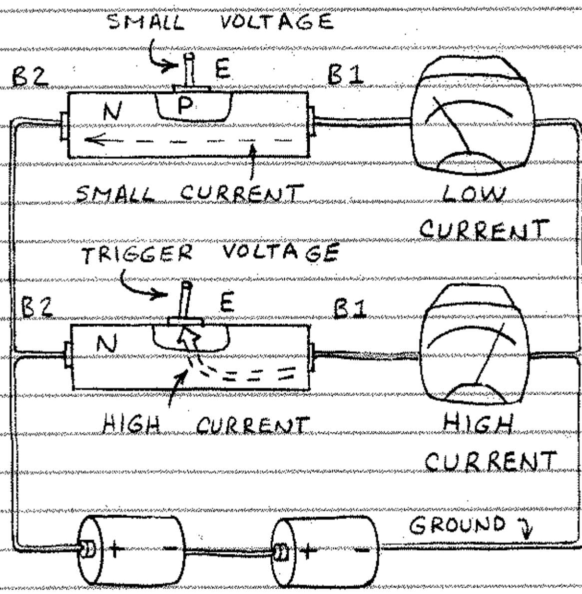


THE UNIJUNCTION TRANSISTOR

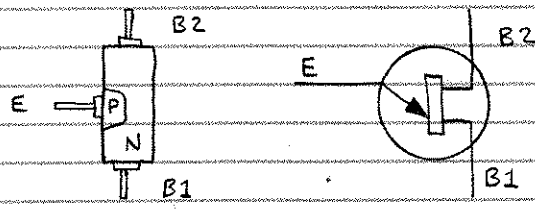
THE UNIJUNCTION TRANSISTOR (UJT) IS NOT A TRUE TRANSISTOR. IT'S MORE LIKE A DIODE WITH TWO CATHODE CONNECTIONS. IT WORKS LIKE A VOLTAGE-CONTROLLED SWITCH AND DOES NOT AMPLIFY.



☐ UJT OPERATION — NORMALLY A SMALL CURRENT WILL FLOW FROM BASE 1 TO BASE 2. WHEN THE VOLTAGE APPLIED TO THE EMITTER REACHES A CERTAIN THRESHOLD (SEVERAL VOLTS), THE UJT SWITCHES ON AND A HIGH CURRENT FLOWS FROM BASE 1 TO THE EMITTER. BELOW THE THRESHOLD VOLTAGE, NO CURRENT FLOWS FROM BASE 1 TO THE EMITTER.

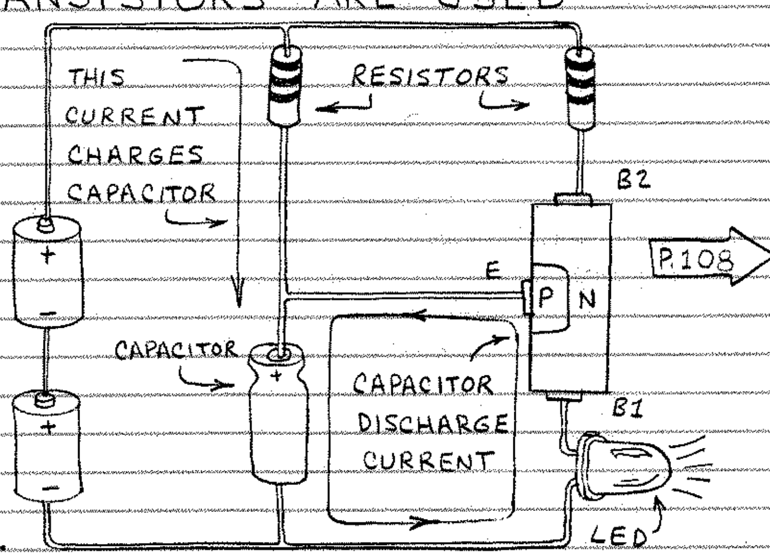


☐ UJT SYMBOL — THE SYMBOL FOR THE UJT RESEMBLES THAT OF A JFET.

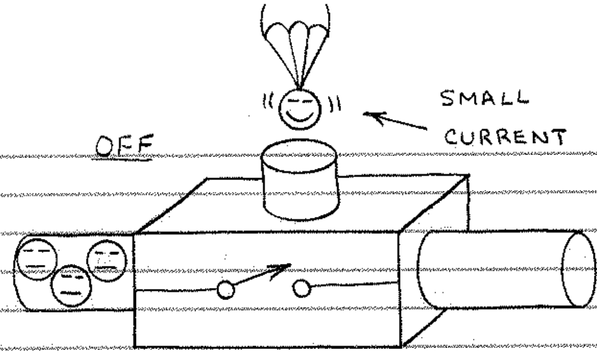


HOW UNIJUNCTION TRANSISTORS ARE USED

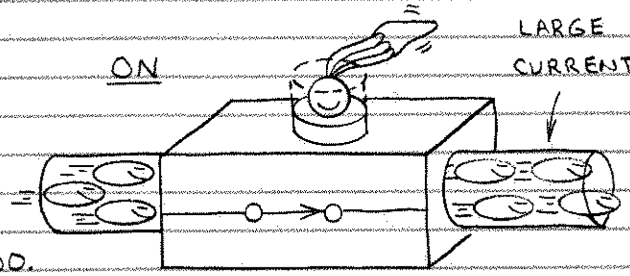
THIS ARRANGEMENT ALLOWS A UJT TO FLASH A LIGHT-EMITTING DIODE (LED). CURRENT FLOWS INTO THE CAPACITOR UNTIL THE UJT'S TRIGGER VOLTAGE IS REACHED. THE CURRENT IN THE CAPACITOR IS THEN "DUMPED" THROUGH THE LED. THE LED GLOWS UNTIL THE CAPACITOR IS DISCHARGED. THE CHARGE-DISCHARGE CYCLE THEN REPEATS.



