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AL BA HR LV MK YU(71) Applicant: **Yorkshire Technology Limited****Bradford****West Yorkshire BD4 7BB (GB)**(72) Inventor: **Ryecroft, Gary****Leeds LS8 1JH (GB)**(74) Representative: **Waddington, Richard et al****Appleyard Lees,****15 Clare Road****Halifax HX1 2HY (GB)**(54) **Motor control system**

(57) A motor control system for a closure mechanism, the system comprising:

a first buffering circuit adapted to buffer a first waveform

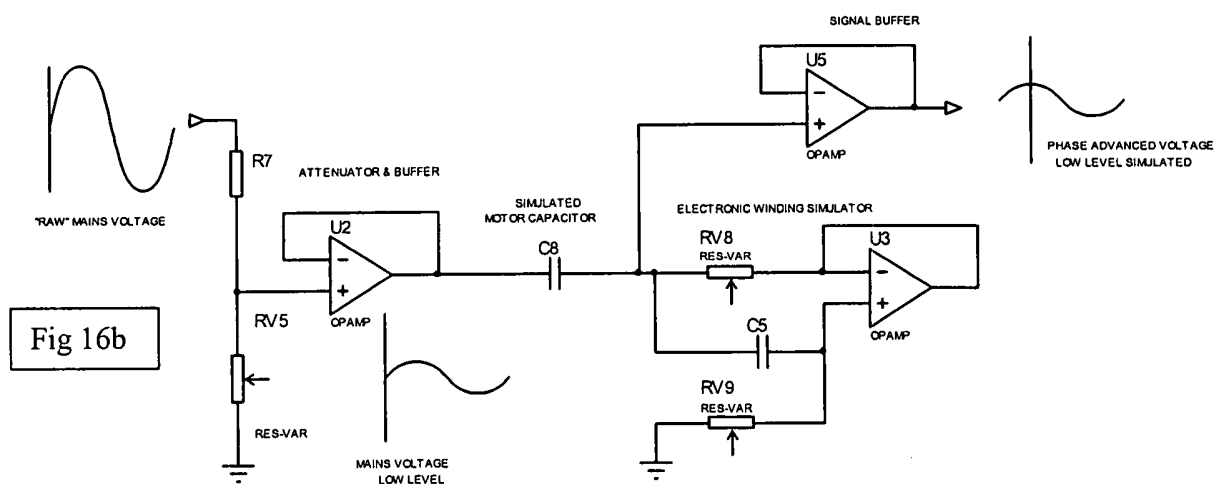
from a motor adapted to receive an electrical supply;

a simulation circuit adapted to take the electrical supply

and to simulate an effect of the motor on the electrical supply and to output a second waveform;

a second buffering circuit adapted to buffer the second waveform; and

comparison means for comparing said first and second waveforms.



Description

[0001] This invention relates to a motor control system and to a method of operating a motor control system.

[0002] Capacitor-run motors are effectively 2 phase induction motors. They have two windings wound in a manner to optimise the available power source, namely a dual phase supply created from a single phase mains voltage source.

[0003] A capacitor in series with one of the windings creates a phase advance and hence a leading magnetic current in one of the motor windings creating a rotational force with good starting torque and load characteristics. Rotation in either direction is possible by simply connecting the source of supply to either of the motor windings with a common capacitor providing the phase-advanced connection to the other winding.

[0004] Commonly when used in very low duty-cycle situations, this type of motor is not rated for continuous operation and is equipped with a thermal trip device. To enable a single pole thermal switch to be used this is normally connected in series with the neutral supply line and is a self resetting device re-making the circuit when cooling has occurred. Also, adjustable limit switches are included to prevent over-travel of the motor/equipment in both directions.

[0005] Traditional control systems for such motors will usually apply power to the one of the motor terminals for a given period of time, which should enable the door (or other system) to travel to its intended limit. The control system has no knowledge of whether the correct travel, or indeed any travel has taken place. It also will not normally be aware of the operation of the thermal trip. The latter could be fairly simply detected by monitoring motor current, but this could be easily mistaken for the motor reaching its intended limit when the limit switch opens. Detection of a motor stall condition by monitoring current is not reliable, because the current drawn is dependent on the motor impedance and will not always give a correct result.

[0006] It is an object of the present invention to address the above disadvantages.

[0007] It is an object of the present invention to overcome the above limitations, as well as providing other control benefits without any intrusive modifications to existing motor systems. It is also an object to provide a system that could be retro-fitted to an existing installation to provide greatly enhanced safety and control features.

[0008] According to a first aspect of the present invention there is provided a motor control system for a closure mechanism, the system comprising: a first buffering circuit adapted to buffer a first waveform from a motor adapted to receive an electrical supply;

a simulation circuit adapted to take electrical supply and to simulate an effect of the motor on the electrical voltage and to output a second waveform;
a second buffering circuit adapted to buffer the sec-

ond waveform; and comparison means for comparing said first and second waveforms.

[0009] The system preferably comprises a motor switch portion, which is preferably operable to switch and/or vary the power supply to the motor.

[0010] The system is preferably adapted to operate with a substantially sinusoidal waveform, preferably a single phase waveform.

[0011] The system preferably incorporates a first attenuation circuit operable to attenuate the first waveform, preferably to a lower voltage, preferably a voltage suitable for an operational amplifier.

[0012] The system preferably incorporates a second attenuation circuit operable to attenuate the second waveform, preferably to a lower voltage, preferably to a voltage suitable for an operational amplifier.

[0013] The first and/or second attenuation circuits preferably each comprise an operational amplifier.

[0014] The first buffering and the first attenuation circuits may be a combined first attenuation and buffering circuit. The second buffering and the second attenuation circuits may be a combined second attenuation and buffering circuit.

[0015] The first waveform from the motor is preferably a waveform at a capacitor-run motor, preferably after a capacitor has caused phase-shifting of the electrical supply. The motor is preferably a capacitor-run motor, more preferably a two-phase induction motor.

[0016] The simulation circuit is preferably adapted to simulate a phase-shifting effect of the motor on the electrical supply. The simulation circuit is preferably adapted to use the same electrical supply as is supplied to the motor.

[0017] The motor control system is preferably a door closure motor control system, more preferably a roller shutter door motor control system. Preferably the closure mechanism is a door or gate, such as a roller door. Preferably, limit switches are adapted to trigger at opposite ends of travel of the closure mechanism, such as a limit of clockwise travel and a limit of counter clockwise travel.

[0018] The electrical signal detection means are preferably adapted to detect conditions of closure mechanism corresponding to the motor running in a first direction, the motor running in a second direction, a limit of travel of the closure mechanism reached for the first direction of travel, a limit of travel of the closure mechanism reached for the second direction, a thermal trip of the motor running in the first or the second direction, an onset of stall condition, a near stall condition, and/or a stall condition.

[0019] The invention extends to a closure mechanism including a motor control system and motor as described in the first aspect.

[0020] The invention extends to a motor control system and motor as described in the first aspect.

[0021] The motor may be a bi-directional motor, such as a capacitor run motor or a two phase induction motor.

[0022] According to another aspect of the present invention there is provided a method of controlling a motor comprising:

buffering a first waveform from a motor receiving an electrical supply; 5
 taking the electrical supply and simulating an effect of the motor on the electrical supply and outputting a second waveform;
 buffering the second waveform; 10
 comparing said first and second waveforms; and
 outputting control signals bases on a result of said comparison.

[0023] All of the features described herein may be combined with any of the above aspects, in any combination. 15

[0024] For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings in which: 20

Figure 1 is a schematic circuit diagram of a motor control system and motor, including various detected waveforms for different modes of operation of the control; 25

Figure 2 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a second configuration of the circuit; 30

Figure 3 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a third configuration of the circuit; 35

Figure 4 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a fourth configuration of the circuit; 40

Figure 5 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a fifth configuration of the circuit;

Figure 6 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a sixth configuration of the circuit; 45

Figure 7 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a seventh configuration of the circuit; 50

Figure 8 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a eighth configuration of the circuit; 55

Figure 9 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms

for a ninth configuration of the circuit;

Figure 10 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a tenth configuration of the circuit;

Figure 11 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a eleventh configuration of the circuit;

Figure 12 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for a twelfth configuration of the circuit;

Figure 13 is a partial view of circuit diagram shown in Figure 1 showing the connections and waveforms for an overload configuration of the circuit;

Figure 14 is a schematic waveform diagram showing mains, capacitor and opto-detector waveforms and timing information;

Figures 15a to 15c show circuits and frequency response graphs for a half motor equivalent circuit, a high impedance half motor equivalent circuit and an electronic motor equivalent circuit;

Figure 16a shows a circuit for obtaining an attenuated low voltage waveform for an operational motor;

Figures 16b shows a circuit for attenuating a supply voltage and simulating a motor circuit;

Figures 17a to 17b show symbolic waveforms for real and reference voltages for three different types of electrical supply;

Figures 18a to 18c show graphs of expected and actual torque for different door operations; and

Figures 19a and 19b show schematic side and front views of a roller shutter door set up.

[0025] In Figure 1 a motor is shown comprising windings W1 and W2 and a capacitor C1. An electric supply is shown schematically by its connections as NEUT and LIVE. Connections to neutral are also shown for a diode D4 to NEUT and also an opto-detector referenced CW LIMIT 8, a thermal trip switch SW3 and also a counter clockwise limit switch opto-detector labelled CCW LIMIT 4.

[0026] The circuitry comprises four opto-detectors: a first labelled STALL/LOAD 2 to detect a stall/excessive load condition; the second referred to above, labelled CCW LIMIT to detect a counter clockwise limit of travel of a door (not shown) controlled by the motor 10; a third opto-detector is labelled CW LIMIT to detect a limit of travel of the door in a clockwise sense of rotation; and a

fourth opto-detector labelled WELD &/or THERM 6 is used to detect a welding of a relay labelled RL1 or a thermal tripping thereof. The opto-detectors take information from a clockwise limit switch SW1, a counter clockwise limit switch SW2, a thermal trip SW3, relays RL1 to RL3, diodes D1 to D8, capacitors C1 and C2 and resistors R1 and R2, as well as waveform amplitudes to detect clockwise and counter clockwise limits of travel, stalling of the motor, increased load on the motor, relay faults and, thermal tripping of the motor.

