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SINGLE-PHASE FULLY-CONTROLLED BRIDGE RECTIFIER (FCB)

AIM: To study the operation of a single-phase fully-controlled bridge rectifier (FCB) for resistive, inductive loads and active (RLE) loads.

APPARATUS:
1) Circuit board.
2) DMM.
3) Ammeter & voltmeter.
4) Dual trace CRO with probes.
5) DC power supply

NOMENCLATURE:

(i) V_o : average (DC) output (load) voltage

(ii) I_o : average output current

(iii) $V_{o\,rms}$: rms output voltage

(iv) V_{ac} : rms output ripple voltage

(v) V_s : rms AC supply voltage

(vi) V_T : ON-state voltage drop of the SCR

(vii) V_{DR} : average voltage drop across all conducting devices

(viii) E_S : active load DC source voltage

(ix) α : firing angle

(x) β : output current extinction angle

(xi) R : total resistance of current sensing resistor, ammeter & load (including the winding resistance of the load inductance, for inductive loads)

(xiii) P_{dc} : DC output (load) power

(xiv) P_{rms} (P_{ac}) : rms (AC) output power

(xv) RF : output voltage ripple factor

(xvi) FF : output voltage form factor

THEORY:

A single-phase FCB, like all line commutated converters (LCC), converts an AC supply into a variable DC voltage, using phase angle control.

Unlike a half-controlled bridge (HCB) whose output voltage is always positive, the average output voltage of a FCB can be positive (rectifying mode : $\alpha < \pi/2$) or negative (inverting mode : $\alpha > \pi/2$). As the output current is always positive for all LCCs, power flows **from** the AC supply **to** the load during rectification, and **from** the load **to** the AC supply during inversion. Hence an **active** (**RLE**) load is necessary for **inversion** operation.

Therefore the FCB converter is a **two-quadrant** converter (I & IV quadrants).

CIRCUIT DESCRIPTION:

1. Power circuit: The power circuit diagram of the single-phase FCB is shown in Fig. 1 while the power circuit waveforms are shown in Figs. 2 to 4. The FCB consists of 4 SCRs (thyristors) T31 to T34 connected in a bridge arrangement. The mains supply is stepped-down by transformer TR5 to 18V and given to the FCB via fuse F1, as the AC supply. The load can either be **R** (R32 with switch S4 in RL position, S6 in L OFF position), or **RL LIGHT** (LIGHT inductive – R32 in series with L1, keeping switch S4 in RL position, S5 in LIGHT position and S6 in L ON position), or **RL HEAVY** (HEAVY inductive – R32 in series with L2, keeping switch S4 in RL position, S5 in HEAVY position and S6 in L ON position), or **LEVEL** (ripple-free : keeping switch S4 in LEVEL position).

The addition, in series, of an **external DC supply**, with proper polarity, converts the **passive RL LIGHT** or **RL HEAVY** load into an **active RLE** load.

The level load consists of a **pnp** transistor based controlled constant current source in parallel with a **npn** transistor based controlled constant current source, comprising of resistors R33 to R36, diodes D34 to D37, pnp transistors T5 & T6, npn transistors T7 & T8 and double-pole selector switch S7 for selecting a LO or HI value of level load current.

SCRs T31 & T33 are turned-ON in the +ve half-cycle of the AC supply at $\omega t = \alpha$, while T32 & T34 are turned-ON in the –ve half-cycle at $\omega t = \alpha + \pi$. Hence the output voltage is $v_O(t) = v_S(t)$ ideally, but $v_O(t) = v_S(t) - 2V_T$ actually, where $v_S(t) = \sqrt{2}V_S \sin(\omega t)$ is the instantaneous supply voltage, from $\omega t = \alpha$ onwards. Similarly, the output voltage is $v_O(t) = -v_S(t)$ ideally, but $v_O(t) = -v_S(t) - 2V_T$ actually, from $\omega t = \alpha + \pi$ onwards (Fig. 2(b)).

For a **R** load, the output current $i_O(t) = v_O(t)/R$ and hence goes to zero at the supply zero crossings at $\omega t = \pi$ and $\omega t = 2\pi$. Hence SCRs T31 & T34 turn-OFF by **natural or line commutation** at $\omega t = \pi$, while T32 & T33 turn-OFF at $\omega t = 2\pi$ (Fig. 2(c)).

For an **inductive** load, the current lags the voltage and hence the output current is **finite** at the zero crossings. Due to the stored magnetic energy in the load inductance, the current cannot reduce to zero instantaneously and therefore continues to flow through the conducting SCRs **even** though the supply voltage has **reversed**. This is because there is **no** freewheeling diode in a FCB, unlike that in a HCB. Therefore, the instantaneous load voltage becomes **negative**, which causes the output current to **reduce**.

The output current, which had started increasing from ωt = α (+ve half cycle) and ωt = α + π (-ve half cycle), now starts reducing as $v_O(t) = v_S(t)$ ideally, ($v_O(t) = v_S(t) - 2V_T$ actually). For a **light** inductive load, $i_O(t)$ falls to zero at ωt = β and ωt = β + π (β < α + π). Therefore SCRs T31 & T34 (ωt = β) and T32 & T33 (ωt = β + π) turn-OFF by **natural or line commutation** at these instants. This is called **discontinuous conduction** mode and occurs for **low** values of the load time constant $\tau = L/R$ (Fig. 3(b)).