THE THYRISTOR

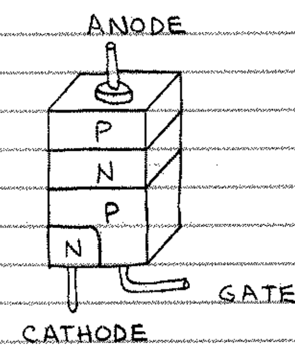


THYRISTORS ARE SEMICONDUCTOR DEVICES WITH THREE LEADS. A SMALL CURRENT AT ONE LEAD WILL ALLOW A MUCH LARGER CURRENT TO FLOW THROUGH THE OTHER TWO LEADS. THE CONTROLLED CURRENT IS EITHER ON OR OFF. THEREFORE THYRISTORS DO NOT AMPLIFY FLUCTUATING SIGNALS LIKE TRANSISTORS DO. INSTEAD THEY ARE SOLID-STATE SWITCHES. THERE ARE TWO FAMILIES OF THYRISTORS, SILICON-CONTROLLED RECTIFIERS (SCRs) AND TRIACs. SCRs SWITCH DIRECT CURRENT AND TRIACs SWITCH ALTERNATING CURRENT.

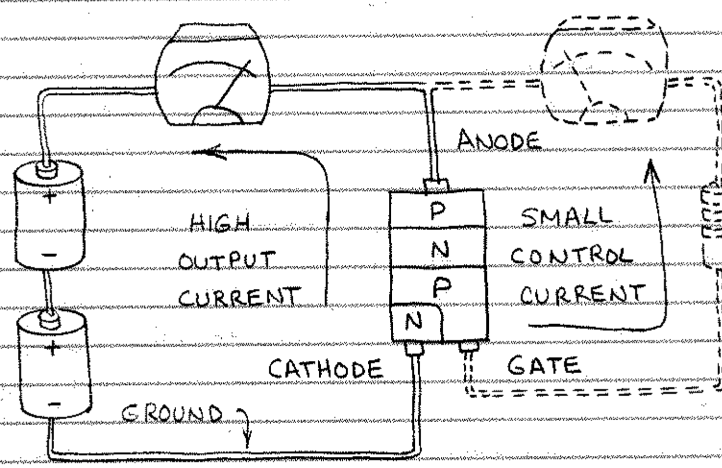


SILICON-CONTROLLED RECTIFIERS (SCRs)

THE SCR IS SIMILAR TO A BIPOLAR TRANSISTOR WITH A FOURTH LAYER AND THEREFORE THREE PN JUNCTIONS. IT IS SOMETIMES CALLED A 4-LAYER PNPN DIODE SINCE IT PASSES A CURRENT IN ONLY ONE DIRECTION.

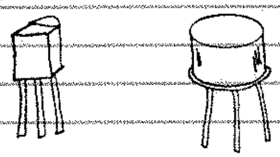


☐ SCR OPERATION — IF THE ANODE OF AN SCR IS MADE MORE POSITIVE THAN THE CATHODE THE TWO OUTERMOST PN JUNCTIONS ARE FORWARD BIASED. THE MIDDLE PN JUNCTION, HOWEVER, IS REVERSE BIASED AND CURRENT CANNOT FLOW. A SMALL GATE CURRENT FORWARD BIASES THE MIDDLE PN JUNCTION AND ALLOWS A MUCH LARGER CURRENT TO FLOW THROUGH THE DEVICE. THE SCR STAYS ON EVEN IF THE GATE CURRENT IS REMOVED! (UNTIL POWER IS DISCONNECTED.)



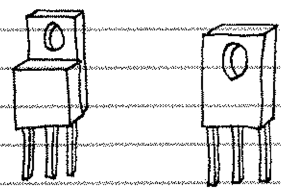
☐ KINDS OF SCRs — SCRs ARE CATEGORIZED ACCORDING TO THE CURRENT THEY CAN SWITCH. HERE ARE THREE GENERAL CATEGORIES (MANY OTHER CASE STYLES ARE AVAILABLE):

LOW CURRENT.



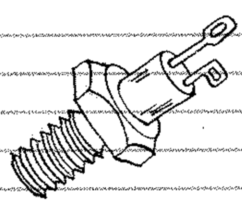
LOW CURRENT SCRs INCLUDE THOSE THAT SWITCH UP TO 1-AMPERE AT UP TO 100-VOLTS.

MEDIUM CURRENT.



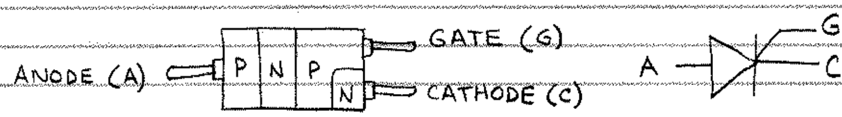
THESE SCRs SWITCH UP TO 10-AMPERES AT UP TO SEVERAL HUNDRED VOLTS. ONE COMMON USE IS SOLID-STATE SWITCHING FOR AUTO ENGINES.

HIGH CURRENT.



