I. Rectifiers

1. Why Study?
   A. application—power supplies
   B. power supply failure very common problem in electronic equipment—need to know how to troubleshoot
   C. everything electronic requires a power supply—need to know how to design

2. Purpose of a Rectifier
   A. to convert AC into DC (Fig. 1)
   B. for power line operated DC power supplies
      i) plug transformers (SHOW example)
      ii) battery chargers
      iii) TV, radio, audio applications
   C. AM detectors in radio

3. Review—What is AC?
A. [Students who have not yet taken ET 104 or other AC course should review Grob's Basic Electronics, 1st Edition, Chapter 15]

B. current which regularly reverses direction

C. like a battery circuit in which the battery is regularly switching polarity (SHOW with circuit of Fig. 2, setting signal generator to very low frequency)

D. graph of generator voltage vs. time (Fig. 3, SHOW on oscilloscope)
4. Types of Rectifiers

A. half-wave

i) typical circuit (CONSTRUCT circuit of Fig. 4)

ii) operation

(a) diode acts as one-way electronic valve
(b) on phase 1 of AC cycle (Fig. 4), current flows through forward-biased diode

(c) on phase 2, current cannot flow

(d) thus current flows only one way through the load and is therefore DC

(e) which end of load is positive?

(f) graph of voltage across load? (Fig. 5)—hence the name half wave (SHOW with oscilloscope)

![Graph of load (lamp) voltage vs. time, half-wave rectifier](image)

(g) what would waveform look like if the diode were shorted?

(h) DC voltmeter reads $V_{AVG} = 0.318 \times V_{PK} = V_{PK} / \pi$

(i) check it with the voltmeter (at higher frequency)

iii) design requirements for diode—must be able to handle the current flow and the reverse voltage

(a) rated $I_{DIODE(avg)} > I_{LOAD(avg)}$
(b) must be able to handle the peak inverse voltage (PIV)

- occurs while diode reverse biased (Fig. 6)

![Diagram of diode circuit](image)

- since no current flows, load drops no voltage
- so entire source voltage is across diode (open) in this series circuit
- = peak of the AC line (for 120 VAC = ?)

B. full-wave bridge

i) typical circuit (draw and CONSTRUCT circuit of Fig. 7 or use bridge rectifier demo board)
(a) four diodes connected
(b) should memorize this important circuit
(c) diodes all point the same direction—to the right, in this case (positive bridge)
(d) packaged bridges available (SHOW example(s))

ii) operation (Fig. 8)
Fig. 8—Current flow in the bridge rectifier circuit
(a) on phase 1 electrons flow through the two circled diodes only
   • their goal is to get to the positive of the supply
   • why don't they detour through the top left-hand diode, entering the cathode end?

(b) on phase 2, electrons flow through two circled diodes only

(c) in both cases, current flow same direction through the load

(d) since current flows on both phases, this is a full wave rectifier

(e) which end of load is positive?

(f) graph of voltage across load? (Fig. 9, SHOW with oscilloscope, substituting a 1-kΩ resistor for the lamp as the load to avoid loading down the signal generator output voltage below 6.3 V)

(g) what would waveform look like if a diode were open?
(h) DC voltmeter reads $V_{AVG} = 0.636 \times V_{PK} = 2 \times V_{PK} / \pi$

(i) check it with the voltmeter (at higher frequency)

iii) design requirements for diode

(a) must be able to handle the current flow: rated $I_{DIODE(avg)} > I_{LOAD(avg)} / 2$ (50% duty cycle)

(b) must be able to handle the peak inverse voltage (PIV)

- occurs while two non-conducting diodes are reverse biased (Fig. 10)
- conducting diodes are like shorts at that time
- assume AC generator voltage is at its peak (worst case)
- consider lower right-hand diode in bridge
- cathode is directly connected to positive of source through forward-biased diode on the top right
- anode is directly wired to negative of source
so this diode sees full supply voltage in reverse at this time

• same is true for top left-hand diode

• on phase 2, the other two diodes get the same treatment

• so all diodes in bridge must be able to withstand PIV of the AC supply

C. full-wave center-tapped (or, per textbook, simply "full-wave rectifier")

i) typical circuit (draw and CONSTRUCT circuit of Fig. 11)

(a) only two diodes required

(b) but special, center-tapped transformer secondary required—recall how it works (Fig. 12)
12.6 VCT means you measure 12.6 VAC (rms) across the full secondary, 6.3 VAC (rms) across either half of the secondary (Vpeak = Vrms / 0.707, explain why)

- on phase 1, at the peak, secondary is like two batteries in series
- on phase 2, at the peak, same, with batteries reversed in polarity

ii) operation (Fig. 13)
(a) on phase 1, only top diode can conduct current (why?)

