United States Patent

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[33] **Great Britain**
[31] **33622/67**

[54] **CONTROL SYSTEMS FOR CRANES**
5 Claims, 8 Drawing Figs.

[52] U.S. Cl. 318/203, 318/258, 318/289
[51] Int. Cl. H02p 1/40
[50] Field of Search 318/202, 203, 258, 289

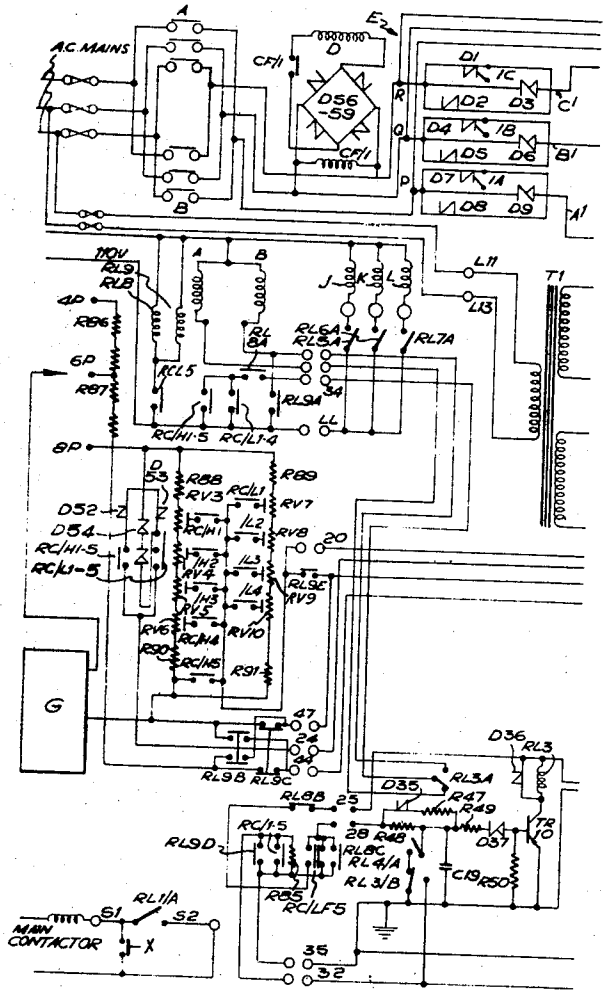
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ABSTRACT: A control system for an electric crane or hoist motor supplied through thyristor circuitry wherein the lifting and lowering speed and travel is controlled by saw tooth voltage generators which adjust the firing angle of the thyristors, the sawtooth waveform being applied to the trigger electrodes of the thyristors.



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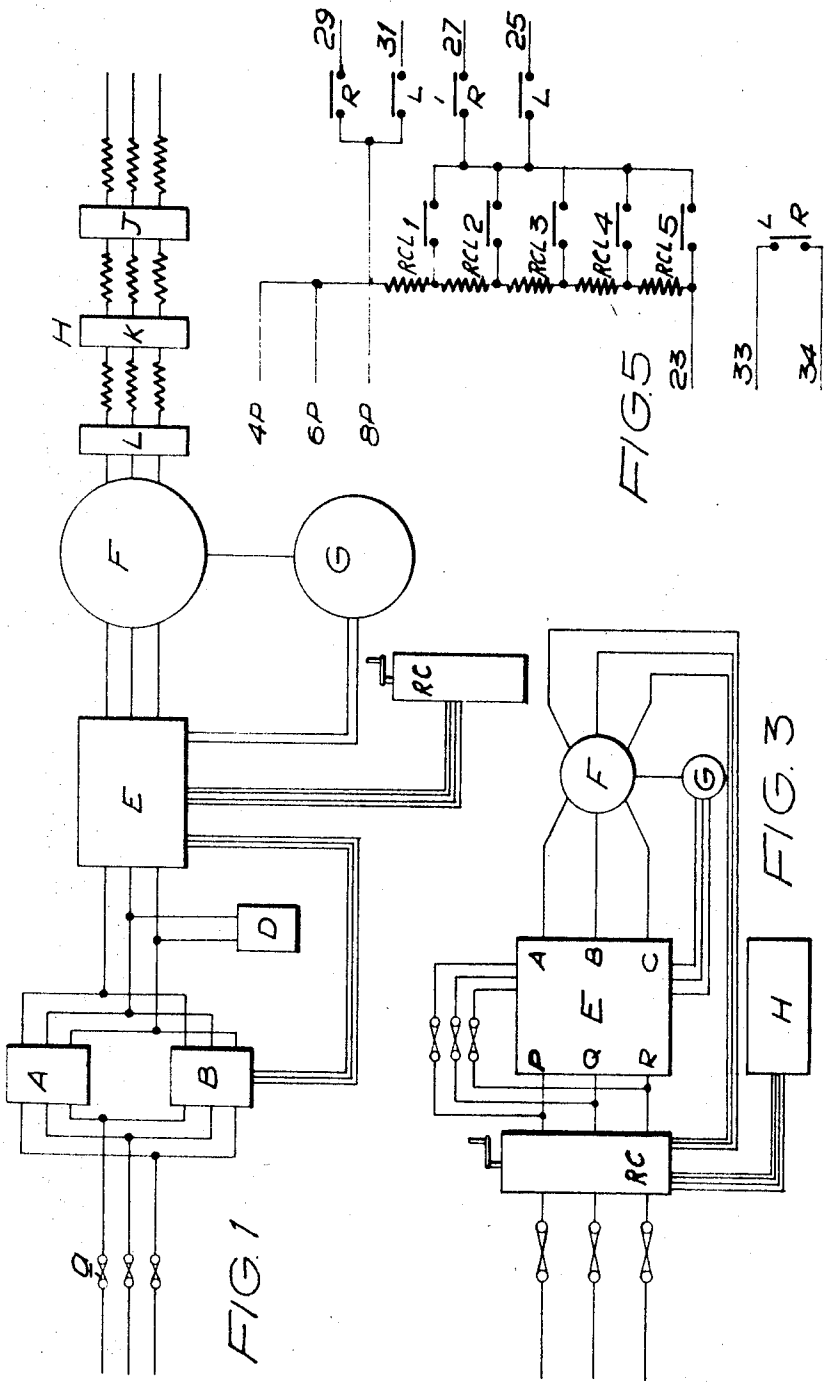