[0027] The opto-detectors, or opto-couplers, comprise an LED that is illuminated via a signal that is current limited using a series resistor (not shown). A phototransistor then switches when the LED is illuminated. The switching of the phototransistor provides a signal to indicate that the opto-detector has a signal input. The opto-detectors advantageously allow the isolation of the detection signals passed to a microprocessor for processing from the larger voltage and current required by the motor.

[0028] In Figure 1 waveforms with reference numerals 2 to 16 show waveforms which will be detected for particular circumstances experienced in the circuitry. Further discussion of these waveforms will be made in relation to Figures 2 to 13. The waveform labelled M is the wave form received from the main supply. The waveform labelled C is the phase-advanced waveform present at the capacitor labelled C1.

[0029] Figure 1 shows the circuitry in the first condition, condition 1. The main relay, RL1, is switched to an off state, meaning that the circuit is in a quiescent state without any faults or conditions existing. In this state there will be no signals from any of the opto-detectors STALL/LOAD, WELD &/or THERM, CCW LIMIT or CW LIMIT.

[0030] The basic principle involved is monitoring of mains and motor waveforms using the opto-couplers described above, although alternative techniques for monitoring the mains voltages could be applied.

[0031] To synchronise the waveforms for analysis by a microprocessor a sync signal is derived from the mains transformer (not shown) used to run the various control circuits. Alternatively, a further opto-coupler or other means could be used to derive this signal. The waveforms shown in the figure are shown as starting at this synchronising point where the mains feed signal rises positively through zero. Any other suitable moment in the waveform could be alternatively used, provided it is locked in time to the incoming mains signal.

[0032] Assumed starting conditions are as follows:-

- 1 All relays de-energised (all contacts normally closed) and capable of normal operation, no faults existing.
- 2 Motor in mid travel with both limit switches CW LIMIT and CCW LIMIT closed.
- 3 Motor in cool condition, thermal trip SW3 closed for normal running.
- 4 Mains "Live" is connected to the common (COM) of RL1.

- 5 Mains "Neutral" connected to the non-motor end of the thermal trip SW3 and also to four further connection points labelled Neut providing return paths for signal monitoring.

[0033] Further particular features of the operation of the circuitry are shown in Figures 2 to 13. In these figures only the relevant parts of the circuit are shown for clarity, together with the relevant wave forms 2 to 16 shown in Figure 1. Each of the figures shows a condition, labelled condition 2 through to condition 12 with a final condition of overload condition shown in Figure 13. These conditions are described as follows.

Condition 2

[0034] This condition is detected when RL1 is connected to MAIN, SAFETY at RL2 is not connected and the thermal trip SW3 is untripped.

[0035] In Figure 2, RL1 is energised, the motor thermal trip SW3 is in normal run (cold) closed state.

[0036] A waveform 2 will be detected by opto-coupler "WELD &/or THERMAL".

[0037] Rectified mains flowing through diode D8 into the opto-coupler and returning to neutral via diode D4 gives detection of the first half cycle.

[0038] The second half cycle is detected by current flowing from neutral through either or both the motor winding W1 and C1, through SW1 CW LIMIT, through the normally closed RL3 contact, through the normally closed RL2 contact through diode D3 into the opto-coupler "WELD &/or THERMAL" and returning to live via diode D9.

[0039] These safety measurements are made before power is supplied to the motor.

Condition 3

[0040] This condition applies when the thermal trip SW3 is tripped.

[0041] In Figure 3, RL1 is energised and thermal trip SW3 is operated ie in (hot) open state.

[0042] A waveform 3 will be detected.

[0043] The first half cycle detected as in Condition 2.

[0044] The second half cycle will be missing due to the absence of a neutral signal through the tripped thermal trip SW3.

[0045] Other fault conditions can possibly generate this waveform but the results obtained from further signals not yet mentioned will clarify the result.

Condition 4

[0046] This condition occurs when RL1 is connected to MAIN, but is welded on. The thermal trip SW3 is untriggered.

[0047] In Figure 4, a waveform 4 will be detected prior to ever operating RL1, as the contact is faulty and welded

closed.

[0048] In this condition the motor is still not driven because of the high impedance of WELD &/or THERM path through RL2 NC. RL2 is provided as a safety switch. In the de-energised state RL2 provides a sensing-current-only switch path between the direction selection relay RL3 and the main relay RL1; this is limited to approximately 1mA and is wholly insufficient to run the motor. RL2 and RL3 are only operated when RL1 is switched off.

Condition 5

[0049] This condition shows that the motor is running clockwise (CW).

[0050] In Figure 5, RL1 is de-energised, RL2 is energised (following prior successful test of RL1 etc.).

[0051] RL1 is then re-energised as it is the normal powering relay.

[0052] The waveforms 5 will be detected.

The in-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NC), diode D1 into the opto-coupler CCW LIMIT and returning to neutral.

[0053] The leading-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NC) SW1, C1, SW2, diode D2 into the opto-coupler CW LIMIT and returning to neutral.

Condition 6

[0054] This condition shows that the motor running clockwise has reached its limit of travel. In Figure 6, RL1 is energised, RL2 is energised, SW1 CW LIMIT opens when the limit of travel of the door is reached. The waveforms 6 will be detected.

[0055] The in-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NC), diode D1, into the opto-coupler CCW LIMIT and returning to neutral.

[0056] The leading-phase half cycle will not be detected as SW1 opening isolates the path into the opto-coupler CW LIMIT and returning to neutral.

Condition 7

[0057] This condition shows a thermal trip or stall of a clockwise running motor.

[0058] In Figure 7, RL1 is energised, RL2 is energised, SW1 is still closed, and SW3 thermal trip operates and opens.

[0059] The waveform 7 will be detected. Without any current flowing through the windings to neutral the virtually zero current through C1 will produce negligible phase shift so the detected waveform will all but synchronise with the mains supply waveform. A stall would also cause an almost identical detection, as the loading of Winding 2 (W2) in stall will negate the phase advance through C1. After the removal of power by the control system following

fault detection, a "cold" test as in Condition 3 will confirm the status.

Condition 8

[0060] This condition shows the motor is running counter clockwise (CCW).

[0061] RL1 is de-energised, RL2 is energised (following prior successful test of RL1 etc.), RL3 is energised to select CCW direction. RL1 is then re-energised as it the normal powering relay. The waveform 8 will be detected.

[0062] The in-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NO), diode D2 into the opto-coupler CW LIMIT and returning to neutral.

[0063] The leading-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NO) SW2, C1, SW1, diode D1 into the opto-coupler CCW LIMIT and returning to neutral.

Condition 9

[0064] This condition indicates that the limit of counter clockwise movement has been reached.

[0065] In Figure 9, RL1 is energised, RL2 is energised RL3 is energised, and SW2 CCW LIMIT opens when the limit of travel of the door is reached. The waveform 9 will be detected.

[0066] The in-phase half cycle will be detected by current from live passing through RL1 (NO), RL2 (NO), RL3 (NO), diode D2 into the opto-coupler CCW LIMIT and returning to neutral.

[0067] The leading-phase half cycle will not be detected as SW2 opening isolates the path into the opto-coupler CCW LIMIT and cause current to return to neutral. This condition detects the counter-clockwise limit being reached.

Condition 10

[0068] This condition indicates that the thermal trip SW3 has been triggered, or a stall, when the motor is running counter clockwise.

[0069] In Figure 10, RL1 is energised, RL2 is energised, SW2 is still closed, and the SW3 thermal trip operates.

[0070] The waveform 10 will be detected. Without any current flowing through the windings to neutral the virtually zero current through C1 will produce negligible phase shift, so the input waveform and the detected waveform will all but synchronise. A stall would also cause an almost identical detection, as the loading of winding 1 (W1) in stall will negate the phase advance through C1. After the removal of power by the control system following fault detection, a "cold" test as in Condition 3 will confirm the status.

Condition 11

[0071] In Figure 11, the motor is powered and running normally in either direction.

[0072] The waveform 11 will be detected. The mains flowing through energised RL1 (NO) passes and rectifies through diode D7 and then is filtered via R2 onto C2 (R1 is just a discharge resistor). This stores a filtered peak value of the mains voltage.

[0073] The peak of the waveform detected through diode D5 or diode D6 will have a greater voltage than the mains voltage caused by the effect of the reactance of the motor winding in series resonating with C1. This will be true regardless of motor direction, in a clockwise direction via SW2 and D6 or in counter clockwise direction via SW1 and diode D5.

[0074] The higher voltage from diode D5 or diode D6 drives opto-coupler STALL/LOAD via R1 & C2.

Condition 12

[0075] This condition shows that the motor is powered and stalled in either direction, see Figure 12.

[0076] The waveform 12 will be detected. The mains flowing through energised RL1 (NO) passes and rectifies through diode D7 and then is filtered via R2 onto C2 (R1 is just a discharge resistor). This still stores a filtered peak value of the mains voltage.

[0077] However the virtual collapse of inductive reactance of the winding currently in series with C1 will cause the normally elevated voltage through diode D5/D6 to collapse and the current through the opto-coupler STALL/LOAD will collapse and the signal disappear.

Overload Condition

[0078] So far we have discussed absolute detection conditions. However the change from normal running signals to stall is dynamic. The normal run signal of 11 diminishes in amplitude and time duration as load increases. Its phase advance with respect to the mains waveform also diminishes. By controlling the microprocessor monitoring the precise timing of the waveforms, overload conditions can be detected by waveforms 13, 14, 15, and 16, which show the onset of a stall at 14, near stall at 15 and a stall at 16.

[0079] By use of this detection it is possible to pre-detect an absolute stall, take appropriate action and probably avoid the resultant rapid motor heating of a full stall, and the inevitability of thermal trip. This is important so that the motor can be still run in reverse and free the entrapped item that was causing the stall condition.

[0080] An equivalent effect also happens to the limit detection signals as phase advance and amplitude reduce. This too can be detected, the onset is however less pronounced.

[0081] A microprocessor (not shown) is used by means of the opto-detectors to detect the waveforms referred to

above and to analyse those waveforms to detect which condition the motor is in. For example a near stall condition could be detected and if the motor is reversed a full stall may be avoided. Software is programmed to look for the outputs of the optocouplers. Each combination of optocoupler outputs from the four optocouplers and an optocoupler for the mains supply is analysed by the software against a standard set of outputs produced for all possible combinations. Thus, with conditions 1 to 12 and overload described above the software programmed into the microprocessor discriminates between possible outputs to determine what condition the system is in. After that, routines are called in the software depending on the identified condition, i.e. if a stall is detected then reversing the door movement could be initiated, or if excess load is detected, then the motor could be stopped.