For highly inductive loads, the load current is **still** present i.e. still freewheeling through T31 & T34 by the time the other SCR pair (T32 & T33) is fired at ωt = α + π. The turning-ON of T32 & T33 reverse-biases T31 & T34 which turn OFF now. Thus the load current is **never** zero and this is called **continuous conduction** mode and occurs for **high** values of the load time constant (Fig. 3(d)).

With continuous conduction, the **average** output voltage V_O is **positive** for α < π/2 and hence the FCB behaves as a **rectifier**, with power flowing from the AC supply to the load. However, for α > π/2 the average output voltage is **negative** and hence the FCB behaves as an **inverter**, with power flowing from the load to the AC supply (the load current is **always positive** as reverse current cannot flow indefinitely through the SCRs). This requires an active load comprising of a voltage source (DC motor, battery, etc.) and its internal resistance and inductance (Figs. 4(b) & 4(c)).

2. Control circuit: The control circuit is also shown in Fig. 7, while the control circuit waveforms are shown in Fig. 8. The control circuit delivers a **line-synchronized high frequency firing pulse train** from ωt = α to ωt = π to SCRs T31 & T33 and from ωt = α + π to ωt = 2π to SCRs T32 & T34.

The control circuit is based on phase control IC TCA785 (U1) whose pin configuration and block diagrams are shown in Figs. 5 & 6, respectively.

The line synchronizing input voltage, V_{SYNC} (**X3**), is obtained from the secondary winding X1 – X2 of control transformer TR1 via a high ohmic resistance R1 and inverse parallel connected clipping diodes D1 & D2.

The TCA785 zero voltage detector detects the zero crossings and transfers them to the synchronization register. This register controls a ramp generator whose capacitor C2 is charged by a constant current determined by R2 and R3, producing a positive going ramp (capacitor) voltage (**X4**). A variable control voltage (**X5**) is produced by R4 and potentiometer R5, which is filtered by R6, C4 & C5 to remove supply voltage ripple and noise.

The ramp voltage is given to the –ve input of the internal comparator, while the control voltage is given to the +ve input. In the +ve half cycle of the synchronizing voltage, the ramp voltage exceeds the control voltage at ω*t* = α, while in the –ve half cycle the same occurs at ω*t* = π + α.

If the inhibit input voltage, V_{IN} (**X6**), is kept high and the pulse extension input PE (pin 12) is grounded, then the +ve half cycle output Q2 (**X8**) is a rectangular pulse from ω*t* = α to ω*t* = π, while the –ve half cycle output Q1 (**X7**) is a rectangular pulse from ω*t* = π + α to ω*t* = 2π. However in order to reduce the SCR gate dissipation as well as reduce the size of the isolation pulse transformer, a high frequency firing pulse train is desirable. This is done by modulating the inhibit input voltage by a rectangular pulse train with duty cycle < 50% obtained from a high frequency (20 KHz) oscillator using IC555 (U2) in the astable mode. Thus the +ve half cycle output Q2 (**X8**) is a high frequency rectangular pulse train from $\omega t = \alpha$ to $\omega t = \pi$, while the –ve half cycle output Q1 (**X7**) is a high frequency rectangular pulse train from $\omega t = \pi + \alpha$ to $\omega t = 2\pi$.

The firing angle **α** can be varied from **0° to 180°** by means of potentiometer **R5**.

Output Q2 is amplified to the appropriate power level by the +ve pulse amplifier. The +ve pulse amplifier is formed by base drive resistors R9 & R11, power transistor T1 (2N1711), pulse transformer TR2, and freewheeling diodes D5 & D6. The first secondary winding of TR2 delivers the pulses to gate (G31) and cathode (K31) of SCR T31 via the gate drive circuit comprising of high speed diode D7 (BA159), current limiting power resistor R12 and shunt resistor R13. The second secondary winding of TR2 delivers the pulses to gate (G33) and cathode (K33) of SCR T33 via the gate drive circuit comprising of high speed diode D8 (BA159), current limiting power resistor R14 and shunt resistor R15.

Similarly, output Q1 is amplified to the appropriate power level by the -ve pulse amplifier. The -ve pulse amplifier is formed by base drive resistors R16 & R17, power transistor T2 (2N1711), pulse transformer TR3, and freewheeling diodes D9 & D11. The first secondary winding of TR3 delivers the pulses to gate (G32) and cathode (K32) of SCR T32 via the gate drive circuit comprising of high speed diode D12 (BA159), current limiting power resistor R18 and shunt resistor R19. The second secondary winding of TR3 delivers the pulses to gate (G34) and cathode (K34) of SCR T34 via the gate drive circuit comprising of high speed diode D13 (BA159), current limiting power resistor R21 and shunt resistor R22.

It is to be noted that the pulse transformers TR2 & TR3 provide the necessary **galvanic isolation** between the control and output sides of the control circuit.