FIG. 5

FIG. 1

FIG. 3

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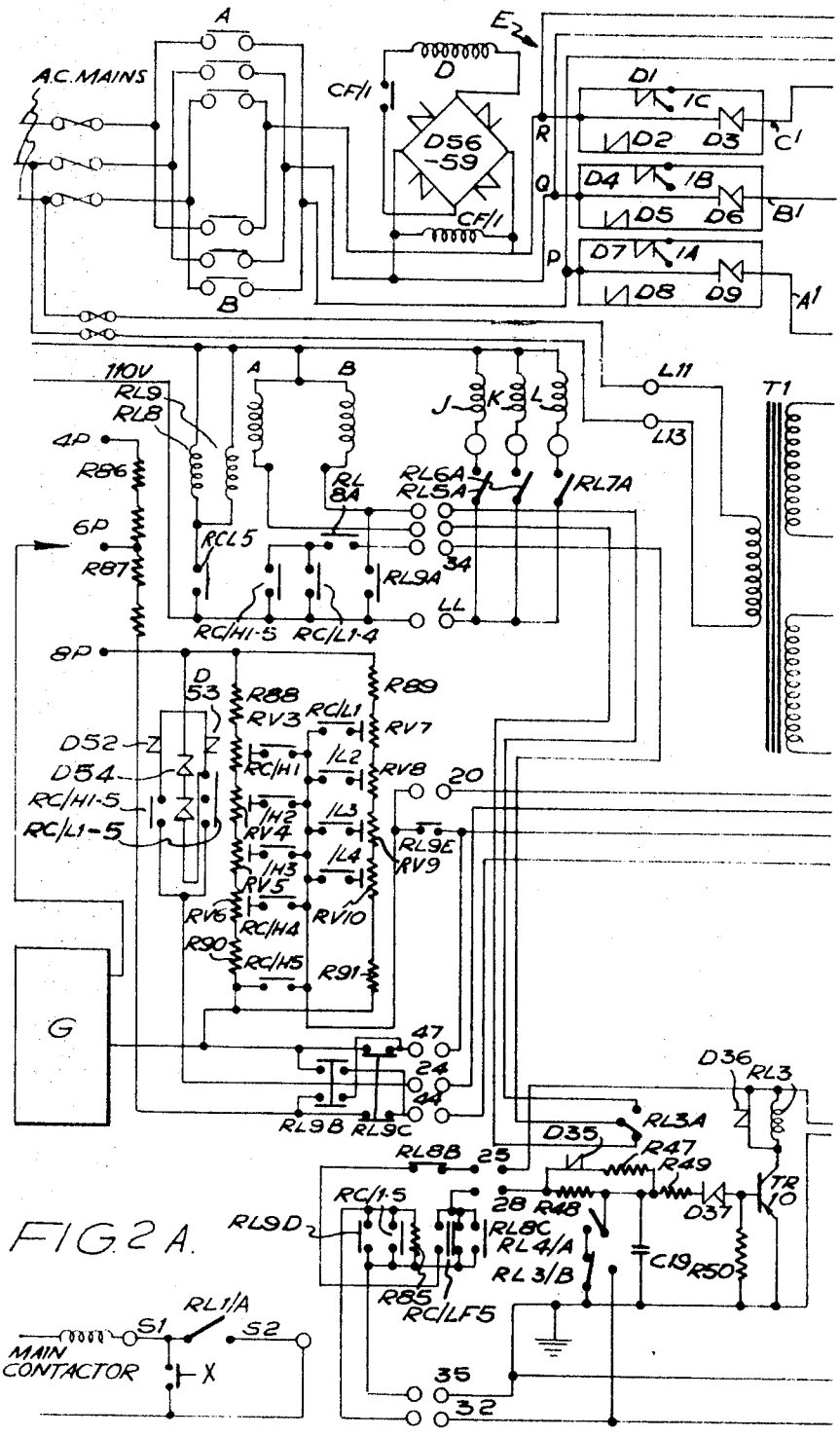
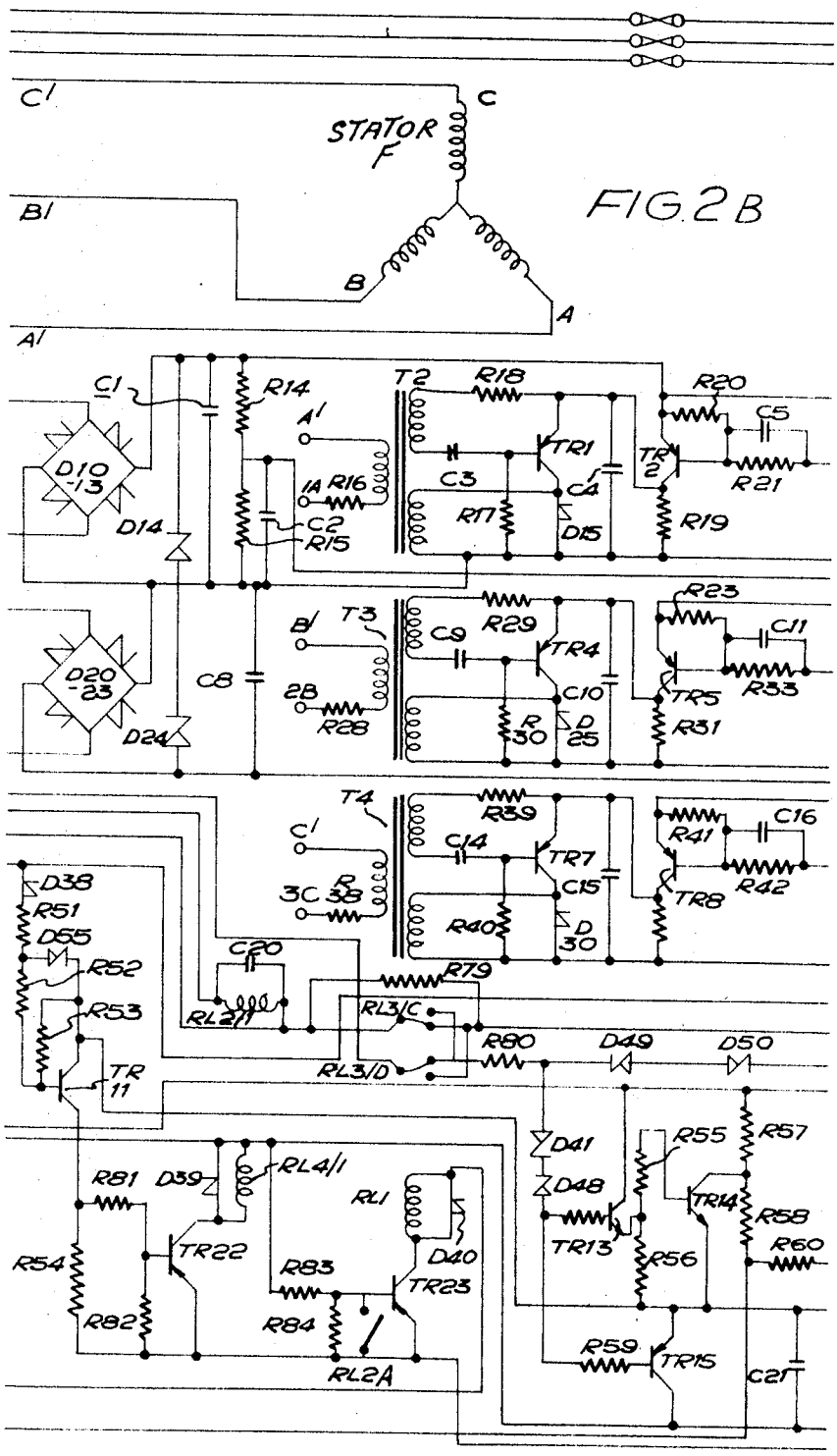