[0082] The basis of the timing is to check for a signal going high on the mains reference to commence a timing procedure. All subsequent timings are taken from that timing point. The software detects the mains going to the positive part of the sine wave.

[0083] Figure 14 shows the timings that are used based on the mains and capacitor waveforms. The figure also shows the behaviour of the four opto-detectors in relation to the mains supply. The reference to open opto and close opto are to CW LIMIT and CCW LIMIT respectively.

[0084] Figure 14 shows example timings that are taken when synchronisation has occurred and the motor is running in the closing direction. Tr represents the start of the timing approximately 1mS after the mains voltage cycle goes positive. S1 5.5 mS after Tr, is used to check that the WELD &/OR THERM and OPEN opto-detector outputs are low and the CLOSE opto-detector output is high.

[0085] S2, 10ms after S1, is a timing point to check that the WELD &/OR THERM opto-detector output is high.

[0086] S3, 2ms after S2, is used to check that the CLOSE opto-detector output is low and the OPEN opto-detector output is high.

[0087] S4, 1.0ms after S3, checks that the STALL/LOAD opto-detector output is low.

[0088] Over a complete cycle, or a number of complete cycles, the outputs of the opto-detectors at the timing steps S1 to S4 are compared to determine the state of the control system.

[0089] Between S5 and S6 in Figure 14 it may be that the sync signal Tr is repeatedly missed. If this occurs a new search to locate Tr will commence. To do this, and to start from scratch, a search window of duration 1ms is used to find the trigger at subsequent oscillations of the mains supply. All timings are taken from the trigger. If the trigger, Tr, is seen in the 1ms window then the window size is halved to 0.5ms. If Tr is not detected at the next oscillation (20.0ms later in Figure 14), then the window is widened again for the next oscillation. Thus, the window may constantly narrow and widen depending on whether the trigger is identified. The variation of the

window and constant updating is a particularly advantageous feature of the system.

[0090] If the trigger signal arrives in the second half of the window, then the window is moved forwards for the next cycle to ensure the window is more central on the trigger. Conversely, if the trigger is in the first part then the window is moved back. The sync signal Tr is taken to have occurred if it falls within the window width. If Tr is missed, the end of the window is taken as the trigger Tr. A value of $w/2$ is subtracted from S1 to correct the overall timing window. If a number of triggers are missed a new search is commenced.

[0091] To allow for missed detections and bearing in mind an operating frequency of 50Hz, several cycles can be missed before action need be taken. Thus when a particular signal is detected 10 times for example, to indicate a stall, it is assumed to be correct. If only one oscillation period indicated a stall, then it could be ignored and assumed to be an error.

[0092] The signals described above have been compared with AC source waveforms. The effect, however of processing the signals through opto-couplers is to cause a "squaring" of the waveform shape so near square waveforms are presented to the microprocessor. These signals are further optimised for precise timing and minimal jitter by the use of Schmitt trigger inputs on the microprocessor. The signal transition, ie Tr, occurs at approximately 25% of peak voltage. The waveforms are as shown in Figure 14. The vertical scales of the digital signals representing the opto-coupler outputs have been compressed to provide clarity in Figure 14, but all are "rail to rail" signals applied to the microprocessor inputs.

[0093] The "W" window referred to is the 1.0ms window generated in software to enable perfect synchronisation with the mains AC waveform. The S5 and S6 timing points are not true measuring points but software timings to provide a closely controlled dynamic window for the synchronisation. The window "W" is reduced in width dynamically under software control to provide a narrow window of opportunity to capture the mains post-zero transition. The narrow window provides a very limited time range for the interrupt to occur and hence gives the system high noise immunity.

[0094] A similar principal of synchronisation can alternatively be used detecting the span of the output of the opto-coupler and deriving a centre of peak detection sync point. The same dynamic detection technique can be applied but detecting two rather than one detection points (rising and falling).

[0095] The signals measured at the inputs are digitally filtered in software to again further enhance noise immunity. The resultant signals obtained at S1, S2, S3, and S4 are then considered by the software routines. From these input states and the various modes of operation, the software can define the precise running / load state of the motor and hence the servo-loop control environment of the motor is created rather than the open loop historical style systems.

[0096] The system is capable of self-learning, because an initial set up is done with standard timings for the waveforms, following which, and after the system is fitted to a door installation, the standard timing values for a stall are then replaced by searching back to the critical timing point. Also, the self learning facility is advantageous for opto-couplers that have a manufacturing tolerance, as is usual.

[0097] By precision measurement of the timings of the above signals accurate information as described can be achieved.

[0098] A particular advantage of the system is the ability to use a pulse train, or the detected waveforms, to pre-detect stalls etc. The pulses are referenced by voltage and time. If, for example, a stall is detected phase changes occur that are accurately detected to develop a diagnosis of the factors that are causing the changes.

[0099] The apparatus discussed can be used to detect bodily entrapment or adverse loading on the shutter. The software can then enact safety and or release protocols.

[0100] The design is primarily suited to permanent capacitor run motors used initially in the movement of roller shutter doors, gate control systems, other reversible closure devices, including reversible covers and other devices.

[0101] The prime advantages of the system described are as follows: -

- 1 Provide detection of primary relay failure (relay weld) .
- 2 Provide detection of motor thermal trip condition.
- 3 Provide detection of a motor reaching its designated travel limits in both directions.
- 4 Provide detection of motor stall condition.
- 5 Provide dynamic load monitoring to detect abnormal motor load.

Alternative embodiment

[0102] A further embodiment having significant advantages over that described above is described below.

[0103] Figures 19a and 19b show schematically a roller shutter door setup. A roller door 100 has laths 102 and is held on an axle 104. A motor 106 winds the axle and so the door 100 is wound onto or off the axle 104, depending on the direction of rotation of the axle 104.

[0104] The system described above in relation to Figures 1 to 13 primarily focussed on detecting significant overload or stall. It is also possible by enhancing the techniques described above to detect not just overload but absolute load to a high level of accuracy. The loading of the door 100 during lift can be detected, as can the over-speeding of the motor 106 during descent, due to the weight of the door 100.

[0105] The load exerted on the motor 106 is not a constant, because it varies with the amount of door 100 being lifted, and with a change to the effective diameter D (see figure 19a) of the amount of door 100 on the axle 104 as

lift takes place and the door 100 winds on.

[0106] The scheme described above used the mains frequency as a reference, which is adequate for the purposes of overload or stall detection. For greater resolution of the load a further point of time reference is required, as described in the following.

[0107] The motor runs normally from a typically 230V 50Hz sinusoidal supply. However normal mains supply suffers significantly from both short term and long term voltage variation as well as distortion of the normal sinusoidal waveform. The problem is exacerbated in the above-described system because the detection point lies away from the zero-crossing point of the mains. Furthermore, the existence of large electrical motors or other highly inductive loads, non-linear switched loads and other electrical equipment close to the door winding mechanisms can and do cause phase distortion and zero crossing errors occurring randomly in normal operation.

[0108] These errors mean that simply increasing the resolution of the existing system will yield diminishing returns as the load signal sought disappears into the background of mains-born variations.

[0109] To achieve the required sensitivity to monitor genuine motor load a new technique is required.

[0110] The underlying phase shift caused by varying load on the motor does in deed exist. However, as mentioned above, when using an absolute mains frequency reference it is not possible to process such a signal to a much greater resolution than the stall or overload conditions described above.

[0111] To achieve successful signal detection, dynamic referencing is required. The dynamic referencing takes the form of a dummy load across the mains supply. This dummy load has an equivalent characteristic to that of the motor but only a fraction of the power taken by a real motor. By this means a replica waveform of an unloaded motor can be simulated. To achieve this in practice an electronic methodology is required to model the unloaded motor, because the inductive element of the dummy load becomes impractically large and causes an inefficient power drain.

[0112] To address this issue a simulated inductor circuit is employed. A "half"-motor equivalent circuit (having only one of the two coils in the usual motor), a high impedance "half"-motor equivalent circuit and an electronic equivalent circuit are shown respectively in Figures 15a to c, along with the plotted voltage /frequency waveform response of each.

[0113] In Figure 15a, a capacitor C1 of size $X_{\mu F}$, the motor winding equivalent, consisting of component parts L1 of value YmH and the resistance R1 of value $Z\Omega$, are connected as shown to achieve the phase advanced side of the winding motor circuit. Gain (dB) and phase angle for this circuit at various frequencies (Hz) are shown on the right side of this diagram.

[0114] In Figure 15b an equivalent circuit but with high impedance is shown. The circuit has the same layout but the capacitor C2 has a value reduced by a factor of 100

(this ratio is not a pre-requisite but the value used is for demonstration of the principal), and the inductance L2 and resistance R2 increased by a factor of 100. As shown in the graph this circuit has the same response as the Half motor equivalent of Figure 15a.

[0115] Figure 15c shows the electronic equivalent of the circuit in Figure 15a. An operational amplifier (U1) has a power supply at $\pm 15V$ (this value is not a pre-requisite but the value used is for demonstration of the principal), much lower than the mains supply used for the motor winding, because of the operating parameters of operational amplifiers. Capacitors C3 and C4 and resistors R3 and R4 are connected as shown. The input waveform IN3 is the same waveform as that provided to the motor winding. Suitable attenuation down to an acceptable voltage is described below. As can be seen the output waveforms are the same as those for the half motor and high impedance equivalents.

[0116] It can be seen that the characteristics of the original circuit (Fig 15a), the theoretical high impedance version (Fig 15b) and the simulated electronic version (Fig 15c) are indistinguishable. This provides the platform for relative signal analysis.

[0117] Owing to voltage limitations of the operational amplifiers, usage of such a circuit directly at the power terminals would not be possible, because operational amplifiers cannot normally take the high voltage that is required for the door closure mechanism.

[0118] A practical suggested circuit is shown in Figure 16b. Operational amplifier U2 attenuates the mains supply voltage to maintain the waveform characteristics, but to reduce the voltage to a level with which the operational amplifier can function. Capacitor C6 simulates the motor capacitor and the operational amplifier U3 with the capacitor C5 and resistors R8 and R9 (shown as variable resistors RV8 and RV9, but may be fixed resistances) simulates the winding, as described in relation to Figure 15c. Operational amplifier U5 buffers the signal from the winding simulator for comparison in a micro processor (not shown) with the actual signal from the motor winding that is obtained as shown in Figure 16a, as follows.