3. Test points:

TP1 : synchronizing voltage

TP2 : ramp voltage

TP3 : control input voltage

TP4 : HFO inhibit pulse train

TP5 : Q1 –ve half cycle output pulse train

TP6 : Q2 +ve half cycle output pulse train

FORMULAE:

1. Ideal:

1.1. General:

1.1.1. Average (DC) output (load) voltage:

$$V_o = \frac{1}{\pi}\int_\alpha^\beta v_o(\omega t)d\omega t = \frac{1}{\pi}\int_\alpha^\beta \sqrt{2}V_S \sin(\omega t)d\omega t = \frac{\sqrt{2}V_S}{\pi}(\cos\alpha - \cos\beta) \tag{1}$$

1.1.2. RMS output voltage:

$$V_{o\,rms} = \left[\frac{1}{\pi}\int_\alpha^\beta v_o^2(\omega t)d\omega t\right]^{1/2} = \left[\frac{1}{\pi}\int_\alpha^\beta 2V_S^2 \sin^2(\omega t)d\omega t\right]^{1/2}$$

$$= V_S\left[\frac{1}{\pi}\left(\beta - \alpha - \frac{\sin 2\beta}{2} + \frac{\sin 2\alpha}{2}\right)\right]^{1/2} \tag{2}$$

1.1.3. Average output current:

$$I_o = \frac{V_o}{R} \quad \text{as the average voltage across the load inductor is zero} \tag{3}$$

1.1.4. Average (DC) output power:

$$P_{dc} = V_o I_o = \frac{V_o^2}{R} \tag{4}$$

1.1.5. RMS (AC) output power:

$$P_{rms}(P_{ac}) = \frac{V_{o\,rms}^2}{R} = \frac{V_S^2}{\pi R}\left[\frac{1}{\pi}\left(\beta - \alpha - \frac{\sin 2\beta}{2} + \frac{\sin 2\alpha}{2}\right)\right] \quad \textbf{only} \text{ for R load} \tag{5}$$

1.1.6. Ripple factor:

$$RF = \frac{V_{ac}}{V_o} = \frac{\sqrt{V_{o\,rms}^2 - V_o^2}}{V_o} = \sqrt{\left(\frac{V_{o\,rms}}{V_o}\right)^2 - 1} = \sqrt{FF^2 - 1} \tag{6}$$

1.1.7. Form factor:

$$FF = \frac{V_{o\,rms}}{V_o} = \sqrt{RF^2 + 1} \tag{7}$$

1.2. Special Cases:

1.2.1. R load (all formulas are **identica**l to the corresponding ones for the **HCB):**

Here β = π. Hence equations (1), (2) & (7) simplify to:

1.2.1.1. Average output voltage:

$$V_o = \frac{\sqrt{2}V_s}{\pi}(1+\cos\alpha) \tag{8}$$

1.2.1.2. RMS output voltage:

$$V_{o\,rms} = V_s\left[\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)\right]^{1/2} \tag{9}$$

1.2.1.5. RMS output power:

$$P_{rms}(P_{ac}) = \frac{V_{o\,rms}^2}{R} = \frac{V_s^2}{\pi R}\left[\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)\right] \quad \textbf{only} \text{ for R load} \tag{10}$$

All other formulas remain unchanged

1.2.2. Inductive load with discontinuous conduction:

Equations (1) to (7) are directly applicable, except (5).

1.2.3. Inductive load with continuous conduction & rectifier mode ($\alpha < \pi/2$):

Here $\beta = \pi + \alpha$. Hence equations (1), (2) simplify to:

1.2.3.1. Average output voltage:

$$V_o = \frac{2\sqrt{2}V_s}{\pi}\cos\alpha \tag{11}$$

1.2.3.2. RMS output voltage:

$$V_{o\,rms} = V_s \tag{12}$$

Equations (1) to (7) are directly applicable, except (5).

1.2.4. Inductive load with continuous conduction & inverter mode ($\alpha > \pi/2$):

Here also $\beta = \pi + \alpha$. Hence equations (1) to (3) simplify to:

1.2.4.1. Average output voltage:

$$V_o = \frac{2\sqrt{2}V_s}{\pi}\cos\alpha \quad \text{same as 1.2.3.1 above}$$

1.2.3.2. RMS output voltage:

$$V_{o\,rms} = V_s \quad \text{same as 1.2.3.2 above}$$

1.2.3.3. Average output current:

$$I_o = \frac{V_o - E_s}{R} = \frac{V_{load}}{R} \tag{13}$$

Equations (4) & (5) are replaced by:

1.2.3.4. DC power absorbed by the load:

$$= V_{load} I_o = (V_o - E_s)\frac{(V_o - E_s)}{R} = \frac{(V_o - E_s)^2}{R} \tag{14}$$

1.2.3.5. DC power supplied by the DC source of active load:

$$= E_s I_o = E_s \frac{(V_o - E_s)}{R} \tag{15}$$

1.2.3.6. Power absorbed by the AC supply:

$$= V_o I_o = V_o \frac{(V_o - E_s)}{R} \tag{16}$$

2. Actual:

2.1. General:

2.1.1. Average output voltage:

$$V_o = V_{o\,ideal} - V_{DR} \text{ (average drops across conducting devices)}$$
$$= \frac{\sqrt{2}V_s}{\pi}(\cos\alpha - \cos\beta) - 2V_T \frac{(\beta - \alpha)}{\pi} \tag{17}$$

2.2. Special Cases:

2.2.1. R load:

Here $\beta = \pi$. Hence equation (17) simplifies to:

2.2.1.1. Average output voltage:

$$V_o = \frac{\sqrt{2}V_s}{\pi}(1 + \cos\alpha) - 2V_T \frac{(\pi - \alpha)}{\pi} \tag{18}$$

2.2.2. Inductive load with discontinuous conduction:

2.2.2.1. Average output voltage:

$$V_o = \frac{\sqrt{2}V_s}{\pi}(\cos\alpha - \cos\beta) - 2V_T \frac{(\beta - \alpha)}{\pi} \quad \text{same as 2.1.1 above}$$