FIG. 2A.

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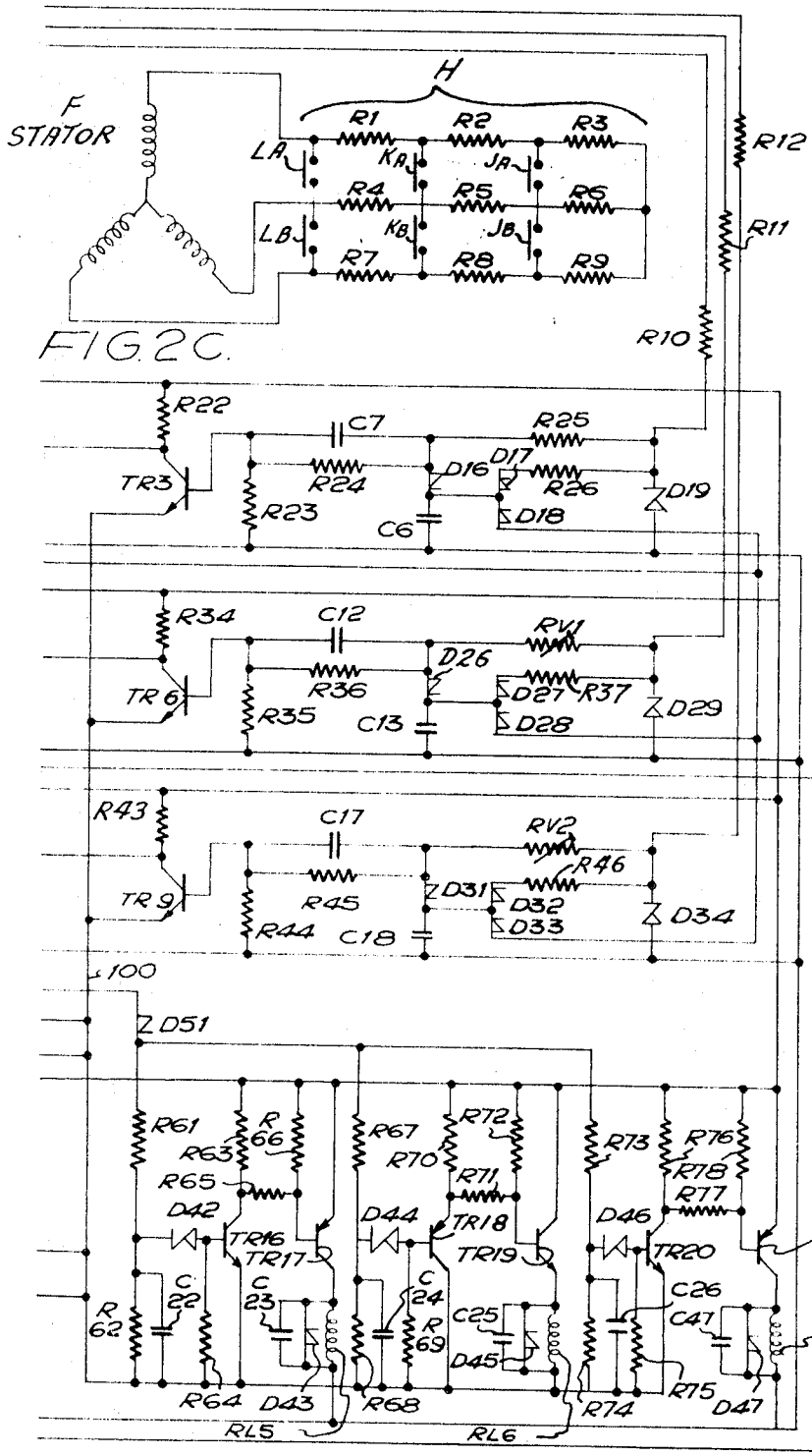


