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BATCH: A3

ANALOG FIRING CIRCUIT FOR THYRISTORS

AIM: To study the operation of an analog IC-based firing circuit for thyristors used In single-phase half-controlled and fully-controlled rectifiers (LCC).

APPARATUS: 1) Circuit board.
2) DMM.
3) Dual-trace CRO with probes.

THEORY:

The firing circuit should deliver line-synchronized high-frequency modulated, isolated gate pulses to the thyristors, with adjustable firing angle α (0 to π). In the half-controlled (HCB) mode, pulses should be delivered to G1-K1 from $\omega t = \alpha$ to $\omega t = \pi$ and to G2-K2 from $\omega t = \alpha + \pi$ to $\omega t = 2\pi$.
In the fully controlled (FCB) mode, pulses should be delivered to G1-K1 from $\omega t = \alpha$ to $\omega t = \alpha + \pi$ and to G2-K2 from $\omega t = \alpha + \pi$ to $\omega t = \alpha + 2\pi$, with a small blanking time between the end of pulse G1-K1 (G2-K2) and start of pulse G2-K2 (G2 – K1).

CIRCUIT DESCRIPTION:

The mains supply is stepped–down by control transformer TR1 which has a 16V secondary. Resistance R1 and back-to-back connected zener diodes D1 & D2 clamp the voltage swing at **A** to + 5.8V. This clamped AC voltage is given to the +ve and –ve ZCDs and their outputs are square–waves co-incident with the zero crossings of the supply voltage. The -ve ZCD output **D** is +ve from $\omega t=0$ to π and –ve from $\omega t= \pi$ to 2π . The –ve ZCD output **B** is inverted w.r.t. the +ve ZCD.

At $\omega t =0$, the rising edge of the +ve ZCD triggers the +ve RAMP GENERATOR whose output **E** is a –ve going ramp from $\omega t= 0$ to 2π. Similarly the output **C** of the –ve RAMP GENERATOR is a –ve going ramp from $\omega t = \pi$ to 2π . A common control voltage **F** is generated by control potentiometer R31 and compared to the outputs of the +ve & -ve RAMP GENERATORS in the +ve & -ve comparators respectively. The +ve COMPARATOR output **G** is –ve from $\omega t = \alpha$ to π and +ve from $\omega t = 0$ to α . Similarly the –ve COMPARATOR output **H** is -ve from $\omega t = \alpha + \pi$ to 2π and +ve from $\omega t = \pi$ to $\alpha + \pi$.

The falling edges of the comparator outputs trigger their respective PULSE STRETCHERS (MONOSTABLES) whose duration is slightly less than T/2 or 180°. Hence the +ve PULSE STRETCHER output **I** is HI from $\omega t = \alpha$ to $\alpha + \pi$ whereas the –ve PULSE STRETCHER output **J** is HI from $\omega t = \alpha + \pi$ to $\alpha + 2\pi$.

The pulse stretcher outputs are ANDed with the high frequency pulses produced by an astable oscillator having a duty cycle less than 50% and a frequency of approximately 20 KHz and are then amplified by the +ve & -ve PULSE AMPLIFIERS and finally given to gate terminals G1-K1 & G2-K2. Galvanic isolation and gate current boosting is provided by pulse transformers TR2 and TR3.

Control of the firing angle is achieved by varying potentiometer R31 to change the control voltage magnitude.

Closing jumpers JP1, JP3, JP5 & JP7 selects the FCB mode, while closing jumpers JP2, JP4, JP6 & JP8 selects the HCB mode.

PROCEDURE:

1. Connect the mains supply.
2. Connect one channel of the CRO to the synchronizing AC voltage across **X1** (live) and **X2** (ground) and the other channel to the +ve ZCD output **D** (**TP4, X15**). Observe and draw the waveforms.
3. Now connect the other channel successively to -ve ZCD output **B** (**TP2, X14**), +ve ramp generator output **E** (**TP5, X11**) -ve ramp generator output **C** (**TP3, X10**), control voltage **F** (**TP6, X12**), +ve comparator output **G** (**TP7**), -ve comparator output **H** (**TP8**), –ve pulse stretcher (monostable) output **J** (**TP10, X17**), +ve pulse stretcher (monostable) output **I** (**TP9, X16**). Observe and draw the waveforms. Measure the +ve & -ve pulse stretcher durations as equivalent angles (in degress).
4. Measure the frequency (f) and duty cycle $t_{ON} / (t_{ON} + t_{OFF}) = t_{ON} /T = f\ t_{ON}$ of the high frequency oscillator output **M** (**TP13, X13**). Draw the waveform to scale.
5. Close jumpers JP2, JP4, JP6 & JP8 and open jumpers JP1, JP3, JP5 & JP7 (HCB selection).
6. Connect the other channel of the CRO to the isolated gate output G1-& observe and draw the waveforms as control voltage is varied using potentiometer R31. Take six read

ings of firing angle α versus control voltage with α varying from minimum (approximately 0°) to maximum (approximately 180°). Plot α versus control voltage.
Repeat for output voltage G2-K2.