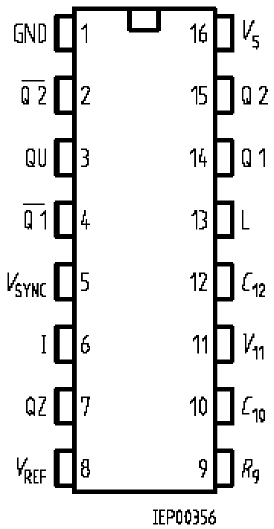
2.2.3. Inductive load with continuous conduction for both rectifier & inverter modes:

Here β = π + α. Hence equation (17) simplifies to:

2.2.3.1. Average output voltage:

$$V_o = \frac{2\sqrt{2}V_S}{\pi}\cos\alpha - 2V_T \qquad (19)$$

Note that $V_{o\,rms}$ is **also** affected by the drops across the conducting devices, but this effect is neglected here.



Pin Configuration
(top view)

Fig. 5 Pin configuration of IC TCA785

Pin Definitions and Functions

Pin	Symbol	Function
1	GND	Ground
2 3 4	$\overline{Q2}$ Q U $\overline{Q2}$	Output 2 inverted Output U Output 1 inverted
5	V_{SYNC}	Synchronous voltage
6 7	I Q Z	Inhibit Output Z
8	V_{REF}	Stabilized voltage
9 10	R_9 C_{10}	Ramp resistance Ramp capacitance
11	V_{11}	Control voltage
12	C_{12}	Pulse extension
13	L	Long pulse
14 15	Q 1 Q 2	Output 1 Output 2
16	V_S	Supply voltage

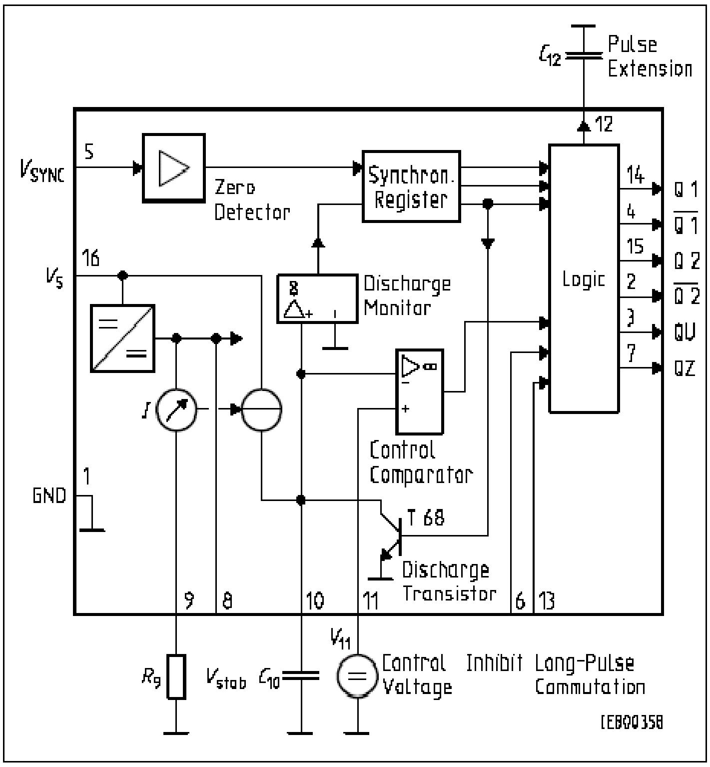


Fig. 6 Block diagram of IC TCA785

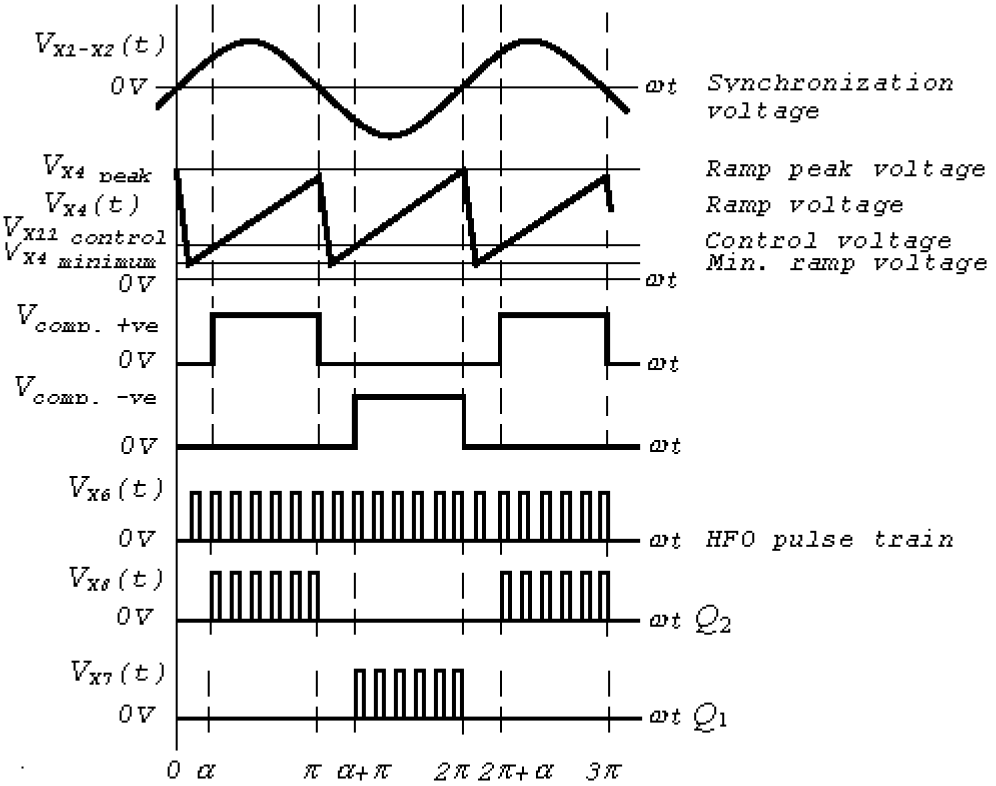


Fig. 8 Control circuit waveforms TCA785

PROCEDURE:

1. Keeping the power circuit supply **OFF**, switch **ON** the control circuit supply.

2. Connect channel 1 of the CRO to the AC (line) synchronizing voltage across **X1** (live) and **X2** (ground) and channel 2 successively to test points TP2 (**X4**) (ramp voltage of TCA785), TP3 (**X5**) (control voltage input to TCA785), TP4 (X5) (high frequency oscillator input), TP6 (X8) (+ve half cycle output pulse train) & TP5 (X7) (-ve half cycle output pulse train). Vary **firing angle control potentiometer R5** and observe the variation of, and **draw to scale**, the waveforms at each of these test points.

3. Measure minimum and maximum firing angles α_{min} &. α_{max} respectively.

5. Switch **OFF** the control supply and disconnect both channels of the CRO.

6. Note that for **all** loads viz, R, RL & RLE, $\sqrt{2}V_S = \text{measured peak voltage} + 2V_T$.

7. R load:

7.1. Put switches S1, S2 & S3 in FCB position, S4 in 'RL' position, S5 in 'LIGHT' position & S6 in 'L OFF' position (switch closed i.e. L1 or L2 **shorted**).

7.2. Connect the DC ammeter (I_O) between X39 & X41, DC voltmeter (V_O) & channel 1 of CRO ($v_O(t)$) between X39 (live) & X46 (common) as shown in Fig. 4 (channel 2 is not connected). The AC supply to the bridge, V_S, is measured with an AC voltmeter connected between the anodes of T31 (X37) and T32 (X38). Note that it is **not** necessary to observe the output current waveform ($i_O(t)$) as the current is proportional to the voltage for a R load.

7.3. Switch **ON** the power circuit supply and the control circuit supply. Observe and **draw to scale** the output voltage waveform $v_O(t)$.

7.4. Vary R5 to obtain 3 different firing angles and measure α, $\sqrt{2}V_S$, $v_O(\omega t = \alpha)$, on the CRO and V_S, V_O and I_O on the meters.

8. Light inductive load (discontinuous conduction) in rectifier mode (α < π/2):

8.1. Put switches S1, S2 & S3 in FCB position, S4 in 'RL' position, S5 in 'LIGHT' position & S6 in 'L ON' position (switch open).

8.2. Connect the DC ammeter (I_O) between X39 & X41, DC voltmeter (V_O) & channel 1 of CRO ($v_O(t)$) between X39 & X46 and channel 2 ($i_O(t) = v_{R37}/R37$) between X45 & X46 as shown in Fig. 4. The AC supply to the bridge, V_S, is measured with an AC voltmeter connected between the anodes of T31 (X37) and T32 (X38).

8.3. Switch **ON** the power circuit supply and the control circuit supply. Observe and **draw to scale** the output voltage waveform $v_O(t)$ and output current waveform $i_O(t)$.

8.4. Vary R5 to obtain 3 different firing angles and measure α, β, $v_O(\omega t = \alpha)$, $v_O(\omega t = \beta)$, $i_O(\omega t = \beta)$ & $i_{O\,max}$ on the CRO and V_O and I_O on the meters.

9. Heavy inductive load (continuous conduction) in rectifier mode (α < π/2):

9.1. Put switches S1, S2 & S3 in FCB position, S4 in 'RL' position, S5 in 'HEAVY' position & S6 in 'L ON' position (switch open).

9.2. Connect the DC ammeter (I_o) between X39 & X41, DC voltmeter (V_o) & channel 1 of CRO ($v_O(t)$) between X39 & X46 and channel 2 ($i_O(t) = v_{R37} / R37$) between X45 & X46 as shown in Fig. 4. The AC supply to the bridge, V_s , is measured with an AC voltmeter connected between the anodes of T31 (X37) and T32 (X38).

9.3. Switch **ON** the power circuit supply and the control circuit supply. Observe and **draw to scale** the output voltage waveform $v_O(t)$ and output current waveform $i_O(t)$.

9.4. Vary R5 to obtain 3 different firing angles and measure α, $v_O(\omega t = \alpha)$, $i_O(\omega t = \alpha)$, $i_{O\,\min}$ & $i_{O\,\max}$ on the CRO and V_o and I_o on the meters.

10. Active (RLE) load in inverter mode (α > π/2) (continuous conduction) :

10.1. Insert a DC supply (E_S) , with proper polarity, in series with the ammeter. For this, open the connection between ammeter -ve and X41, connect ammeter -ve to the DC supply -ve and connect DC supply +ve to X41. With this, the passive inductive load is converted into an active load. Note carefully the polarity of the DC supply. Since the direction of the load current cannot reverse, this polarity allows the DC supply in the active load to feed power back into the AC supply during inversion. Set the DC supply voltage to 30V (it should be greater in magnitude than the largest possible voltage of the FCB i.e. when $\alpha = 0 \text{ or } \pi.$ so that the load current is always positive).