- electrons start at center tap, flow through load, diode, and back to top of secondary
- top diode is like a short circuit, so load sees how much voltage? (half of full secondary = 9 V peak)
- which end of load is positive? (mark it)

(b) on phase 2, only bottom diode can conduct

- electrons go the same direction through the load (purpose of the exercise), starting at center tap, and ending at bottom of transformer secondary
- load again sees (nearly) full peak voltage of half the secondary, 9 V

(c) graph of voltage across load? (Fig. 14)
(d) what would waveform look like if one diode were open?

(e) DC voltmeter reads $V_{AVG} = 0.636 \times V_{PK} = 2 \times V_{PK} / \pi = 0.636 \times 9 \, V = 5.72 \, V$

(f) check it with the voltmeter

iii) design requirements for diode

(a) must be able to handle the maximum (peak) current flow and the average current flow

$$I_{DIODE(avg)} > I_{LOAD(avg)} / 2 \, (50\% \, \text{duty cycle})$$

(b) must be able to handle the peak inverse voltage (PIV)

- $V_{PIV} = \text{peak voltage of full secondary} \, (18 \, V \, \text{in this case})$

- show using Fig. 13, phase 1

- bottom diode is reverse biased at this time

- anode is directly wired to negative of source
• cathode connects to positive end of secondary through a short circuit (forward-biased diode on top)

• so full peak secondary voltage, 18 V, is across the bottom diode in reverse

• same is true for top diode on phase 2

5. Comparison of Types

A. cost and complexity

i) half-wave is cheapest and simplest

ii) requires only one diode and simple transformer

iii) used in switching regulated power supplies, and low current supplies

iv) bridge is next best, and most common type, using pre-packaged bridge module and simple transformer

B. diode losses

i) bridge output is two diode drops less than full secondary voltage (why?)

   (a) main drawback of bridge

   (b) at low voltages (5 V, e.g.) can be significant loss

   (c) also means power loss and heating of diode—may require additional heat sinking on diode

ii) full-wave center-tapped is better than bridge

   (a) only one diode drop (why?)

   (b) means less heat lost in diodes

   (c) used in high current supplies
C. ease of filtering

i) important consideration because it determines size of required filter capacitor

ii) either full-wave circuit (bridge or center-tapped) is better than half-wave (why?)

(a) voltage peaks come twice as often with full-wave

(b) capacitor doesn't have time to dip very far in voltage

(c) will be studied in depth later

6. Example Problems

A. unknown or unrecognized types (Fig. 15)

i) possible to draw these rectifier circuits several different ways—student must learn to recognize and analyze each

ii) general method of analysis (demonstrate on example)

(a) assume one phase of the AC and assign polarity to the AC source
(b) ask yourself if there's any path for electrons to flow from a more negative to a more positive voltage through the circuit

(c) if so, trace that path, noting the direction of flow through the load(s), and the peak voltage applied to the load(s)

(d) do the same for the other phase

iii) example circuit is a "center-tapped bridge" (note bridge circuit, but with center-tapped transformer), providing positive and negative output voltages as measured from same ground

B. design (time permitting)—design a 24-VDC supply

i) bridge circuit

ii) full-wave center-tapped circuit

II. MATERIALS

1. 2 silicon diodes

2. bridge rectifier demo board

3. small lamp

4. signal generator

5. oscilloscope and probes

6. 0-center ammeter

7. digital multimeter

8. sample diode bridge for display

9. DC power supply

10. 12-VCT transformer

11. sample plug transformer power supply
12.  1,000-Ohm resistor