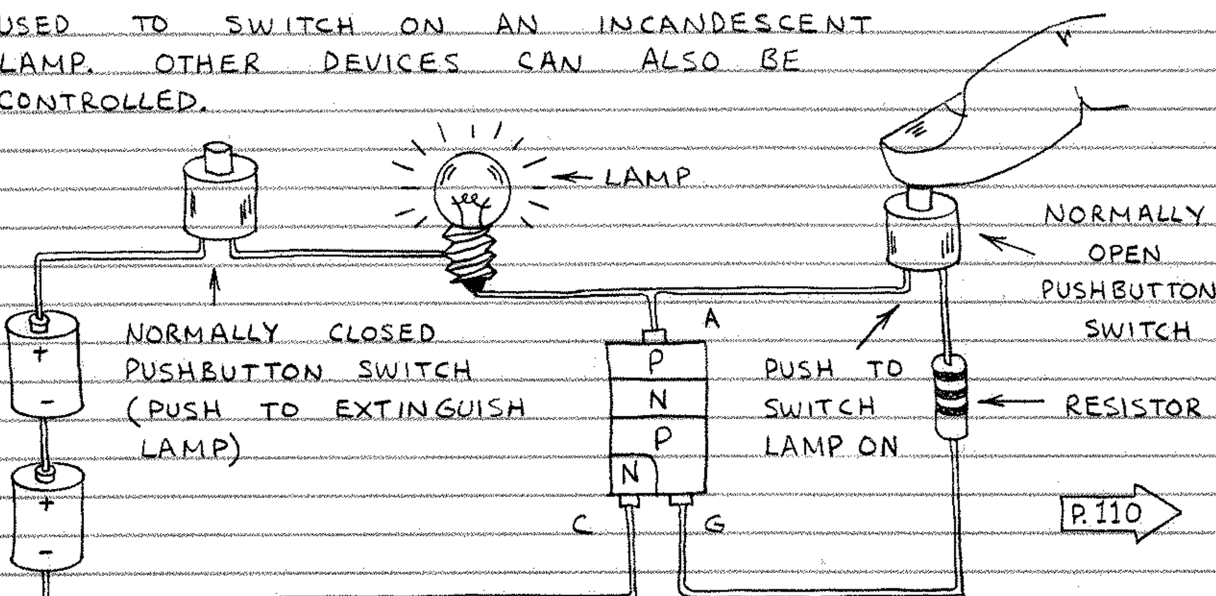
THESE SCRs CAN SWITCH UP TO 2,500-AMPERES AT UP TO SEVERAL THOUSAND VOLTS! THEY CONTROL MOTORS, LIGHTS, APPLIANCES, ETC.

☐ SCR SYMBOL.



HOW SCRs ARE USED

THIS ARRANGEMENT SHOWS HOW AN SCR IS USED TO SWITCH ON AN INCANDESCENT LAMP. OTHER DEVICES CAN ALSO BE CONTROLLED.



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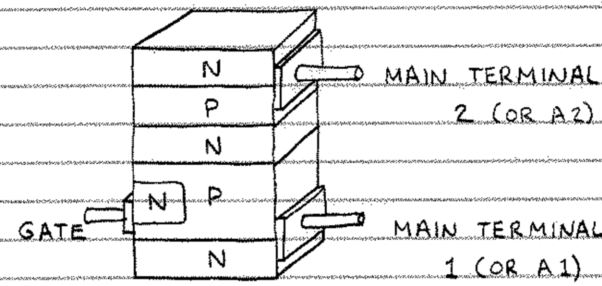
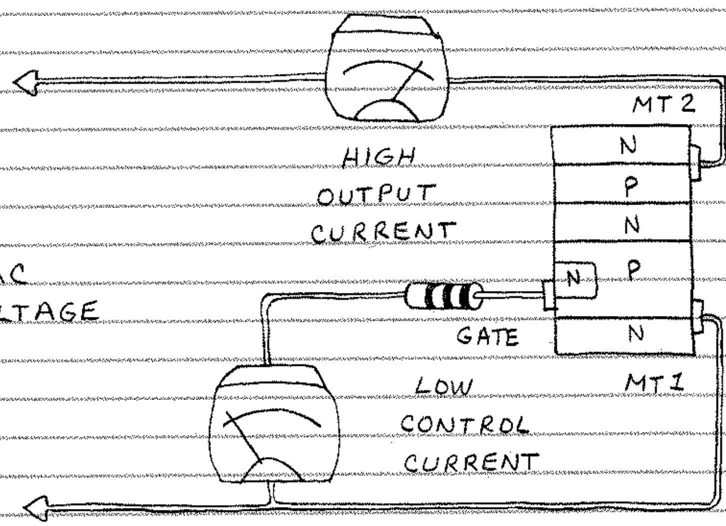
TRIACS

THE TRIAC IS EQUIVALENT TO TWO SCRs CONNECTED IN PARALLEL. THIS MEANS TRIACS CAN SWITCH BOTH DIRECT AND ALTERNATING CURRENT. NOTICE THAT THE TRIAC HAS FIVE LAYERS PLUS AN EXTRA N-TYPE REGION. ALSO NOTE HOW ALL THREE LEADS MAKE CONTACT WITH TWO LAYERS.

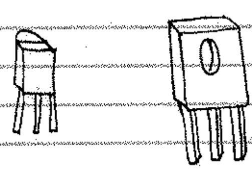


☐ TRIAC OPERATION — THE TWO PARALLEL SCRs THAT FORM A TRIAC FACE IN OPPOSITE DIRECTIONS (REVERSE-PARALLEL). WHEN USED TO SWITCH ALTERNATING CURRENT, THE TRIAC STAYS ON ONLY WHEN THE GATE RECEIVES CURRENT. REMOVE THE GATE CURRENT AND IT SWITCHES OFF WHEN THE AC PASSES THROUGH 0 VOLTS.



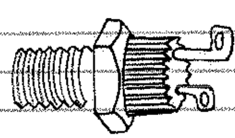
☐ KINDS OF TRIACS — TRIACS, LIKE SCRs, ARE CATEGORIZED ACCORDING TO THE CURRENT THEY CAN SWITCH. TRIACS DON'T HAVE THE VERY HIGH POWER CAPABILITY OF HIGH CURRENT SCRs. HERE ARE TWO CATEGORIES:

LOW CURRENT.