10.2. Put switches S1, S2 & S3 in FCB position and S4 in LEVEL position.

10.3. Switch **ON** the power circuit supply and the control circuit supply.

10.4. Observe and **draw to scale** both the output voltage $v_O(t)$ and current $i_O(t)$ waveforms. For α < π / 2, V_o is +ve and for α > π / 2, V_o is –ve.

10.5. Vary R5 to obtain 3 different firing angles and measure α, $v_O(\omega t = \alpha)$, $i_O(\omega t = \alpha)$, $i_{O\,\min}$ & $i_{O\,\max}$ on the CRO and V_o and I_o on the meters.

OBSERVATIONS:

1. Minimum firing angle α_{min} = °

2. Maximum firing angle α_{max} = °

3. R load:

R = Ω, V_s = V, $\sqrt{2}V_s$ = V

Sr. No.	α°	$v_o(\alpha)$ V	V_o V	I_o A
1.				
2.				
3.				

4. Light inductive load (discontinuous conduction) in rectifier mode ($\alpha < \pi/2$):

R = Ω

Sr. No.	α°	β°	$v_o(\alpha)$ V	$v_o(\beta)$ V	$i_{o\ max}$ A	$i_o(\beta)$ A	V_o V	I_o A
1.								
2.								
3.								

5. Heavy inductive load (continuous conduction) in rectifier mode ($\alpha < \pi/2$):

R = Ω

Sr. No.	α°	$v_o(\alpha)$ V	$i_o(\alpha)$ V	$i_{o\ min}$ A	$i_{o\ max}$ A	V_o V	I_o A
1.							
2.							
3.							

6. Active (RLE) load in inverter mode ($\alpha > \pi/2$) (continuous conduction) :

R = Ω, E_s = V

Sr. No.	α°	$v_o(\alpha)$ V	$i_o(\alpha)$ A	$i_{o\ min}$ A	$i_{o\ max}$ A	V_o V	I_o A
1.							
2.							
3.							

CALCULATIONS:

1. Ideal:

Calculate the ideal values of V_o, $V_{o\,rms}$, I_o, P_{dc}, P_{rms}, RF, FF, DC power absorbed by the load, DC power supplied by the source & power absorbed by the AC supply for all the above cases using equations (1) to (16).

2. Actual:

Calculate the actual values of V_o & I_o using equations (17) to (19) above and compare with the measured values.

RESULT TABLES:

1. R load:

Sr. No.	V_o V			I_o A			$V_{o\,rms}$ V calc.	P_{dc} W calc.	P_{rms} W calc.	RF calc.	FF calc.
	Meas.	Calculated		Meas.	Calculated						
		Actual	Ideal		Actual	Ideal					
1.											
2.											
3.											

2. Light inductive load (discontinuous conduction) in rectifier mode ($\alpha < \pi/2$):

Sr. No.	V_o V			I_o A			$V_{o\,rms}$ V calc.	P_{dc} W calc.	P_{rms} W calc.	RF calc.	FF calc.
	Meas.	Calculated		Meas.	Calculated						
		Actual	Ideal		Actual	Ideal					
1.											
2.											
3.											

3. Heavy inductive load (continuous conduction) in rectifier mode ($\alpha < \pi/2$):

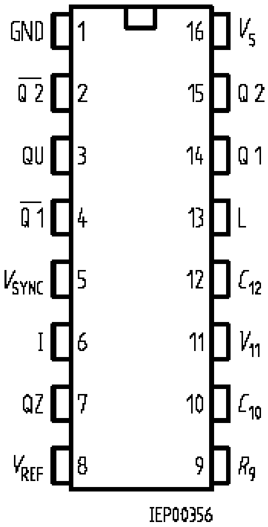
Sr. No.	V_o V			I_o A			P_{dc} W calc.	P_{rms} W calc.	RF calc.	FF calc.
	Meas.	Calculated		Meas.	Calculated					
		Actual	Ideal		Actual	Ideal				
1.										
2.										
3.										

4. Active (RLE) load in inverter mode ($\alpha > \pi/2$) (continuous conduction) :

Sr. No.	V_o V			I_o A			P_{dc} W calc.	P_{rms} W calc.	RF calc.	FF calc.
	Meas.	Calculated		Meas.	Calculated					
		Actual	Ideal		Actual	Ideal				
1.										
2.										
3.										

CONCLUSIONS:

LIST OF FIGURES:



Pin Configuration
(top view)

Fig. 5 Pin configuration of IC TCA785

Pin Definitions and Functions

Pin	Symbol	Function
1	GND	Ground
2 3 4	$\overline{Q2}$ Q U $\overline{Q2}$	Output 2 inverted Output U Output 1 inverted
5	V_{SYNC}	Synchronous voltage
6 7	I Q Z	Inhibit Output Z
8	V_{REF}	Stabilized voltage
9 10	R_9 C_{10}	Ramp resistance Ramp capacitance
11	V_{11}	Control voltage
12	C_{12}	Pulse extension
13	L	Long pulse
14 15	Q 1 Q 2	Output 1 Output 2
16	V_S	Supply voltage