[0119] In figure 16a the mains supply is provided to the winding impedance L3, the motor capacitor C6 and the resistance R6. This results in a phase advanced signal. This signal is attenuated and buffered using operational amplifier U4 having resistances R11 and R10 as shown to give a phase advanced signal of lower voltage that can be compared with that from the simulation circuit in the micro processor described above.

[0120] It will be appreciated that the only difference between the signal from the motor circuit in Figure 16a and the simulated circuit in Figure 16b is due to the load on the motor circuit resulting from movement (or blocked movement) of the door. Thus, any deviation between the two signals is due to a change in the load on the system, which change in load may be due to a stall, an unexpected blockage to movement at the door, an unexpected weight during lifting of the door, or another unexpected load, or

may be due to an end of travel of the door at its fully open position or fully closed position.

[0121] The flexibility of the system is enhanced by the use of variable resistors, but it would be possible to replace the components RV5, RV8 & RV9 with fixed resistors, for lower cost manufacture. The variable resistors enable the system to be adapted to a wide range of motor characteristics. This control can be automated by the use of electronically controlled potentiometers.

[0122] The effect of mains waveform distortion, phase asymmetry, voltage variations etc. all cause the real phase change detected in the first embodiment to be "buried" in pseudorandom waveform distortion errors. Such errors are commonly caused by large motor systems and pulsed power systems. The system of this embodiment cancels out all of those effects by comparing two signals that differ only to effects caused by loading of the motor circuit.

[0123] Figures 17a to 17c show "Symbolic Waveform" diagrams for some forms of waveform distortion that occur which would mean that any system referencing to say a zero crossing point of the mains would read the dimensions A,B,&C as all different. Such an error will always exist as any zero crossing detection system always requires the signal to be detected as it leaves the zero voltage and passes some arbitrary threshold. Use of such a reference point will inherently cause errors. In these Figures the solid line is the reference signal from the simulated circuit and the dotted line is the signal from the motor. Figure 17a shows the waveform for a standard mains supply. Figure 17b shows the distorted waveform commonly caused by the presence of large motors connected to the local electricity supply. Figure 17c shows a distorted waveform commonly caused by the presence of large power controlled loads connected to the local electricity supply.

[0124] The symbolic waveform diagram shows the electronically generated reference signal and the motor's capacitor phase signals as they would typically appear. The phase shift is exaggerated for diagrammatic clarity but the effect of the load when opening the door and the assist of the weight of the door on closing are both shown. In any opening direction the motor signal leads the reference signal. In a closing direction the reference signal leads the motor signal.

[0125] Also the phase shift observed is not constant throughout the travel of the door. As the door starts to lift, successive laths 102 of the roller door 100 are "picked-up" by the motor so more load is applied. A second effect also occurs in that the effective diameter D of the axle 104 increases as the door 100 is rolled hence causing an increase of torque.

[0126] The net effect is a zero starting and near zero finishing torque with a peak of torque required just below mid lift position.

[0127] To detect the effects of excessive load in the upward opening direction, or a collision of the door with an object in the downward direction software controlling

the system will learn, or be pre-programmed with a torque profile for each direction and hence be able to detect alien loads or impacts by virtue of deviation from the expected curve for a correctly moving door. Figures 18a to 18c show theoretical torque curves illustrating different effects. The normal curve for the door is shown in a solid line. The dashed line shows the torque actually required from the motor.

[0128] The torque curve will be derived empirically at time of installation, although the parameters will be bounded by a basic model within the system software. The degree of phase advance/retard from the unloaded motor ideal relates directly although not perfectly linearly to a loss of or increase in the expected load. This evaluation will be made by a microprocessor and software, calculating the degree of variance encountered, its persistence (level of filtering) and its relevance to the position of travel.

[0129] In Figure 18a a curve representing an item snagged on the door and being lifted is shown. The position of the door on its travel from closed to open is shown on the X-axis, torque is shown on the Y-axis. Extra torque is required from the motor to lift the unexpected load, as shown by the dashed line above the expected torque curve. NB in practice the increased torque curve would be proportional rather than stepped increase, but for clarity the simplistic view is shown.

[0130] In Figure 18b a curve representing an object trapped into the roll of the door onto the shaft is shown. The position of the door on its travel from closed to open is shown on the X-axis, torque is shown on the Y-axis. The torque follows the normal curve and then rapidly increases when the item is trapped in the rolled door.

[0131] In Figure 18c a curve representing an obstruction encountered as the door descends is shown. The position of the door on its travel from open to closed is shown on the X-axis, torque is shown on the Y-axis.

[0132] The detection of such an unexpected change in torque will result in the control system removing power from the door to cause a stop and, if appropriate a partial reversal of the motion to release the entrapment.

[0133] The system of the second embodiment has significant advantages over the first, in particular the system concept has less dependency on mains frequency stability and artificial mains substitutes such as generators and power inverters will have little or no effect on performance.

[0134] The ability to effectively monitor hazardous torque levels from the motor means that a reduced range of motor variants could be employed with the ensuing benefits of economies of manufacturing scale, because fewer motors would need to be manufactured/stocked in order to cater for the same range of operational capabilities as would previously have been the case.

[0135] To enable unusually large motors to control smaller shutters, the use of phase power control may be incorporated to limit the available torque. The use of a triac to control the power using the phase of the detected

waveforms is one way in which the power control may be implemented. The distortion caused by the inclusion of the waveform of such an addition will have negligible detrimental effect on the enhanced sensing technology of the second embodiment.

[0136] The system may be provided in a form that can be programmed on installation to suit the particular set up, or may be provided in a form to suit a given motor, which has a torque curve that is already known. Practically speaking the circuitry for the motor winding circuit and for the simulation circuit can be provided in a small form that can be secured to a housing of the motor 106 or close thereto, or indeed may be included in a barrel of the motor housing to form an integrated control solution.

[0137] Attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

[0138] All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

[0139] Each feature disclosed in this specification (including any accompanying claims, abstract and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

[0140] The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

Claims

1. A motor control system for a closure mechanism, the system comprising:

a first buffering circuit adapted to buffer a first waveform from a motor adapted to receive an electrical supply;

a simulation circuit adapted to take the electrical supply and to simulate an effect of the motor on the electrical supply and to output a second waveform;

a second buffering circuit adapted to buffer the second waveform; and

comparison means for comparing said first and

second waveforms.

2. A motor control system as claimed in claim 1, which comprises a motor switch portion operable to switch and/or vary a power supply to the motor.
3. A motor control system as claimed in claim 1 or claim 2, which incorporates a first attenuation circuit operable to attenuate the first waveform to a lower voltage.
4. A motor control system as claimed in any preceding claim, which incorporates a second attenuation circuit operable to attenuate the second waveform to a lower voltage.
5. A motor control system as claimed in either claim 3 or claim 4, in which the first and/or second attenuation circuits each comprise an operational amplifier.
6. A motor control system as claimed in any preceding claim, in which the first waveform from the motor is a waveform at a capacitor-run motor, after a capacitor has caused phase-shifting of the electrical supply.
7. A motor control system as claimed in any preceding claim, in which the simulation circuit is adapted to simulate a phase-shifting effect of the motor on the electrical supply.
8. A motor control system as claimed in any preceding claim, in which the closure mechanism is a door or gate, such as a roller door.
9. A motor control system as claimed in any preceding claim, which includes a control portion adapted, in response to measurement of a response of a motor, to provide values for settings of variable resistors of the simulation circuit.
10. A motor control system as claimed in claim 9, in which the variable resistors are set automatically to values determined by the control portion.
11. A motor control system as claimed in claim 9 or claim 10, in which the control portion is operable to apply phase power control of a motor controlled by the motor control system, in addition to control reacting to output from the comparison means.
12. A motor control system as claimed in any one of claims 1 to 11 housed in a motor housing.
13. A motor incorporating a motor control system as claimed in any one of claims 1 to 12.
14. A method of controlling a motor comprises:

buffering a first waveform from a motor receiving
an electrical supply;
taking the electrical supply and simulating an
effect of the motor on the electrical supply and
outputting a second waveform;
buffering the second waveform;
comparing said first and second waveforms; and
outputting control signals bases on a result of
said comparison.