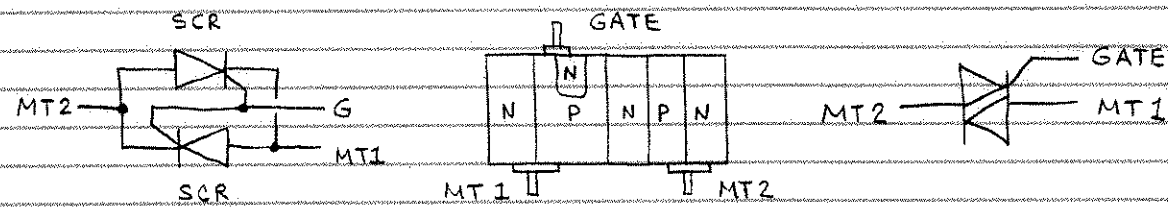
LOW CURRENT TRIACS SWITCH UP TO 1-AMPERE AT UP TO SEVERAL HUNDRED VOLTS. OTHER CASE STYLES ALSO USED.

MEDIUM CURRENT.



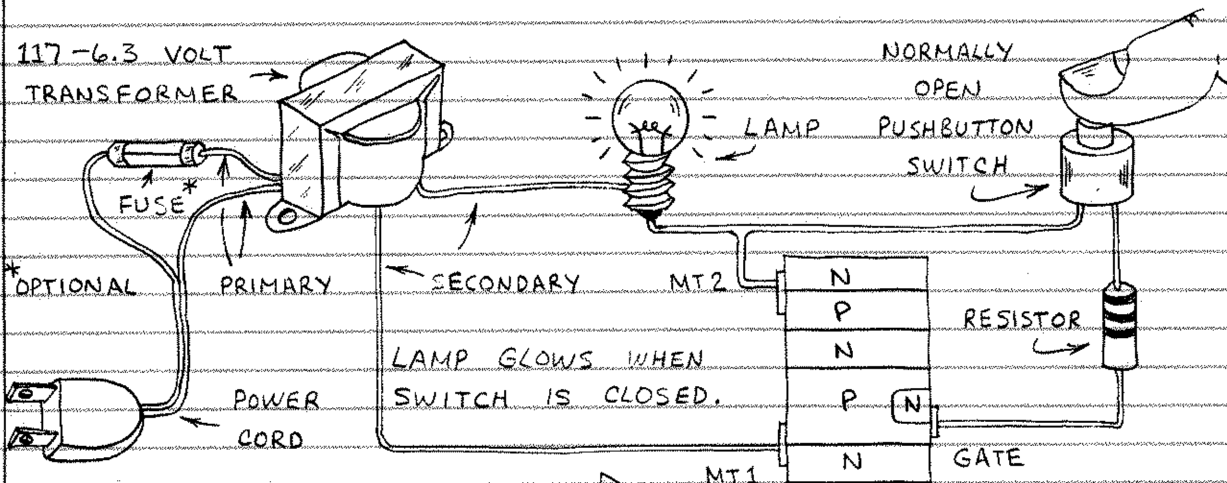
THESE TRIACS SWITCH UP TO 40-AMPERES AT UP TO 1,000-VOLTS. MANY CASE STYLES ARE AVAILABLE.

☐ TRIAC SYMBOL — REMEMBER, THE TRIAC IS THE SAME AS TWO REVERSE-PARALLEL SCRs:



HOW TRIACS ARE USED

THIS ARRANGEMENT SHOWS HOW A TRIAC CAN SWITCH ON A LAMP POWERED BY HOUSEHOLD LINE CURRENT. MOTORS AND OTHER DEVICES CAN ALSO BE CONTROLLED.

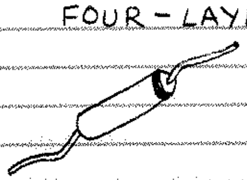


CAUTION: DO NOT ASSEMBLE. P. 111

TWO-LEAD THYRISTORS

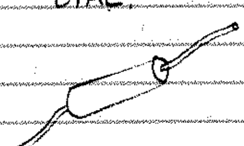
AN SCR OR TRIAC WILL SWITCH ON WITHOUT A GATE SIGNAL IF THE VOLTAGE ACROSS ITS OTHER TWO LEADS REACHES A CERTAIN LEVEL (THE BREAKDOWN VOLTAGE). THIS SELF-SWITCHING ABILITY MAKES POSSIBLE TWO-LEAD THYRISTORS.

FOUR-LAYER DIODE.



A FOUR-LAYER DIODE IS AN SCR WITHOUT A GATE. IT SWITCHES DC VOLTAGE.

DIAC.



A DIAC IS A THREE-LAYER DEVICE SIMILAR TO A PNP JUNCTION TRANSISTOR WITHOUT A BASE LEAD. IT SWITCHES AC VOLTAGE.