FIG. 2C.

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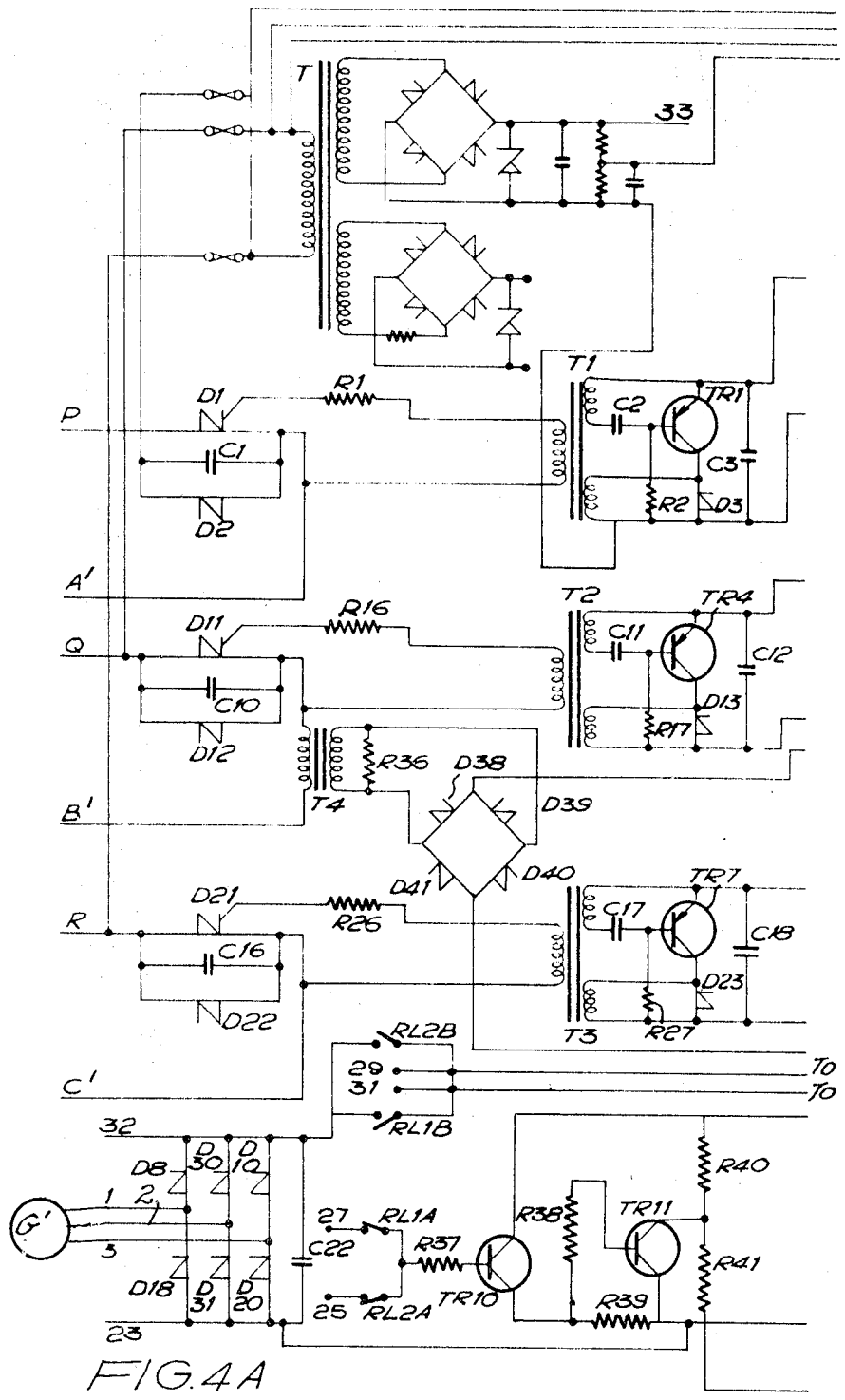
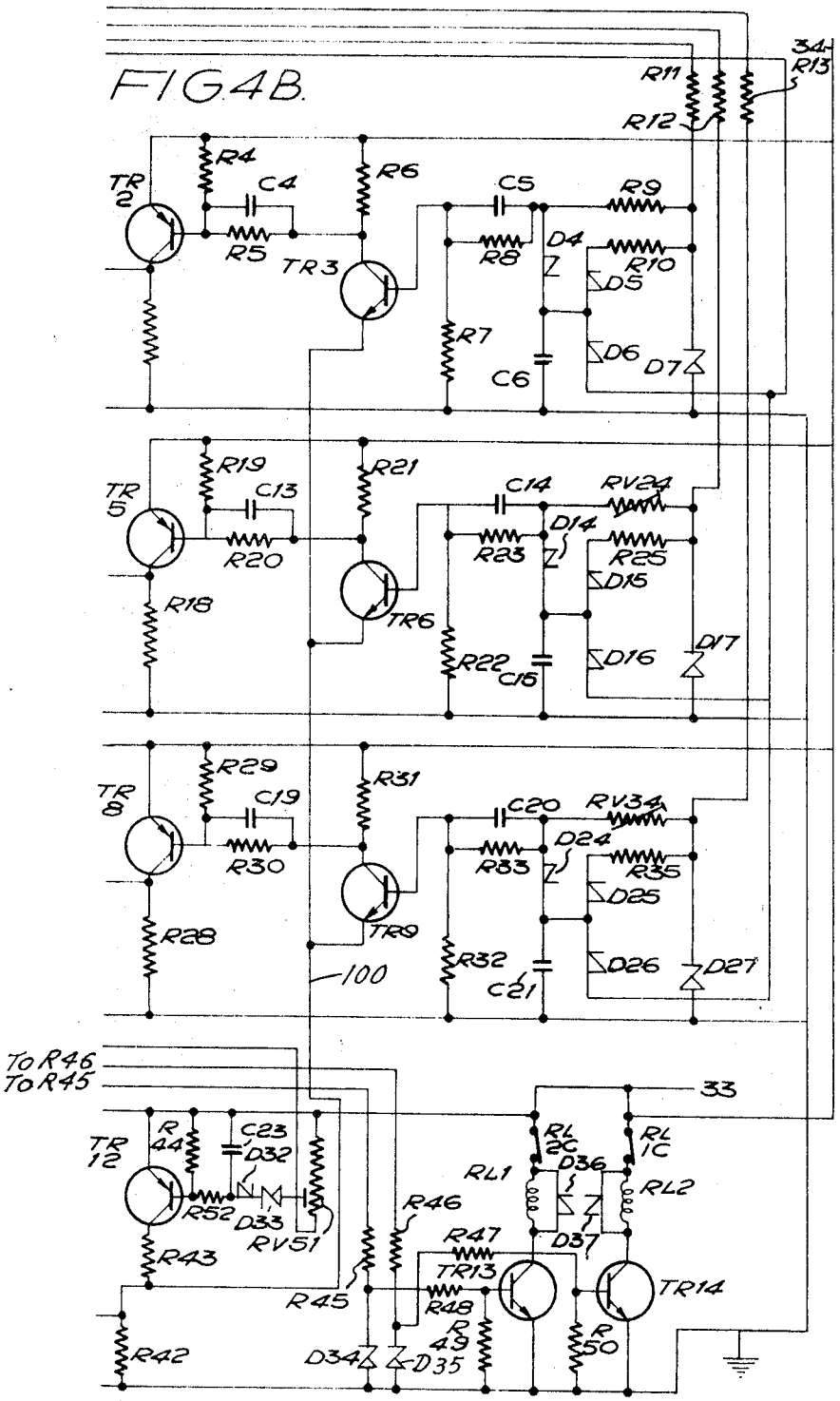