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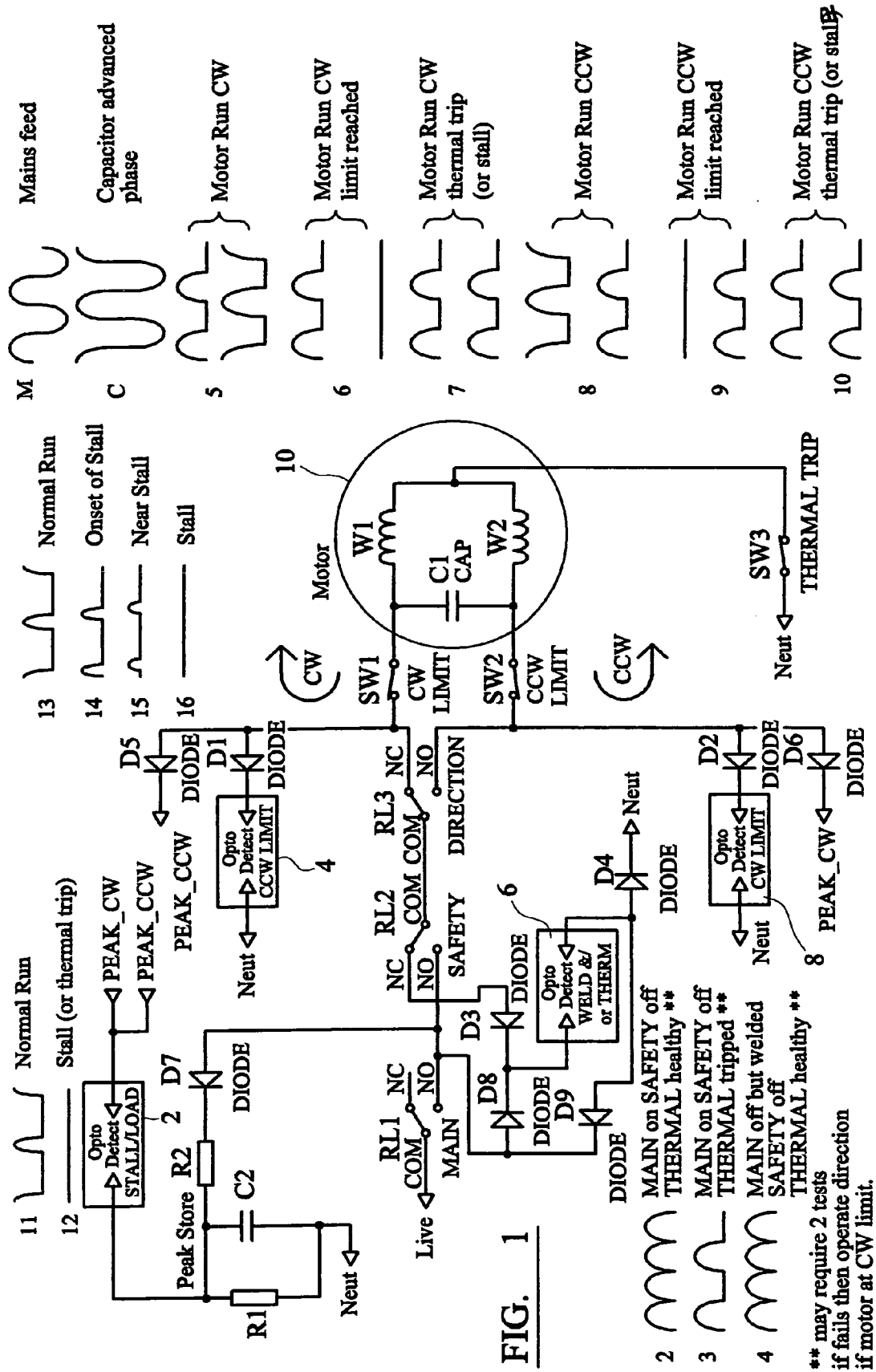
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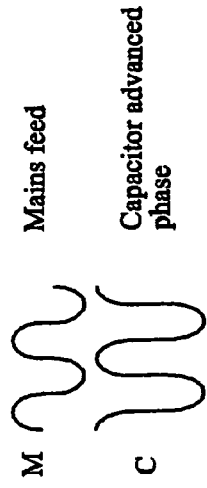
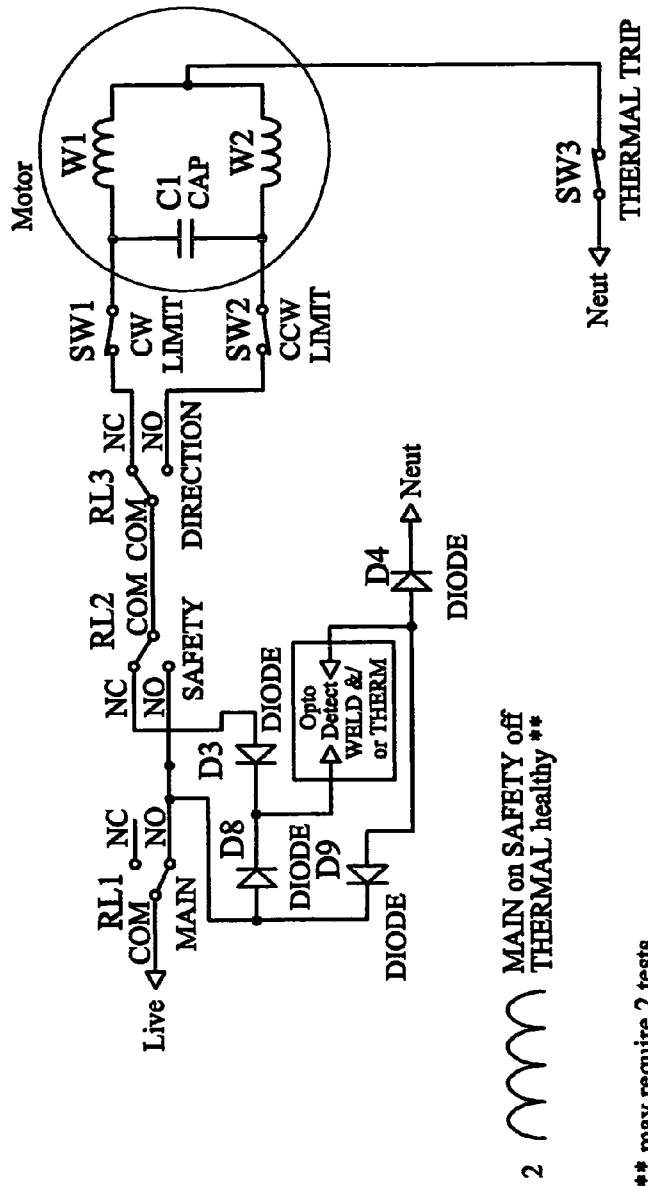


FIG. 2



** may require 2 tests if fails then operate direction if motor at CW limit.

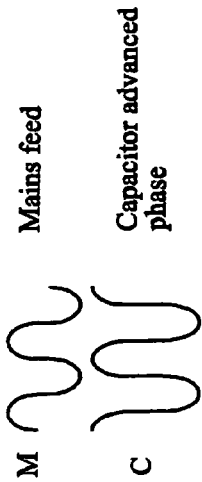
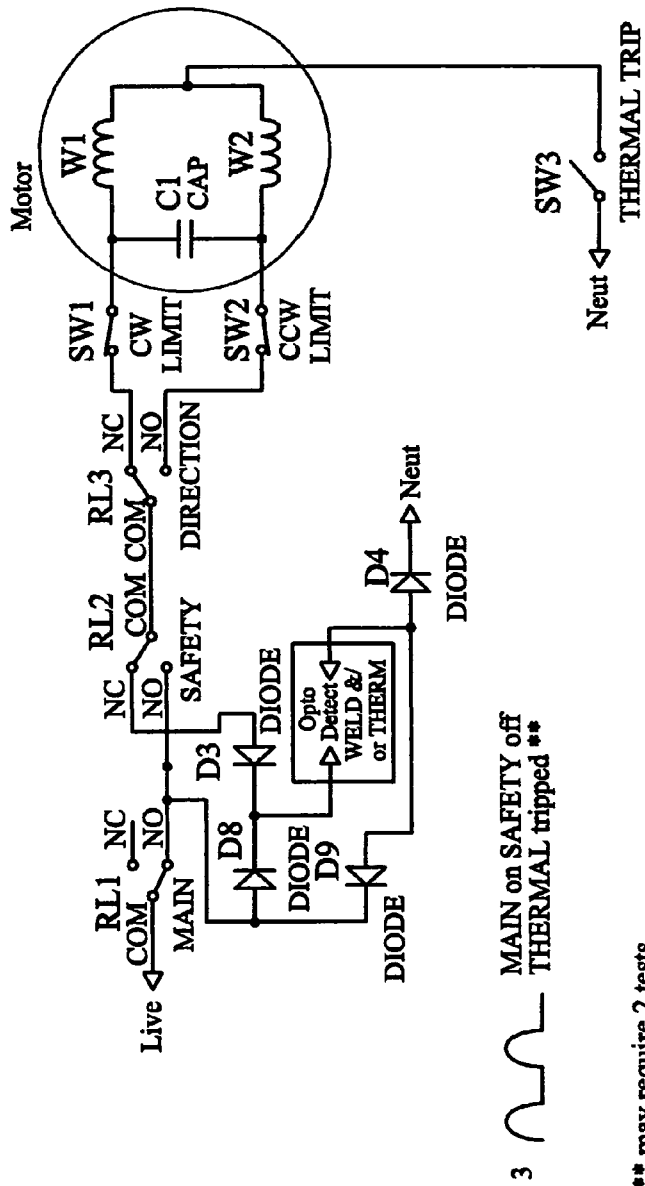