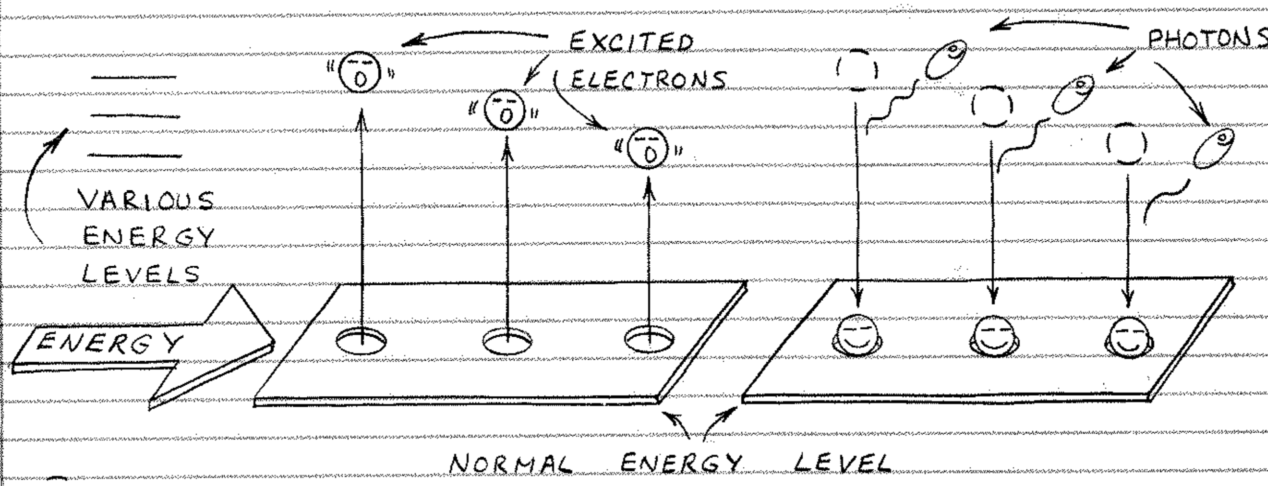
4. PHOTONIC SEMICONDUCTORS

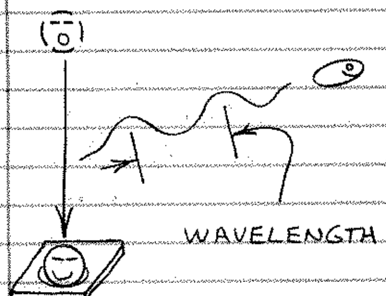
PHOTONICS IS THE FAST GROWING FIELD OF ELECTRONICS INVOLVING SEMICONDUCTOR DEVICES THAT EMIT AND DETECT LIGHT. BEFORE LOOKING AT SOME PHOTONIC COMPONENTS, LET'S TAKE A QUICK LOOK AT SOME FACTS ABOUT LIGHT.

LIGHT

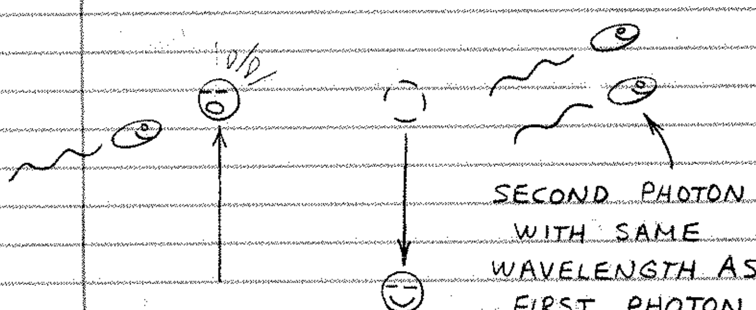
"LET THERE BE LIGHT..."

LIGHT IS COMPOSED OF PARTICLES CALLED PHOTONS THAT BEHAVE LIKE WAVES OF ENERGY. PHOTONS ARE NOT NECESSARILY VISIBLE AND ONLY THOSE YOU CAN SEE ARE COLLECTIVELY CALLED LIGHT. PHOTONS ARE PRODUCED WHEN AN ELECTRON THAT'S BEEN EXCITED TO A HIGHER THAN NORMAL ENERGY LEVEL FALLS BACK TO ITS NORMAL LEVEL.



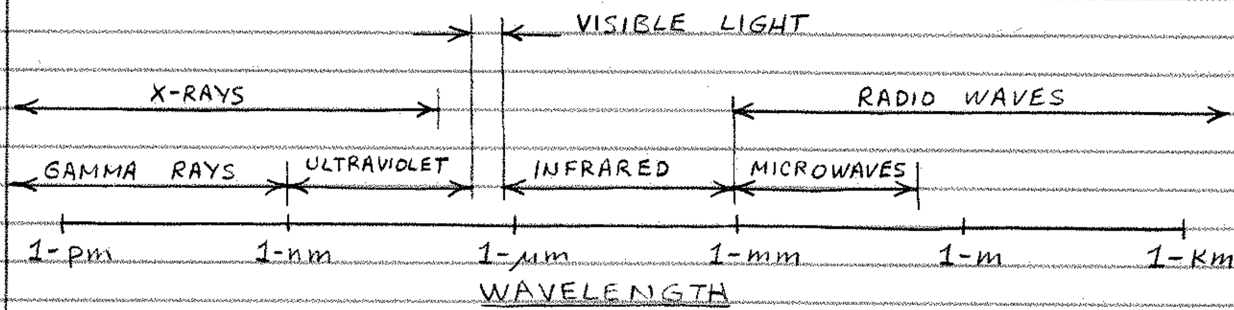


REMEMBER, PHOTONS ACT LIKE WAVES. THE DISTANCE BETWEEN CRESTS IS THE WAVELENGTH. ELECTRONS EXCITED TO HIGHER ENERGY LEVELS EMIT PHOTONS WITH SHORTER WAVELENGTHS THAN ELECTRONS EXCITED TO LOWER LEVELS.



EXCITED ELECTRONS CAN RESUME THEIR NORMAL LEVEL SPONTANEOUSLY. OR A PHOTON WITH THE PROPER WAVELENGTH CAN STIMULATE AN EXCITED ELECTRON TO RETURN TO ITS NORMAL LEVEL.