FIG. 4A

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FIG.4B.



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CONTROL SYSTEMS FOR CRANES

This invention relates to improvements in control systems for cranes and hoists.

According to the invention a control system for cranes or hoists comprising thyristor circuitry employing sawtooth voltage waveform for controlling the lifting and lowering speed of cranes and hoists.

The invention will be described with reference to the accompanying drawings:

FIG. 1 is a diagrammatic view of one form of the invention,

FIGS. 2A, 2B, 2C show a circuit diagram for the form of the invention shown diagrammatically in FIG. 1, FIGS. 2B and 2C are continuations of 2A;

FIG. 3 is a diagrammatic view of a further arrangement;

FIGS. 4A and 4B show a circuit diagram of the modified arrangement of the invention shown diagrammatically in FIG. 3. FIG. 4B is a continuation of FIG. 4A;

FIG. 5 is a detail diagram of part of the circuit of the controller RC shown in FIG. 3.

When using a slip ring or squirrel cage motor F (FIG. 1) the supply is fed through fuses *a* to reversing contactors A and B which may be static switches. The contactors, A, B are controlled by the driver by operation of the controller RC, which may be replaced by relays if remote control is required.

The operation of the contactors A or B by the controller C also operates a brake D, which is of the electromagnetic type.

The voltage from the contactors is also applied to a static control unit E the diagram of which is shown in FIGS. 2A—2C.

The controlled voltage from the static control unit E is then fed to the motor F, which may be a squirrel cage or slip ring motor. The motor F drives a tachogenerator G to provide feedback to the control unit E.

When a slip ring motor is used (FIG. 1) the motor resistance is short-circuited by contactor contacts J, K and L. The contactors J, K, L are controlled through a tachogenerator G and the control unit E so that they operate at the correct motor speed to give optimum torque over the speed range.

The complete control circuit for a hoist is shown in FIG. 2A–20.

The speed is controlled by varying the voltage to the motor by means of thyristors D1, D4 and D7. The thyristors are series elements in the motor supply leads, terminals P and A^1, Q and B^1, R and C^1 being provided for each of the supply phases as shown in FIG. 2A for lifting and lowering. The travel control is shown in FIG. 4A by diodes D1 and D2, D11 and D12, D21 and D22 and their associated capacitors C1, C10 and C16.

The return current from the motor passes through rectifiers D2, D5 and D8; surge suppressors D3, D6 and D9 conduct when surge voltages are present to clip the voltage and protect the thyristors.