7. Open jumpers JP2, JP4, JP6 & JP8 and close jumpers JP1, JP3, JP5 & JP 7 (FCB selection).
8. Repeat step 6.

OBSERVATIONS:

1. +ve pulse stretcher duration =
2. -ve pulse stretcher duration =
3. f_{HFO} = Hz.
4. Duty cycle of HFO =

SR.NO.	MODE	CONTROL VOLTAGE V	FIRING ANGLE °
1.	HCB		
2.	HCB		
3.	HCB		
4.	HCB		

5.	HCB		
6.	HCB		
7.	FCB		
8.	FCB		
9.	FCB		
10.	FCB		
11.	FCB		
12.	FCB		

CONCLUSIONS:

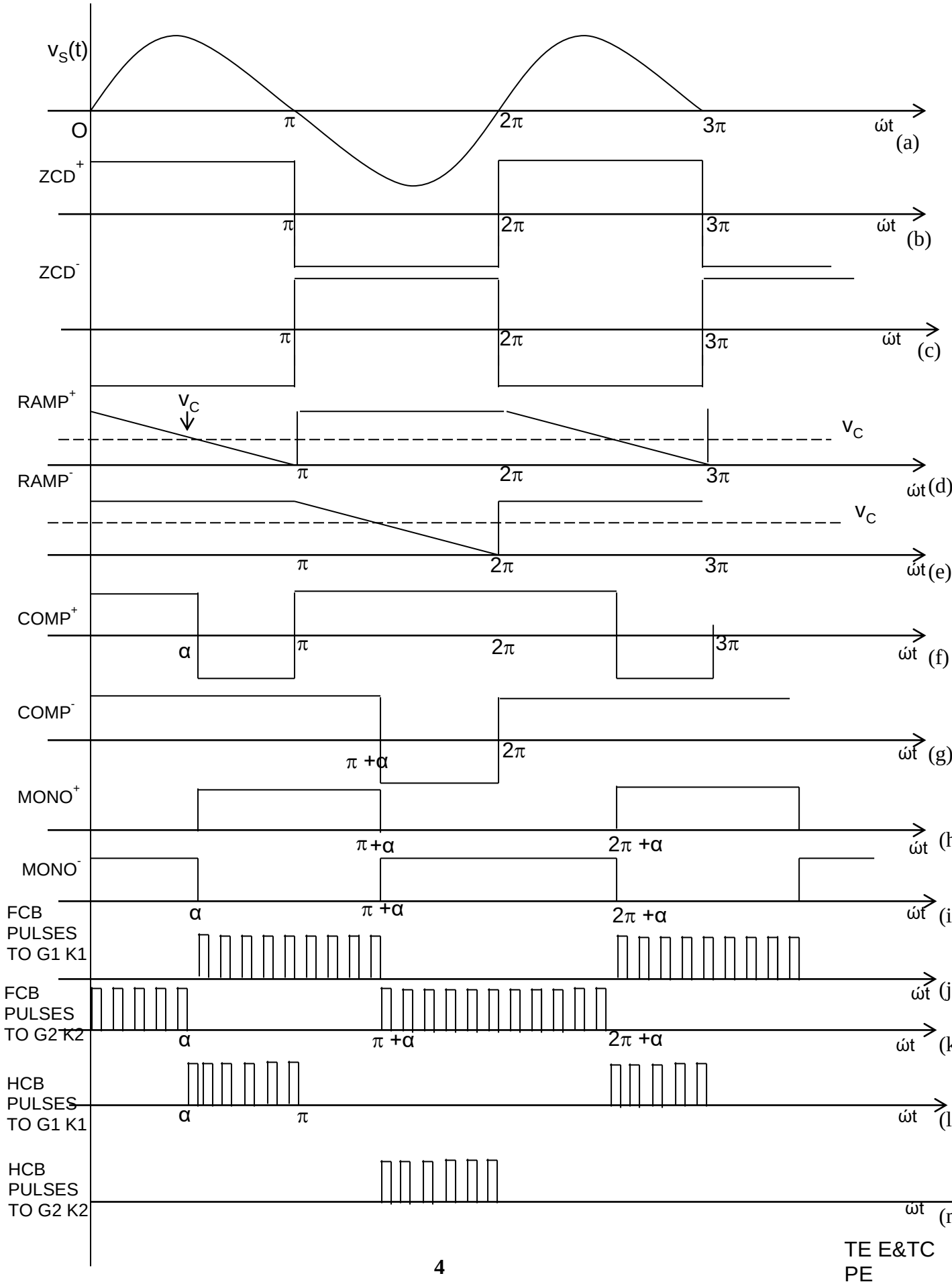

Fig.2 Analog circuit waveforms

Exp-3 Analog Firing circuit

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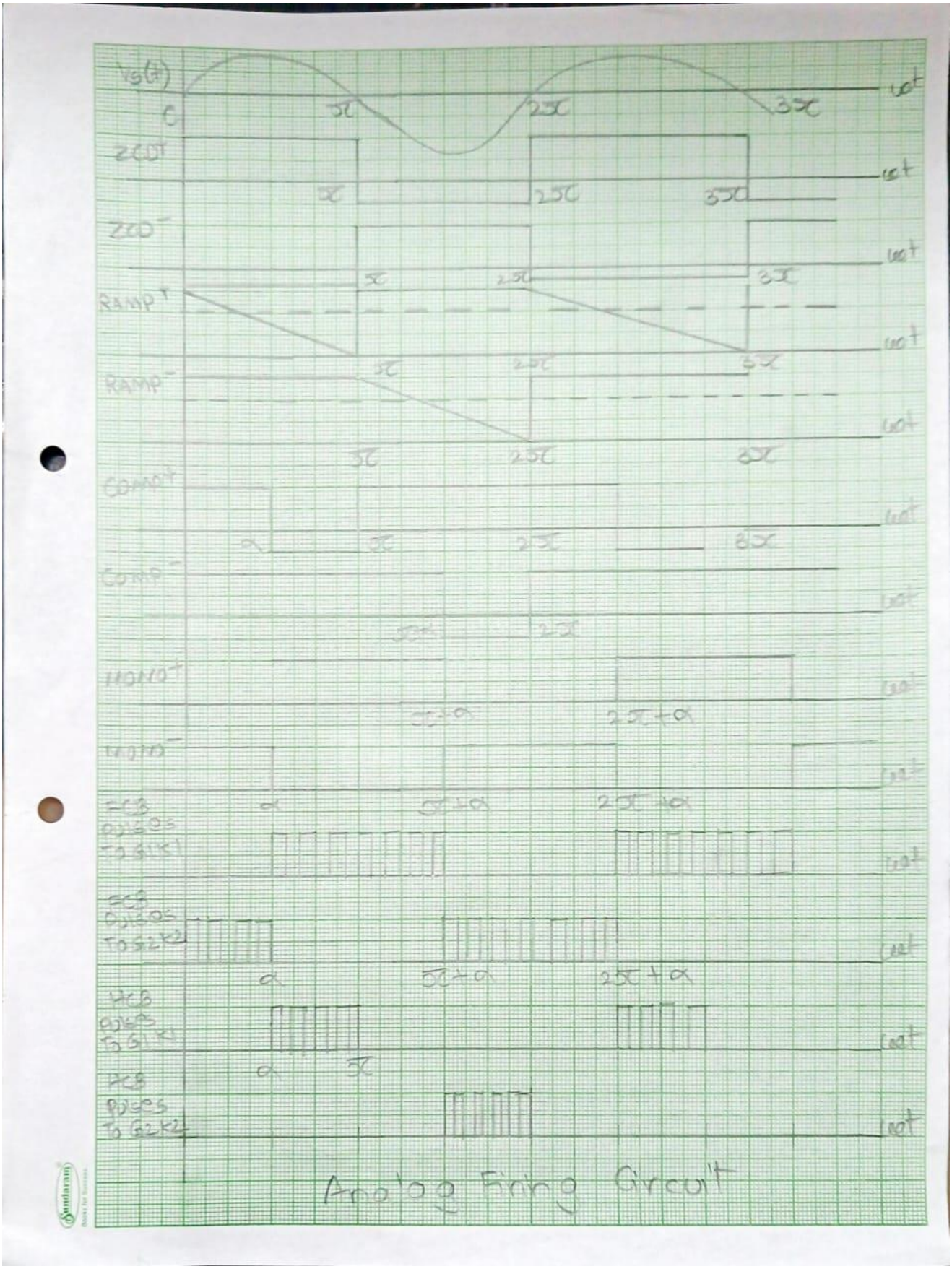
* observations.

	HCB	FCB
+ve pulse shether duration.	α to π	α to $\pi+\alpha$
-ve pulse shether duration	$\pi+\alpha$	$\pi+\alpha$ to $2\pi+\alpha$

Sr No	Mode	Control V	Firing Angle.
1	HCB	9.65V	0°
2	HCB	8.28V	30°
3	HCB	6.31V	60°
4	HCB	4.25V	90°
5	HCB	2.15V	120°
6	HCB	0.2V	150°
7	FCB	8.39V	180°
8	FCB	6.64V	210°
9	FCB	4.50V	240°
10	FCB	2.51V	270°
11	FCB	0.38V	300°


Vs(t)
ZCDT
ZCD⁻
RAMP⁺
RAMP⁻
COMP⁺
COMP⁻
MONO⁺
MONO⁻
PCB PULSES TO G1K1
PCB PULSES TO G2K2
PCB PULSES TO G1K1
PCB PULSES TO G2K2
Analog Firing Circuit