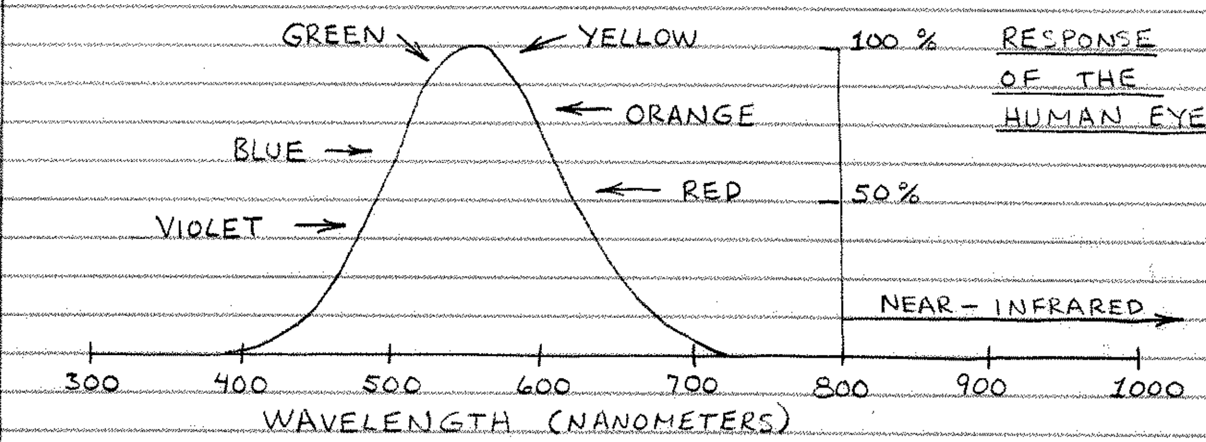
☐ THE ELECTROMAGNETIC SPECTRUM — VISIBLE LIGHT IS A FORM OF ELECTROMAGNETIC RADIATION. THE WAVELENGTH OF LIGHT IS SPECIFIED IN NANOMETERS (1-NANOMETER IS A BILLIONTH OF A METER). THE DIAGRAM BELOW SHOWS THE RELATIONSHIP OF LIGHT TO OTHER FORMS OF ELECTROMAGNETIC RADIATION.



1-pm = 1 PICOMETER (0.000 000 000 001 METER)
1-nm = 1 NANOMETER (0.000 000 001 METER)
1-μm = 1 MICROMETER (0.000 001 METER)
1-mm = 1 MILLIMETER (0.001 METER)
1-m = 1 METER (39.37 INCHES)
1-Km = 1 KILOMETER (1000 METERS)

THESE LINES ARE ONE MILLIMETER (1-mm) APART.

☐ THE OPTICAL SPECTRUM — ULTRAVIOLET, VISIBLE AND INFRARED RADIATION ARE TOGETHER CALLED THE OPTICAL SPECTRUM. HERE'S AN EXPANDED DIAGRAM OF THE OPTICAL SPECTRUM:

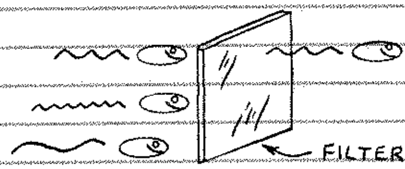


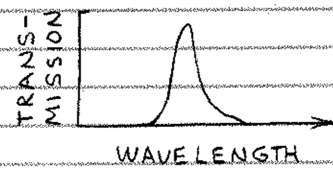
MANY PHOTONIC SEMICONDUCTORS EMIT OR DETECT NEAR-INFRARED RADIATION. SILICON, FOR EXAMPLE, CAN DETECT VISIBLE LIGHT. BUT IT IS MOST SENSITIVE TO NEAR-INFRARED AT ABOUT 880 nm. BECAUSE SO MANY PHOTONIC COMPONENTS CAN OPERATE IN BOTH THE VISIBLE AND NEAR-INFRARED, IT'S COMMON TO REFER TO NEAR-INFRARED AS LIGHT.

OPTICAL COMPONENTS

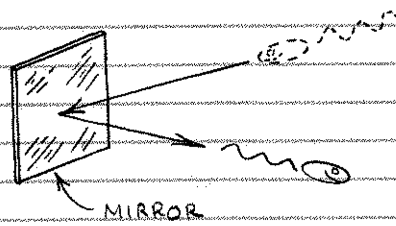
OPTICAL COMPONENTS CONDUCT, BEND OR CHANGE THE CHARACTERISTICS OF LIGHT. SEVERAL ARE VERY IMPORTANT IN MANY APPLICATIONS OF PHOTONIC SEMICONDUCTORS:

1. FILTERS TRANSMIT ONLY A NARROW BAND OF OPTICAL WAVELENGTHS.



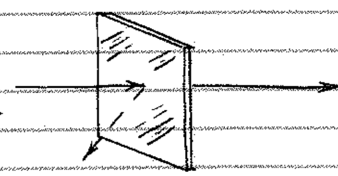


2. REFLECTORS REFLECT SOME OR MOST OF AN ONCOMING LIGHT BEAM. SOME LIGHT MAY OR MAY NOT BE TRANSMITTED.



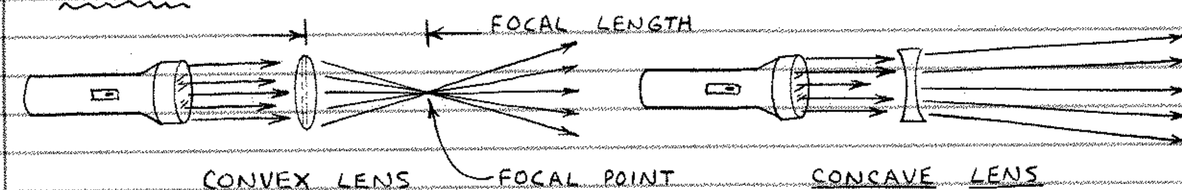
THOSE WITH A VERY SMOOTH SURFACE (LIKE MIRRORS) ARE CALLED SPECULAR REFLECTORS.