For hoisting, full power is initially applied to the motor by operation of controller RC contact RC/H1, for first speed and RC/H2 for second, etc., to ensure that the load always hoists, and on reaching the set speed, the firing angle of the thyristors is controlled so that the motor power is reduced sufficiently to maintain that speed.

Any deviation of speed will cause a corresponding change of motor power to correct the change of speed.

For lowering moderate to heavy loads the motor is connected as for hoisting and, when the controller RC is operated, the hoist contactor A is energized and the brake D will release. The firing angle of the thyristors is such that no power will be applied to the motor and the load will accelerate down under gravity. At the set lowering speed the thyristor firing angle will change and apply sufficient braking power to maintain that speed.

For light loads, when the brake D is released the load will not descend. A circuit comprising transistor TR10, relay RL3, transistor TR11, TR22, relay RL4 and their associated components will, after a short delay and no tachogenerator output,

reverse the motor and the tachogenerator connection for wind down at the correct speed, similar to the hoisting operation.

For lowering on notches RC/1—4 (FIG. 2A) a full rotor resistor H (R1—R9) FIG. 2C is left in.

The operation is as follows: when lowering on notches RC/L (1—4), terminal 28 is disconnected from terminal 35 (earth) and connected to terminal 25 (supply) by a contact RE/LF5 on controller RC. Capacitor C19 starts to charge through R48 when the voltage across C19 exceeds the conduction voltage of the Zener diode D37. Transistor TR10 will conduct operating relay RL3 to reverse the motor torque by means of its contact RL3A deenergizing contactor A and energizing contactor B, connecting the motor F in the lowering direction.

Contacts R3L/C and R3L/D reverse the polarity of the tachogenerator induced voltage such that the polarity of the signal applied to transistor TR13 and TR15 FIG. 2B is as for hoisting and a reduction in motor power when the set speed is reached takes place similarly to that for hoisting.

Contact RL3/B prevents contact R14/A discharging capacitor C19 once contact RL3/B also short circuits resistor R85 to ensure that the thyristors are initially turned full on.

Resistor R47 and diode D35 ensure a quick discharge of C19 when the controller RC is returned to the "off" position via terminal 28 now reconnected to terminal 35 (earth).

Should there be a load on the hook, the load will descend under gravity when the brake is released. The tachogenerator G which is coupled to the motor will turn and produce a voltage which will cause transistor TR11 to conduct and hence transistor TR22. Transistor TR22 will energize relay RL4 which will discharge capacitor C19 by means of contact RL4A preventing R13 from operating.

The base of transistor TR11 is connected to one tachogenerator connection via resistors R52 and R51, the emitter of transistor TR11 is connected to the other tachogenerator connection via relay contact RL3/C, when the tachogenerator starts to turn the small voltage generated causing the transistor to conduct.

Zener diode D55 clips the voltage to prevent damage to transistor TR11 when the tachogenerator is running at fast speed the resistor R51 acts as the ballast resistor. Resistor R52 limits the base current of TR11 at fast speed when the full Zener voltage is present across D55. Resistor R53 is to tie the base of transistor TR11 to its emitter when no drive is present.

Then transistor TR11 conducts, a voltage is developed across its collector load R54, this voltage drives transistor TR22 via resistor R81 and resistor R82 ties the base of transistor TR22 to its emitter when transistor TR11 is not conducting. When transistor TR22 conducts, relay RL4 its collector load is energized. Diode D39 prevents damage to transistor TR22 when a voltage is induced in the relay RL4 coil when the transistor TR22 is turned off.

Contact RL9A energizes the down contactor, contact RL9D short circuits R85 to give full drive to the thyristors. Contact RL9E ensures that the drive to the thyristors is unaffected by speed, (i.e., no feedback). Contacts RL8B and RL8C ensure that the delay circuit operating RL3 is inoperative, and contact RL8A interlocks the hoist contactor A by opening thereby preventing feed to contactor B. Contacts RL9B and RL9C reverse the tachogenerator output polarity to enable the rotor contactors to operate.

Relay RL8 when deenergized has a slight delay to enable the changeover from power lowering to brake lowering to be carried out reasonably smoothly when changing from notch RCL5 to notch RCL4.

When lowering on notch RCL5 the motor is conventionally powered, contact RCL5 on the controller operating relays RL8 and RL9.

For hoisting and lowering on notch RCL5 where a slip ring motor is used, the contactors J, K and L (FIG. 1) are operated at the correct motor speeds by the circuitry TR16, TR17 and relay RL5 and associated components for contactor J, transistors TR18, TR19, and relay RL6 and associated components for contactor K, transistors TR20, TR21 and relay

RL7 and associated components for contactor L. These circuits are fed from the tachogenerator G, the output of which is fed to a potential divider, one for each contactor. R61 and R62 for contactor J, R67 and R68 for contactor K, R73 and R74 for contactor L (FIG. 2C).

When the voltage at the junction of the resistors R61—R62, R67—R68, R73—R74 exceeds the voltage rating of Zener diodes D42, D44 and D46, the transistors TR16, TR18, TR20 will conduct and operate their respective relays RL5, RL6 and RL7, which in turn will operate their respective contacts J, K and L.

Capacitors C22, C23, C24, C25, C26 and C47 are to smooth out any fluctuation in drive voltage, diodes D43, D45 and D47 protects transistors TR17, TR19 and TR21 from damage resulting from the inductive kick when turning off similarly as for diode D39. Resistors R66, R72 and R78 are for bias purposes and rectifier D51 prevents reverse voltage from being applied when lowering at slow speed. As speed is reduced, the voltage at the potential dividers R61—R62, R67—R68, R73—R74 will fall below the Zener voltage of diodes 42, 44, 46 and the transistors TR16, TR18, TR20 will stop conducting thereby releasing the relays RL5, RL6 and RLK7 and contactors J, K, and L.