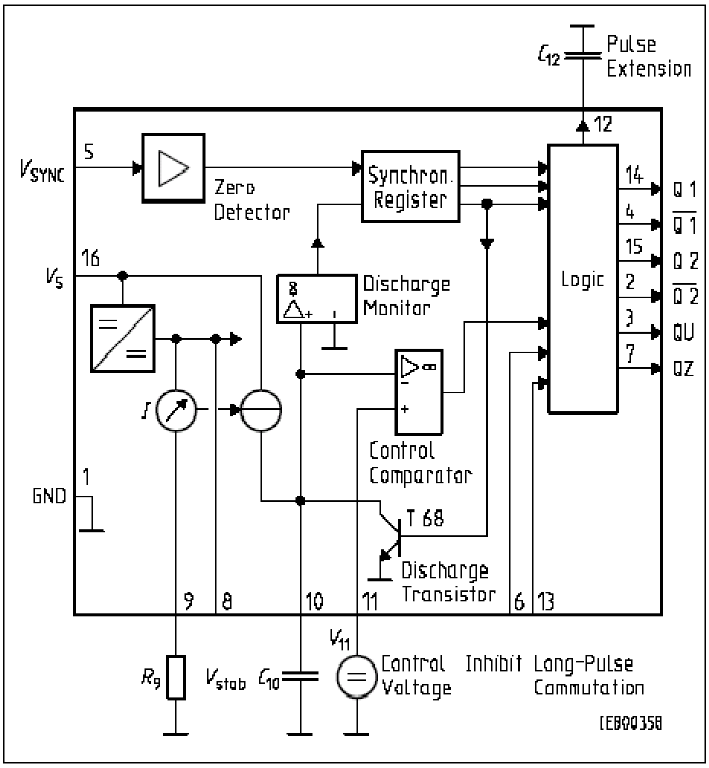


Fig. 6 Block diagram of IC TCA785

TE E&TC
PE
FCB

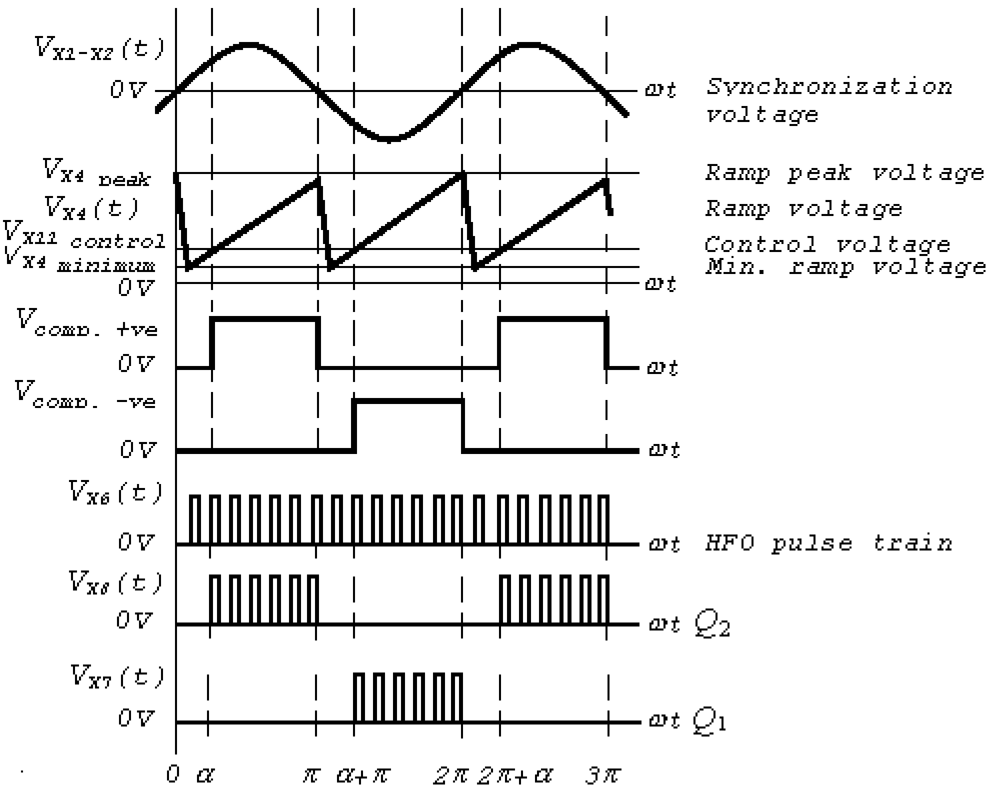


Fig. 8 Control circuit waveforms TCA785

TE E&TC
PE
FCB

Exp-4 → Single phase FCB

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AIM - To study the operation of a single-phase fully-controlled bridge rectifier (FCB) for resistive, inductive loads and active (RLE) loads.