FIG. 3



** may require 2 tests if fails then operate direction if motor at CW limit.

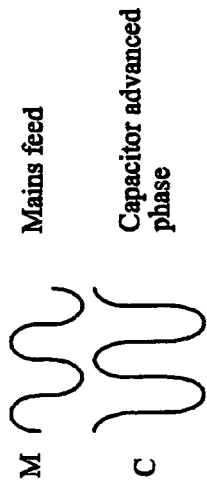
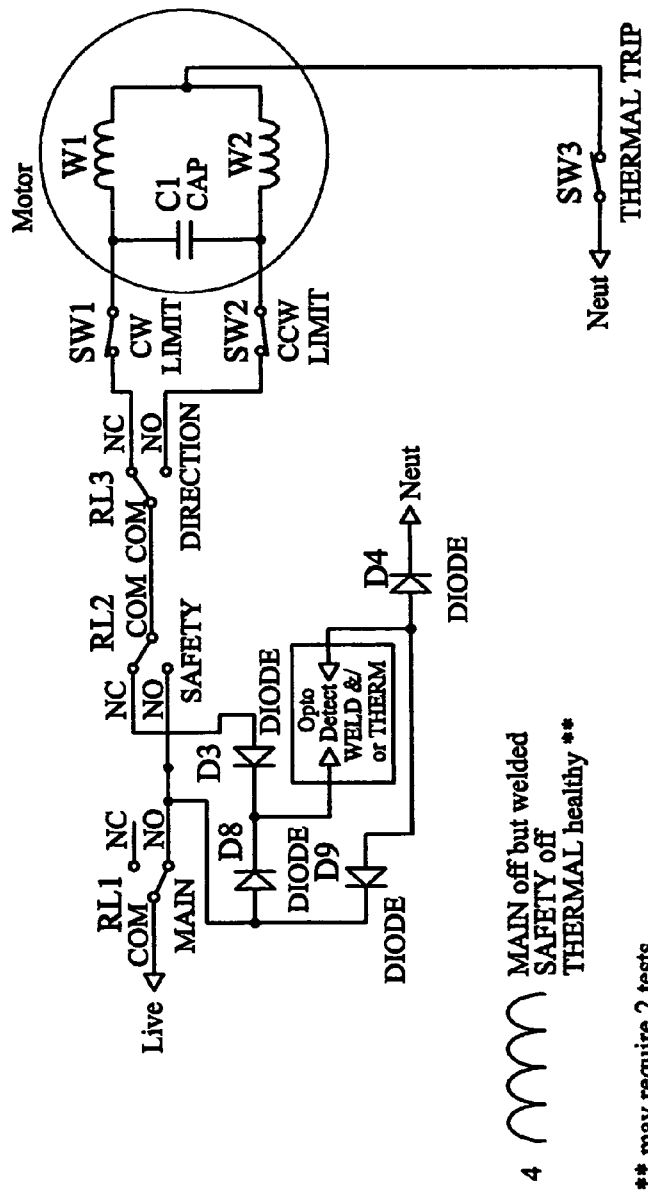
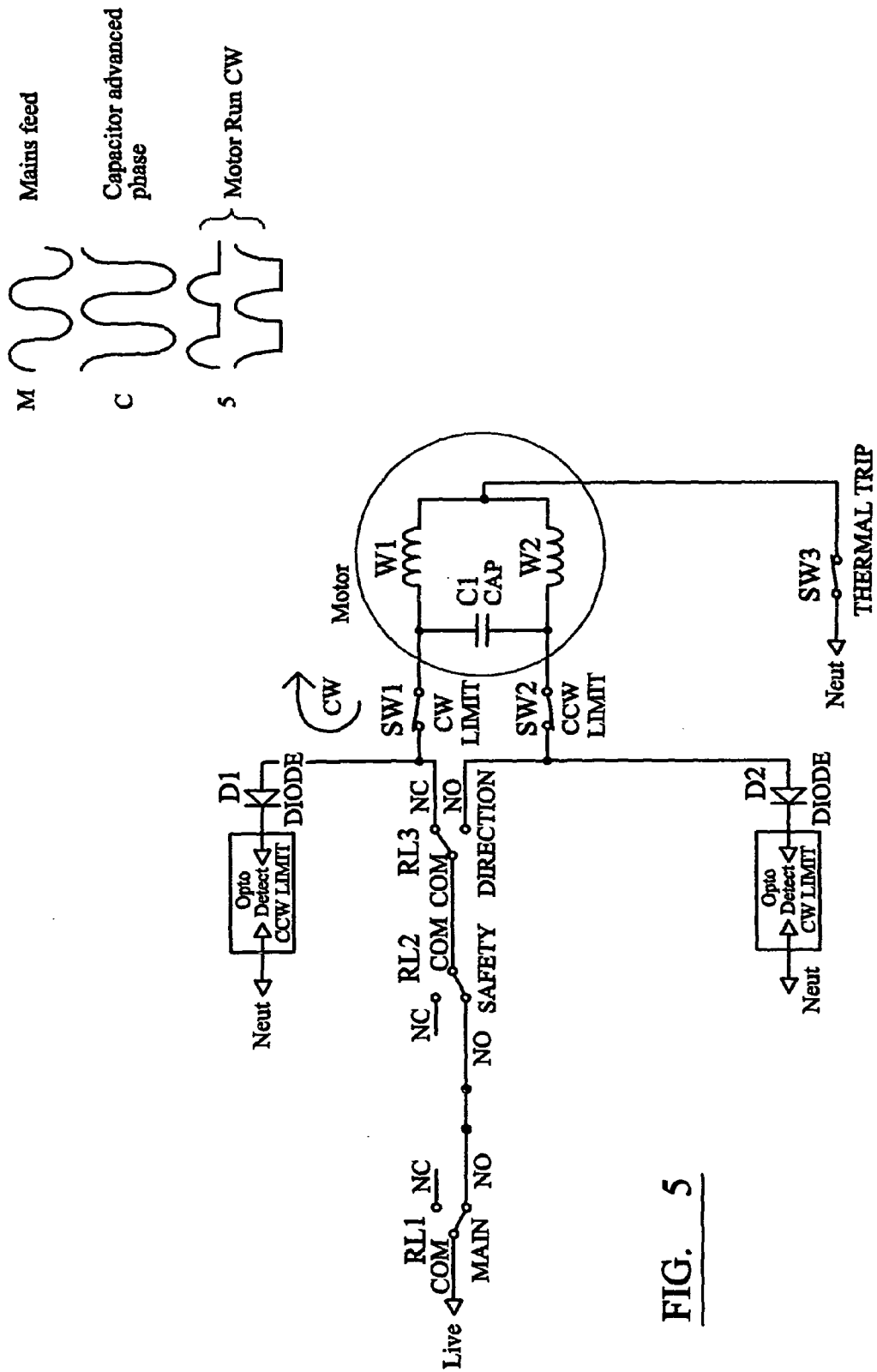