Transistor TR23, Zener diode D54, relays RL1 and RL2 and associate circuitry ensure that, on lowering, if the maximum set overspeed is exceeded for any reason, the crane main contactor is deenergized, due to Zener diode D54 conducting and energizing relay RL2 which deenergizes relay RL1 by short circuiting the drive applied to transistor TR23 through resistors R83 and R84 by means of contact RL2A. This applies the brake and cuts off power to the motor until the reset button X is operated (FIG. 2A), diode D40 protects transistor TR23 similarly as diode D39 protects transistor TR22.

The control of the firing angle of the thyristors is carried out by a sawtooth voltage waveform derived from the phase to be controlled at terminals P, Q and R in FIG. 2A, the sawteeth are achieved by charging from a square wave of fixed amplitude via resistors R25, RV1 and RV2 and capacitors C6, C13 and C18, one for each phase. The square waves are obtained from the sinusoidal supply by Zener diodes D19, D29 and D34 in conjunction with the ballast resistors R10, R11, R12. The sawteeth are applied to the bases of the transistors TR3, TR6 and TR9 via resistors R24, R36 and R45 and speed up capacitors C7, C12 and C17 to improve waveform front so that each will conduct when its sawteeth voltage exceeds that of the common emitter bias 100.

The output obtained across the collector loads R22, R34 and R43 of transistors TR3, TR6 and TR9 are fed through resistors R21, R33 and R42, capacitors C5, C11 and C16 to drive transistors TR2, TR5 and TR8 each having a bias resistance R20, R32 and R41. When these transistors conduct, an output voltage appears across the collector load resistors R19, R31 and R100.

To vary the conduction angle, the bias is adjusted by a transistor (TR13, TR14, TR15) controlled from the tachogenerator G.

Variable resistors RV1 and RV2 are to adjust the rated rise of the sawteeth so that all three phases are identical.

The discharge of capacitors C6, C13 and C18 is carried out by D16, D17, D18, R26 / D26, D27, D28, R37 / D31, D32, D33, R46 to ensure quick discharge to a clamp voltage level supplied by resistors R14, R15 and decoupled by capacitor C2.

For hoisting all loads and lowering light loads the bias 100 is set to approximately zero so that the thyristors are turned on as soon as the sawtooth starts. This gives full power to the motor. When the set speed is attained, the transistors TR13 and TR14 start to conduct and raise the bias level until just sufficient power is fed to the motor to maintain the set speed. Any increase in speed will result in lower power being fed to the motor and any decrease in speed will result in increased power being fed to the motor to correct any deviation.

For lowering heavy to moderate loads, where the motor is used as a brake, the bias 100 is set to a level above the peak of the sawtooth so that the load will descend under gravity until the set speed is attained. The transistor TR15 will thereby be caused to conduct by the tachogenerator and the bias 100 will reduce, thus causing the thyristors to conduct and feed braking power into the motor.

The operation of transistor TR13, TR14 and TR15 is as follows: when the selection hoist speed is attained the voltage applied to terminals 20 and 47 from the tachogenerator exceeds the conducting voltage of the Zener diode D48 causing transistor TR13, i.e. the emitter follower to conduct, the voltage across its emitter load R56 driving transistor TR14 via resistor R55. The collector current of transistor TR14 flows through the circuit comprising resistor R57 and R60, the voltage across R60 forming the emitter bias 100 for transistors TR3, TR6 and TR9. This voltage causes TR3, TR6 and TR9 to start to turn off and reduce the conducting angle of the thyristors D1, D4 and D7 to reduce power to the motor F.

This also applies to lowering light loads after relay RL3 has operated.

When a moderate to heavy load is lowered the resistor R85 (FIG. 2A) is in circuit and the bias is such that transistors TR3, TR6 and TR9 are off, and no power is fed to the motor (FIG. 2B). The load will descend under gravity until the selected speed is attained when the tachogenerator voltage applied to terminals 20 and 47 exceeds the conducting voltage of Zener diode D41 when transistor TR15 will start to conduct due to base drive following through resistor R59 and reduce the bias 100 until transistors TR3, TR6 and TR9 start to conduct to turn on the thyristors D1, D4 and D7 and produce braking torque by means of the motor F.

Zener diodes D49 and D50D49 and D50 and ballast resistor R80 are to protect transistors TR13 and TR15 from overvoltage when slow is selected while in fast motion, the voltage then being high until the control has reduced the speed. Capacitor C21 damps any possible oscillation of the bias 100 to which it is connected.

The hoisting and lowering speed selection notes, five for each direction are shown in FIG. 2A (RE/H1 to RE/H5 for hoisting RC/L1 to RC/L4 for lowering, RC/L5 is full speed) which select the percentage of the tachogenerator voltage fed to the control unit C. Fine control of speed in by RV3-RV10. A rectifier selector, RC/H1-5 for hoisting, RC/L1-5 for lowering, which acts as a safety device is also shown.

The rectifier selected D52 or D53 in FIG. 2A is opposing the potential of the tachogenerator output for the direction selected. Should a lowering motion take place when on a hoisting notch, the rectifier D52 will conduct and relay RL2 in FIG. 2B will operate, thereby deenergizing the contactor A and applying the brake D via contact RL2A, transistor TR23 and deenergizes relay RL1 to open circuit the hoist main contactor circuit. Similarly rectifier D53 will conduct and the same will follow if the unit is hoisting when on a lowering notch.

To enable a standard unit to be capable of controlling the speeds of motors with varying numbers of poles resistors R86 and R87 are used so that a constant full speed voltage is derived independent of the number of motor poles and hence full speed r.p.m. decreased and a fully variable speed control is available, when the tapped resistor chain becomes a single potentiometer.