3. BEAMSPLITTERS REFLECT PART OF AN ONCOMING LIGHT BEAM AND TRANSMIT THE REMAINDER.



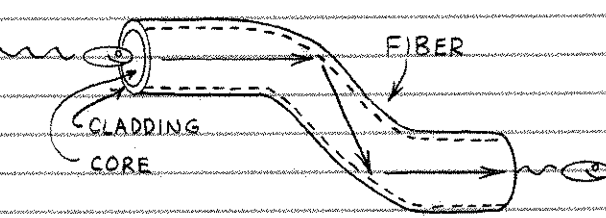
A GLASS MICROSCOPE SLIDE MAKES A GOOD BEAM SPLITTER. (EACH SURFACE REFLECTS 4%.)

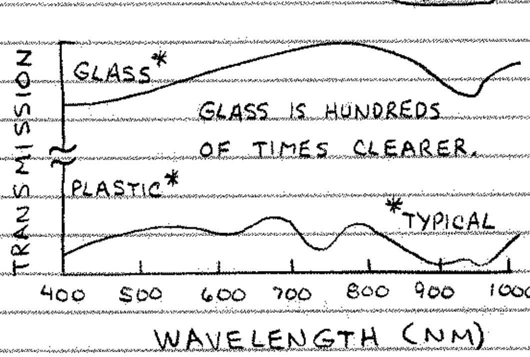
4. LENSES BEND LIGHT. THE MOST IMPORTANT ARE:



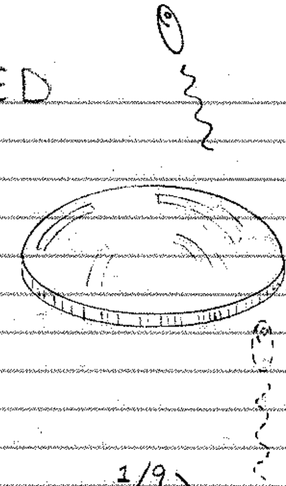
CONVEX LENSES ARE OFTEN USED IN CONJUNCTION WITH SEMICONDUCTOR LIGHT SOURCES AND DETECTORS. FOR EXAMPLE, THEY CAN COLLECT AND FOCUS LIGHT ONTO A MINIATURE DETECTOR.

5. OPTICAL FIBERS ARE THIN, FLEXIBLE STRANDS OF HIGHLY TRANSPARENT GLASS OR PLASTIC THAT CONDUCT LIGHT. THE LIGHT TRAVELS THROUGH A CORE SURROUNDED BY A THIN CLADDING. PLASTIC FIBERS ARE INEXPENSIVE. GLASS FIBERS ARE MUCH MORE TRANSPARENT. BOTH KINDS TRANSMIT SOME WAVELENGTHS MUCH BETTER THAN OTHERS. HIGH QUALITY FIBERS ARE USED TO SEND TELEPHONE CALLS AND COMPUTER DATA VIA PULSES OF LIGHT.



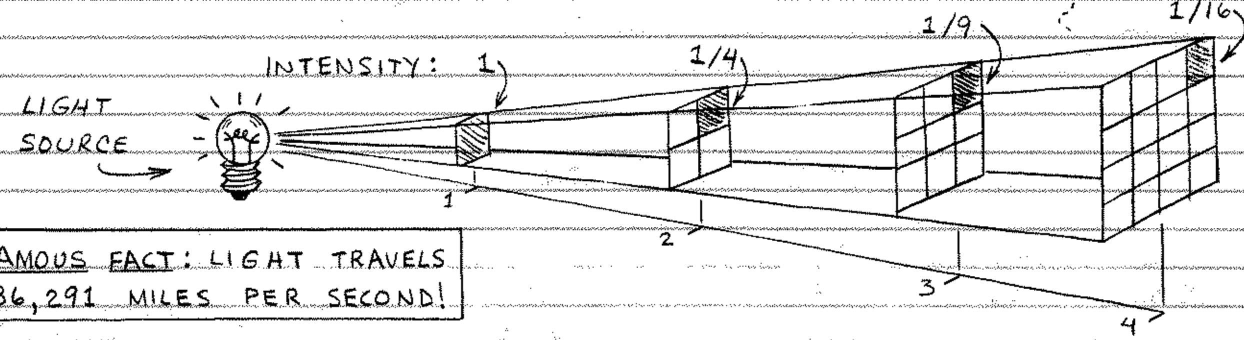


HOW CONVEX LENSES ARE USED



MANY SEMICONDUCTOR LIGHT SOURCES AND DETECTORS ARE EQUIPPED WITH A BUILT-IN CONVEX LENS. THIS PAGE EXPLAINS WHY AND SHOWS HOW EXTERNAL LENS ARE USED WITH SOURCES AND DETECTORS.

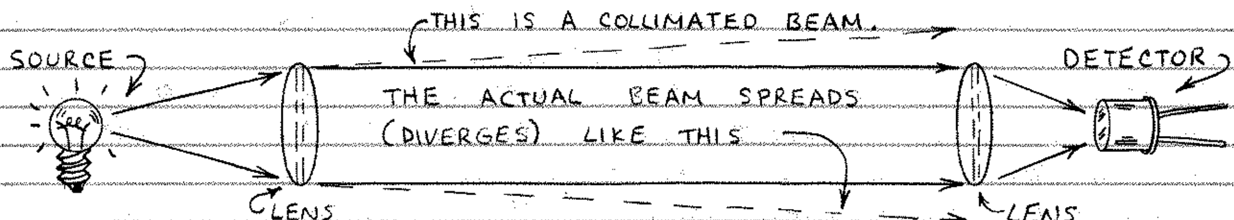
☐ THE INVERSE SQUARE LAW.