FIG. 4



** may require 2 tests
if fails then operate direction
if motor at CW limit.



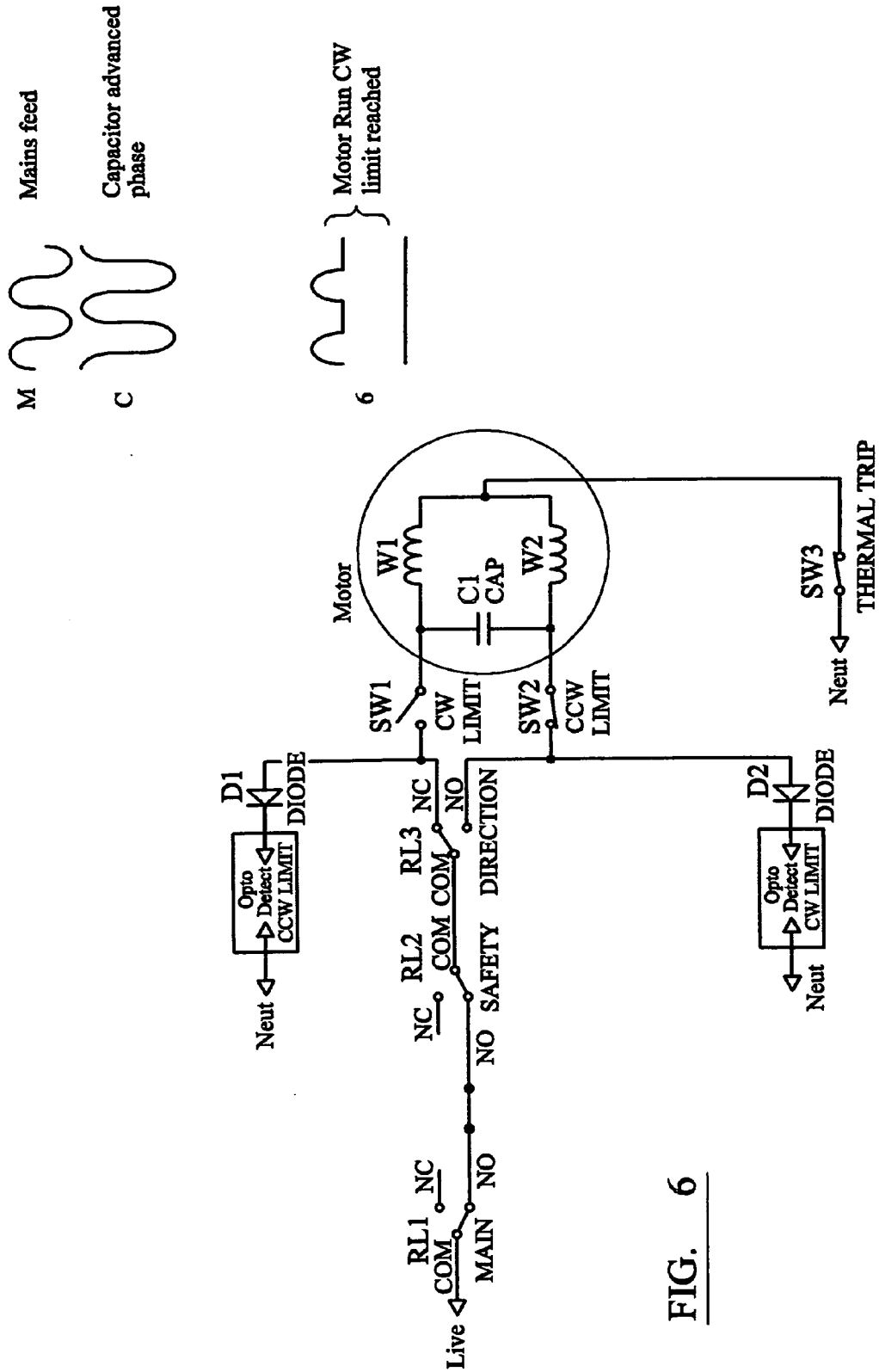


FIG. 6

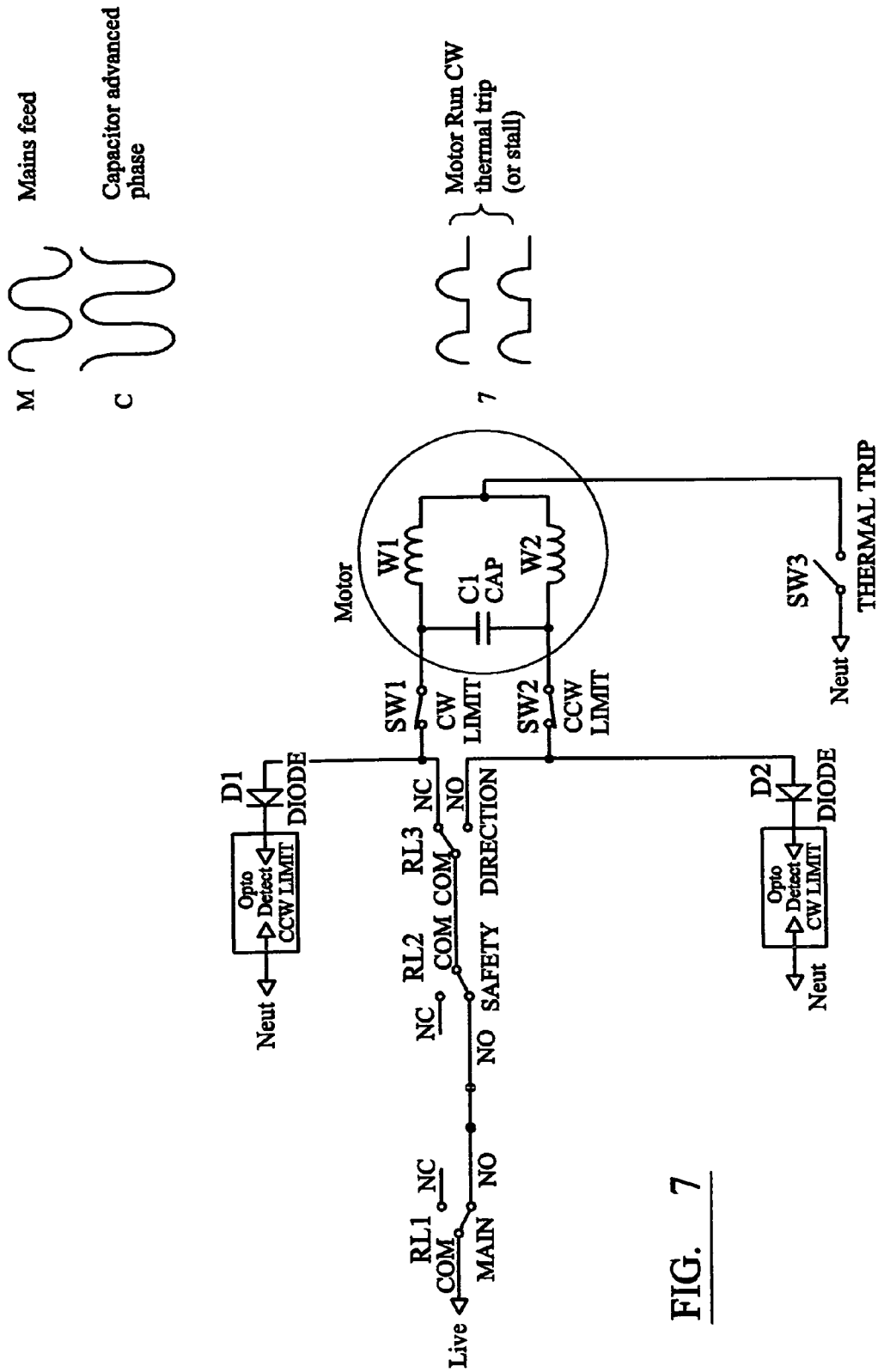


FIG. 7

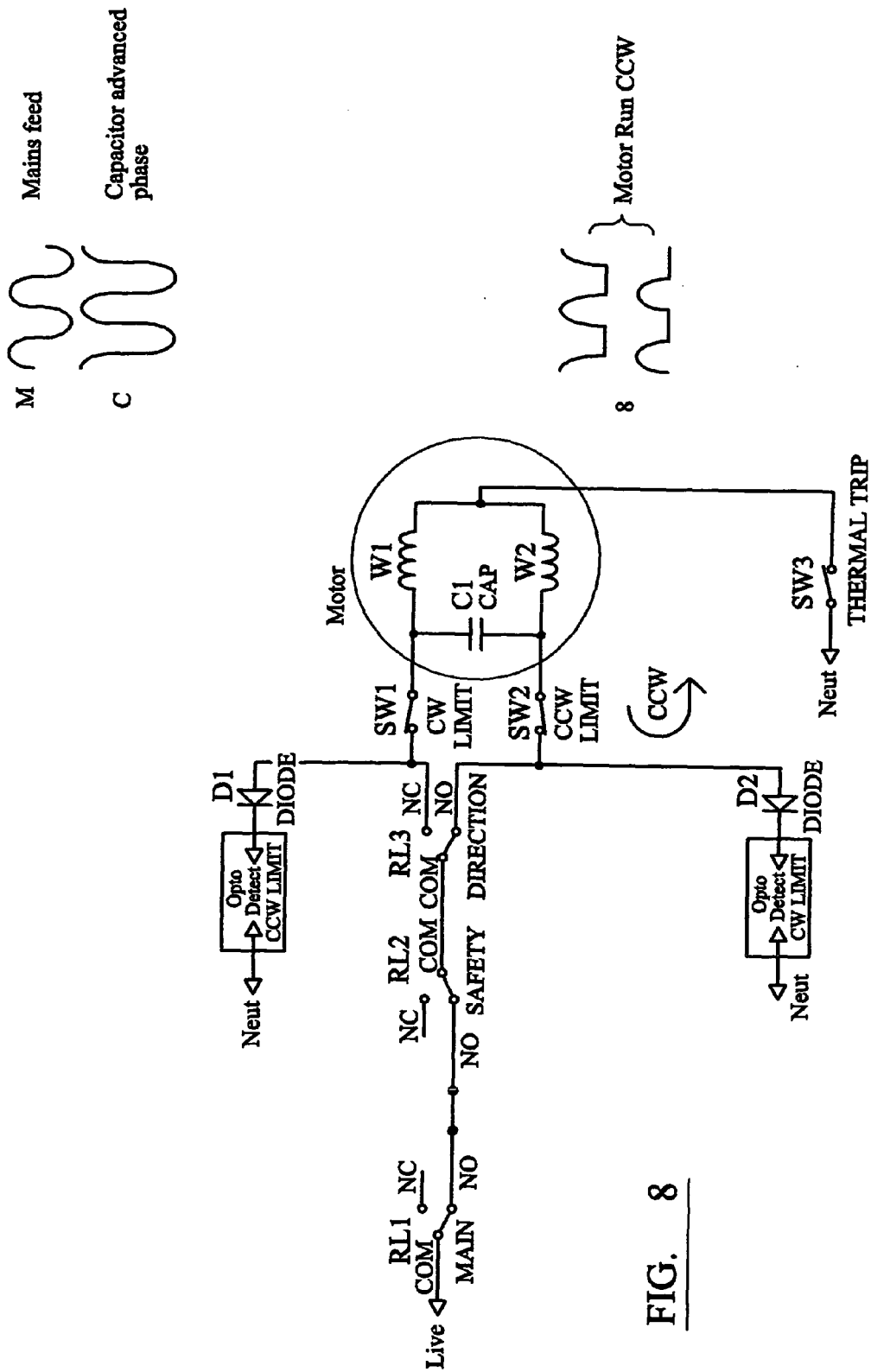


FIG. 8

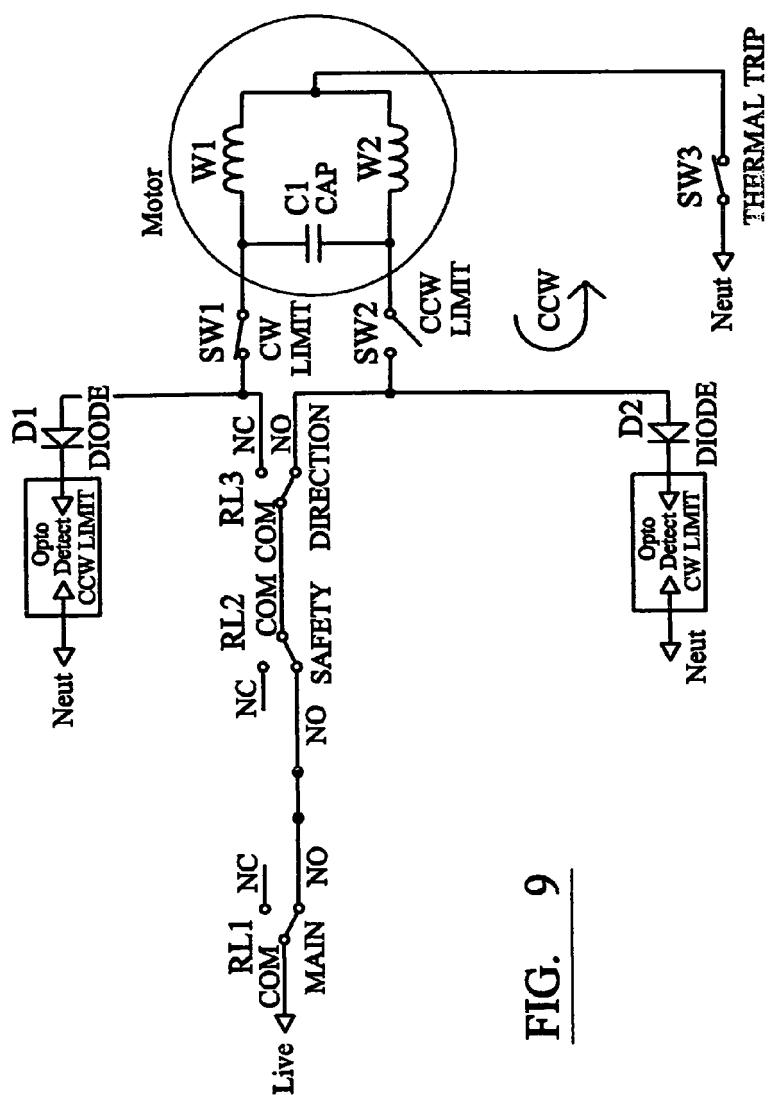
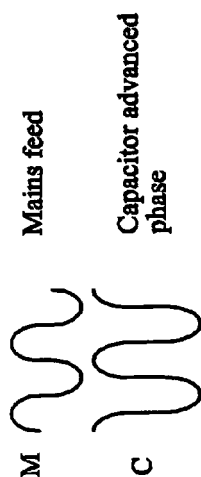
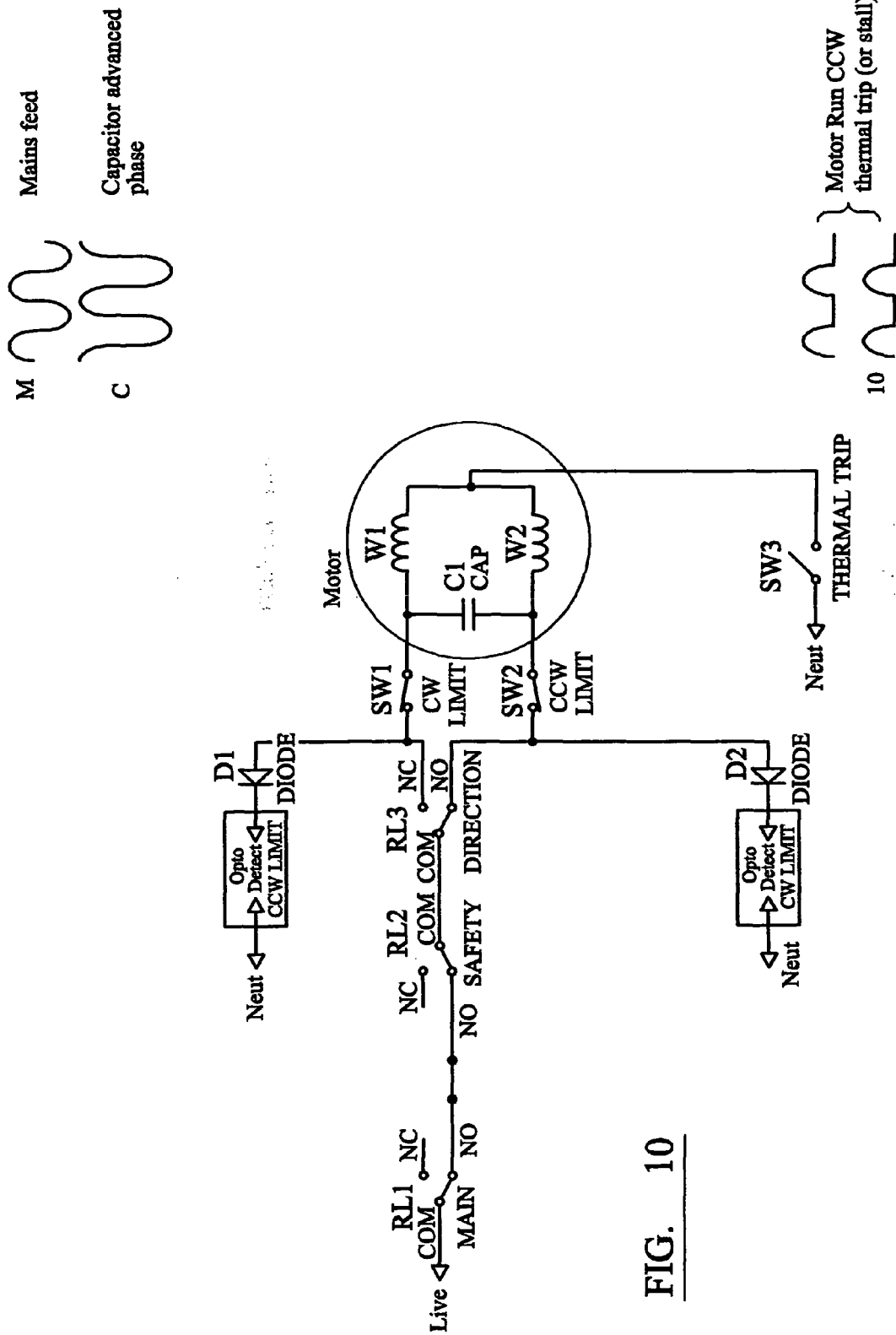