The low voltage power for the transistors TR1—TR23 is obtained from transformer T1, FIG. 2A, connected to the supply via terminals L11 and L13 and fuses.

Two low voltage outputs are obtained from the transformer T1, each connected to a bridge rectifier D10—13 and D20—23 to obtain DC voltage.

The voltage is stabilized by means of Zener diodes D14 and D24 and are filtered by means of capacitors C1 and C8.

A contactor CF FIG. 2A is to enable the electromagnetic brake D to deenergize quickly, by breaking the DC connection and preventing the brake holding off due to the inductive

currents circulating through the rectifier bridge D56—D59, while the magnetic field collapses.

A travel motion which is similar to that of FIG. 2 may be employed having an A/C tachogenerator G1 and a current limiting transformer T4 as is shown in FIGS. 3—5. The transformer T4 (FIG. 4A) output which is rectified by the rectifier bridge D38—D41 and is fed to a load resistor RV51, a small load R36 is also present on the AC output in case of open circuit in the rectifier D38—D41 at some time.

The DC voltage across the load RV51 which is proportional to the AC load current passing through the primary of transformer T4 is connected to the base of transistor TR12 via Zener diode D33, rectifier D32 and resistor R52.

Capacitor C23 smooths out any ripples in the rectified voltage when the voltage at the wiper of resistor RV51 exceeds the Zener voltage of diode D33, the transmitter TR12 will conduct, current will flow through its collector load R43 and R42 to vary the bias 100 applied to the sawteeth transistors TR3, TR6 and TR9 and reduce the motor power.

The current at which this takes place is adjustable by means of the wiper on resistor RV51 and will control the motor acceleration and protect the motor and equipment from over current.

Control is similar to that in FIG. 2 where TR13 and TR14 are now TR10, and TR11 in FIG. 4A.

R55, R56, R57, R60 are now R38, R39, R40 R41 and R42.

Since the output from the tachogenerator G1 is rectified to DC by rectifier D8, D10, D18, D20, D30, D31 the polarity is the same for both directions of travel, relays RL1 and RL2 driven from the tachogenerator via transistors TR13 and TR14 enable the control unit to distinguish the direction of travel. The relay RL1 and RL2 depending on the direction selected, is energized by the controller contacts R or L terminals 25 or 27 (FIG. 5) depending on whether right or left has been selected.

Once a direction has been selected and tachogenerator output obtained, the correct relay is energized, with contacts RL1B or RL2B indirectly maintaining the relays RL1 or RL2 by the rectified output from the tachogenerator until motion in that direction has almost ceased. Contact RL1A or RL2A ensures that no speed limitation is imposed if the selected direction is reversed, until after the motion passes through zero in order to be able to reverse brake. Contacts RL1C and RL2C ensure that when a direction has been selected and either RL1 or RL2 energized, the other relay cannot operate until the first relay deenergizes when motion passes through zero.

The transistors TR13 and TR14 which have the relays RL1 and RL2 in their collectors are driven from the rectified tacho output via ballast resistors R45 and R46 which in conjunction with Zener diodes D34, D35 prevent damage to the transistors TR13 and TR14 when full voltage is applied. The drive to the bases of transistors TR13 and TR14 are taken from across the Zener diodes D34, D35 by resistors R47, R48, R49, R50. Diodes 36 and D37 prevent damage to the transistors on deenergization.

The relays controlling the direction of travel will operate at a very small drive voltage from the tacho and will not deenergize even when reverse direction is selected until motion in the original direction has ceased, the operation being similar to that for the lifting and hoisting control.

When open loop control is required the tachogenerator G1 relays RL1 and RL2, transistors TR10 and TR11 and associated components are omitted, and control is carried out with a variable resistor in place of TR11, the current limiting feature is retained.

What I claim is:

1. A control system for a reversible electric crane or hoist motor having a brake associated therewith, comprising an electrical supply source; supply circuit means including motor reversing means, brake actuating means, and thyristor means connecting said supply source to said motor; controller circuit means including a tachogenerator driven by said motor, a static control circuit receiving a feedback signal from said tachogenerator and connected to and applying a control signal to said thyristor means for adjusting the firing angle of said thyristor means in response to said feedback signal, thereby accurately and smoothly controlling the speed of said motor; said controller circuit means also including hoisting and lowering contact means operable to actuate said motor reversing means to a hoisting or lowering position and to actuate said brake actuating means to a brake release condition, and means associated with said static control circuit for permitting a sufficiently heavy load to initially accelerate downwardly under gravity to a predetermined speed when said hoisting and lowering contact means has been set for lowering and for then causing said static control circuit to change the firing angle of said thyristor means to apply current to said motor in a hoisting direction, thereby applying sufficient motor braking power to maintain said predetermined speed.

2. A control system as defined in claim 1, wherein, when said hoisting and lowering contact means is initially set for lowering, said motor reversing means is still positioned as for hoisting so that the load, if sufficiently heavy, initially falls only under gravity until the predetermined speed is reached at which time said thyristors means will pass current in a motor hoisting direction, thereby effectively applying braking power to said motor to maintain the predetermined speed.

3. A control system as defined in claim 2, said controller circuit means including time delay circuit means operative after a period of time to automatically actuate said motor reversing means to a lowering position to effect lowering at said predetermined speed, thereby initially positively driving said motor in a lowering direction when the load is too light to initially descend under gravity.

4. A control system as defined in claim 1, wherein said motor is a slip ring motor in which the value of rotor resistance is controlled by the motor speed.

5. A control system as defined in claim 1, comprising means for stopping said motor and applying said brake in the event said crane lowers when said controller has been set for ho sting.