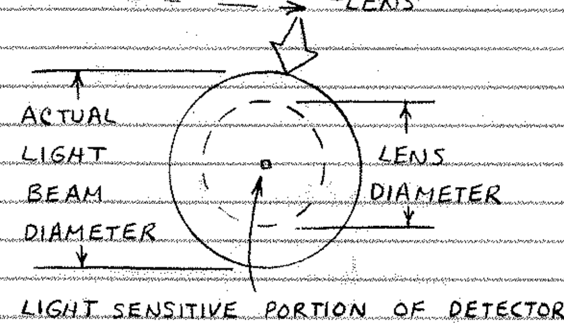


FAMOUS FACT: LIGHT TRAVELS 186,291 MILES PER SECOND!

AS LIGHT FROM A VERY SMALL SOURCE SPREADS OUTWARD, ITS INTENSITY IS INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE. IN OTHER WORDS, IF THE DISTANCE IS 3, THEN THE INTENSITY IS 1/9 THE INTENSITY WHEN THE DISTANCE IS 1. A CONVEX LENS CAN CANCEL THIS INTENSITY REDUCTION.

☐ THE CONVEX LENS.





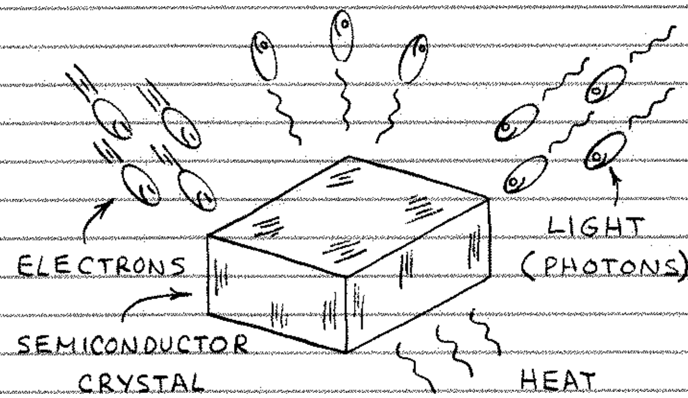
THE BEAM SPREAD ANGLE (THE DIVERGENCE) IN RADIANS* IS THE DIAMETER OF THE SOURCE DIVIDED BY THE FOCAL LENGTH OF THE LENS. THIS MEANS LENSES WITH LONGER FOCAL LENGTHS GIVE NARROWER BEAMS. (BUT LENSES WITH LONG FOCAL LENGTHS COLLECT LESS LIGHT THAN THOSE WITH SHORT FOCAL LENGTHS...)

WITH CAREFUL LENS PLACEMENT ALL THE LIGHT WITHIN THE DASHED CIRCLE CAN BE FOCUSED ONTO THE LIGHT SENSITIVE PORTION OF THE DETECTOR. (SURE BEATS THE INVERSE SQUARE LAW!)

*ONE RADIAN IS 57.3 DEGREES. (THERE ARE 360° IN A CIRCLE.)

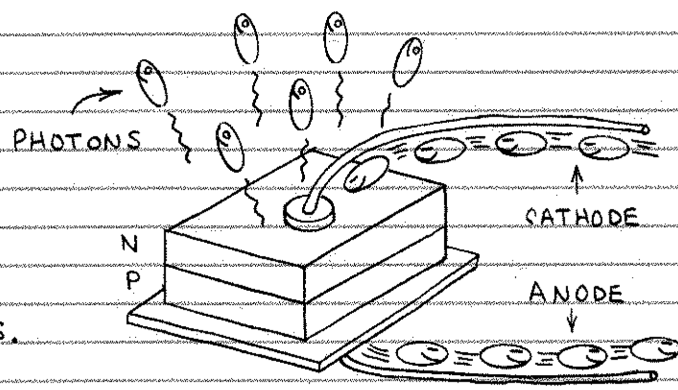
SEMICONDUCTOR LIGHT SOURCES

WHEN BOMBARDED BY LIGHT, HEAT, ELECTRONS AND OTHER FORMS OF ENERGY, MOST SEMI-CONDUCTOR CRYSTALS WILL EMIT VISIBLE OR INFRARED LIGHT. THE BEST SEMICONDUCTOR LIGHT SOURCES, HOWEVER, ARE PN JUNCTION DIODES.



LIGHT EMITTING DIODES

THE LIGHT EMITTING DIODE CONVERTS AN ELECTRICAL CURRENT DIRECTLY INTO LIGHT. THEREFORE THE LIGHT EMITTING DIODE (LED) IS MORE EFFICIENT THAN MANY OTHER LIGHT SOURCES.



☐ LED OPERATION— THE FORWARD VOLTAGE ACROSS A DIODE MUST EXCEED A THRESHOLD LEVEL BEFORE A CURRENT CAN CROSS THE JUNCTION. FOR SILICON, WHICH EMITS A TINY AMOUNT OF NEAR-INFRARED, THE THRESHOLD IS 0.6-VOLT. FOR GALLIUM ARSENIDE, WHICH EMITS CON-SIDERABLE NEAR-INFRARED, THE THRESHOLD IS 1.3-VOLTS. THIS VOLTAGE EXCITES THE ELECTRONS. WHEN THE ELECTRONS CROSS THE JUNCTION AND COMBINE WITH HOLES, THEY EMIT PHOTONS.