* Observations

① R load:

Sr NO	α^0	$V_0(\alpha)$ Volts	V_0 Volts	I_0 Amps
1	72	26.6 V	10.63 V	0.23 A
2	56	23.2 V	12.80 V	0.34 A
3	26	12.0 V	15.50 V	0.41 A

② Light Inductive load $R = 1\,\Omega$

Sr NO	α^0	β^0	$V_0(\alpha)$ V	$V_0(\beta)$ V	i_0 max A	$i_0(\beta)$ A	V_0 V	I_0 A
1	107°	216°	29.6	14.8	4.00	8.00	4.87	0.13
2	47°	207°	28.0	18.4	14.4	12.00	7.54	0.20
3	16°	194°	60.0	17.6	36.0	22.4	11.21	0.30

→

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③ Heavy Inductive load $R = 1\Omega$

Sr No	α°	$V_o(\alpha)$ V	$i_o(\alpha)$ V	i_{omin} A	i_{omax} A	V_o V	I_o A
1	46°	6.4	9.6	24	11.2	15	0.38
2	36°	7.8	10.0	19.2	9.80	13.43	0.34
3	26°	8.8	11.2	20.8	8.80	14.58	0.32

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* Calculations:

- R load :

  $V_{orms} = 0.707\ V_{peak}$

  $= 1.11 \times V_o$

  Eg $V_{orms} = 1.11 \times 10.63 = 11.79\ V$

- $P_{dc} = V_o \cdot I_o$

  Eg $P_{dc} = 10.63 \times 0.1 = 1.063\ W$

- $P_{rms} = \frac{V_{rms}^2}{R}$

  Eg $P_{rms} = \frac{4.2^2}{R} = 0.46 W$

- $FF = \frac{V_{rms}}{V_o}$

  Eg $FF = \frac{4.2}{3.8} = 1.1$

- $RF = \sqrt{FF^2 - 1}$

  Eg - $RF = \sqrt{1.1^2 - 1} = 0.45$

Similarly calculated for R-L heavy & light inductive load.

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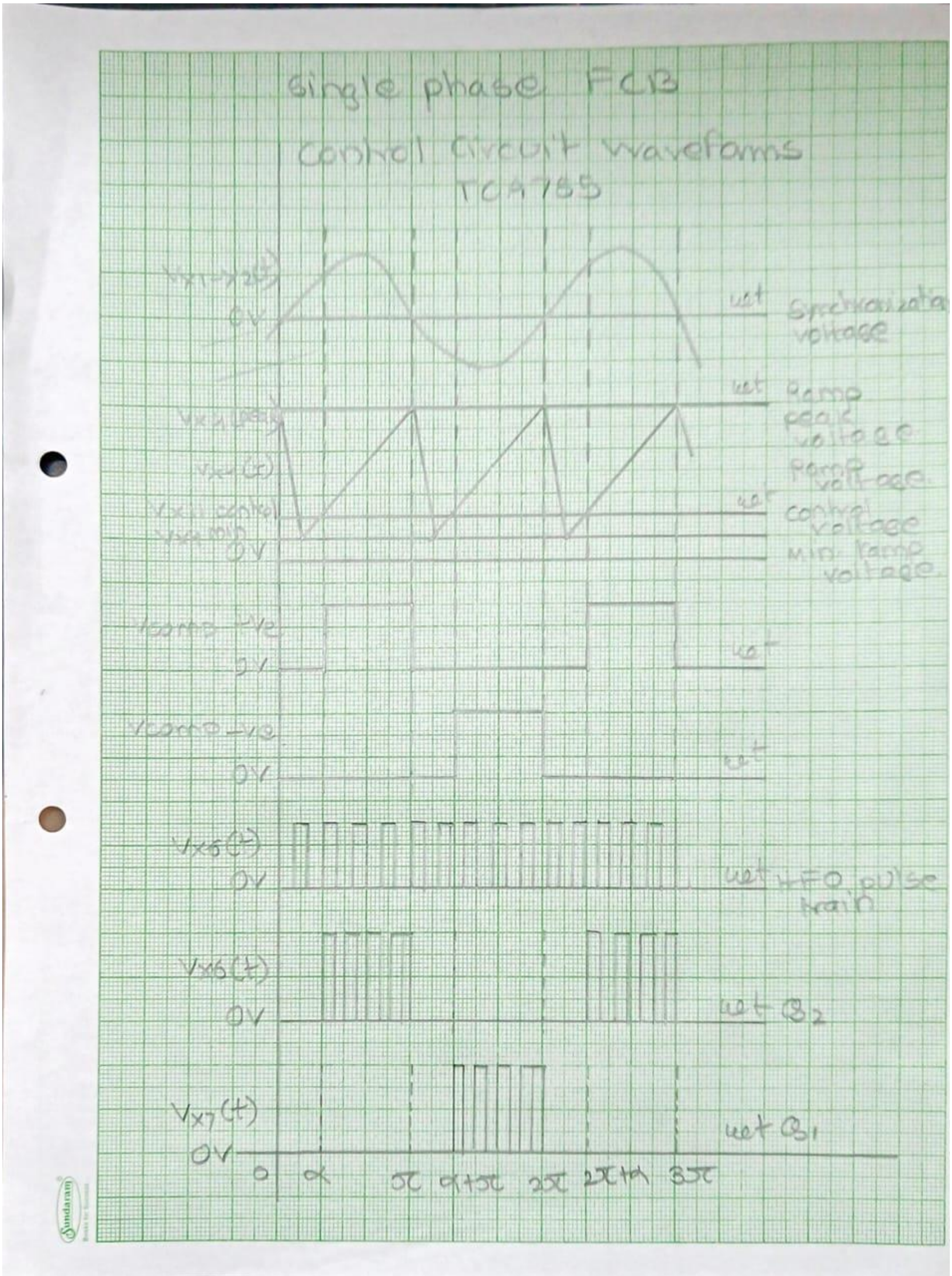
Single phase FCB
Control circuit waveforms
TCA785
Synchronization voltage
Ramp peak voltage
Ramp voltage
control voltage
min ramp voltage
HFO pulse train
Q2
Q1
0
α
π
α+π
2π
2π+α
3π