FIG. 9



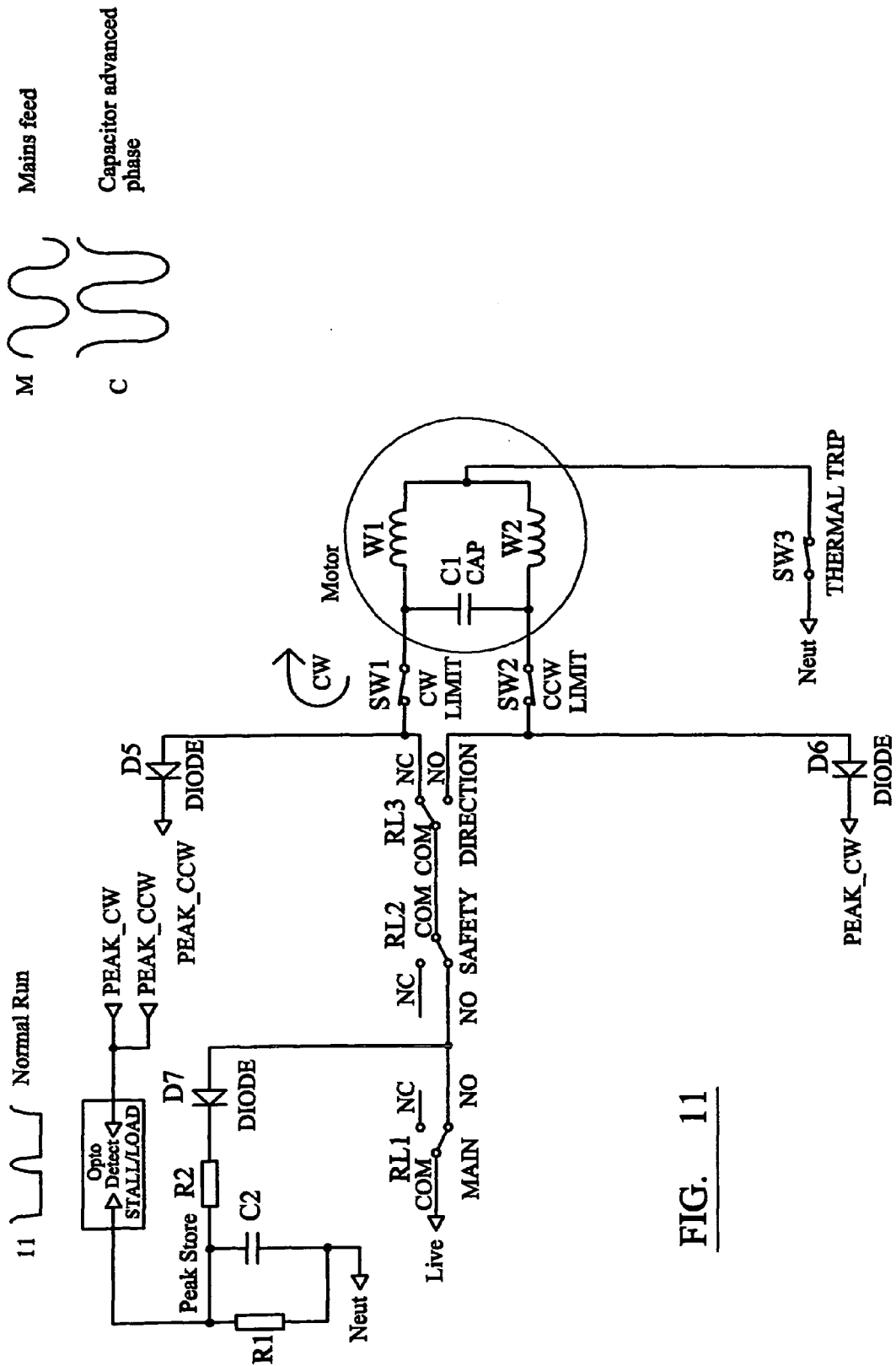


FIG. 11

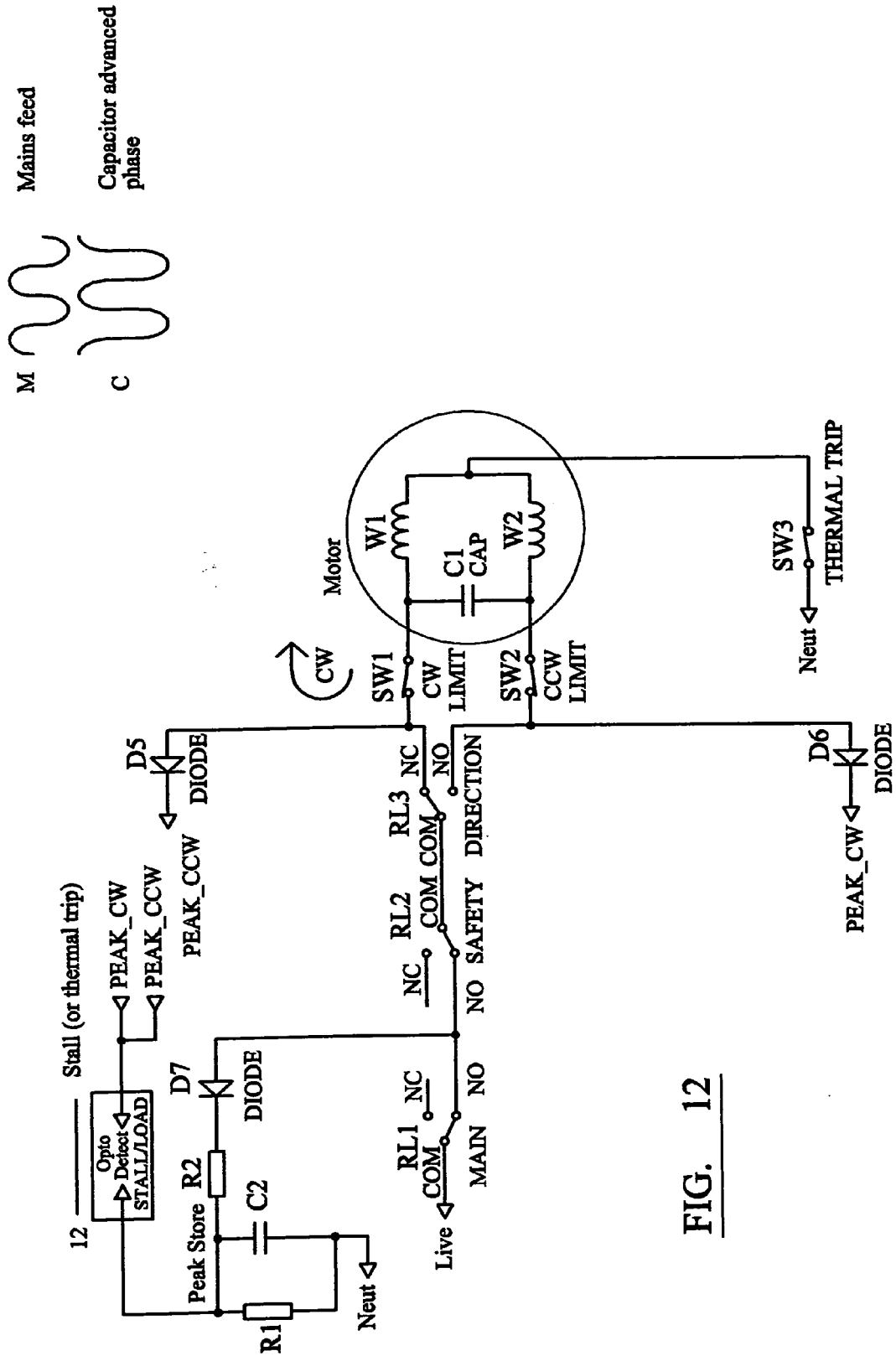


FIG. 12

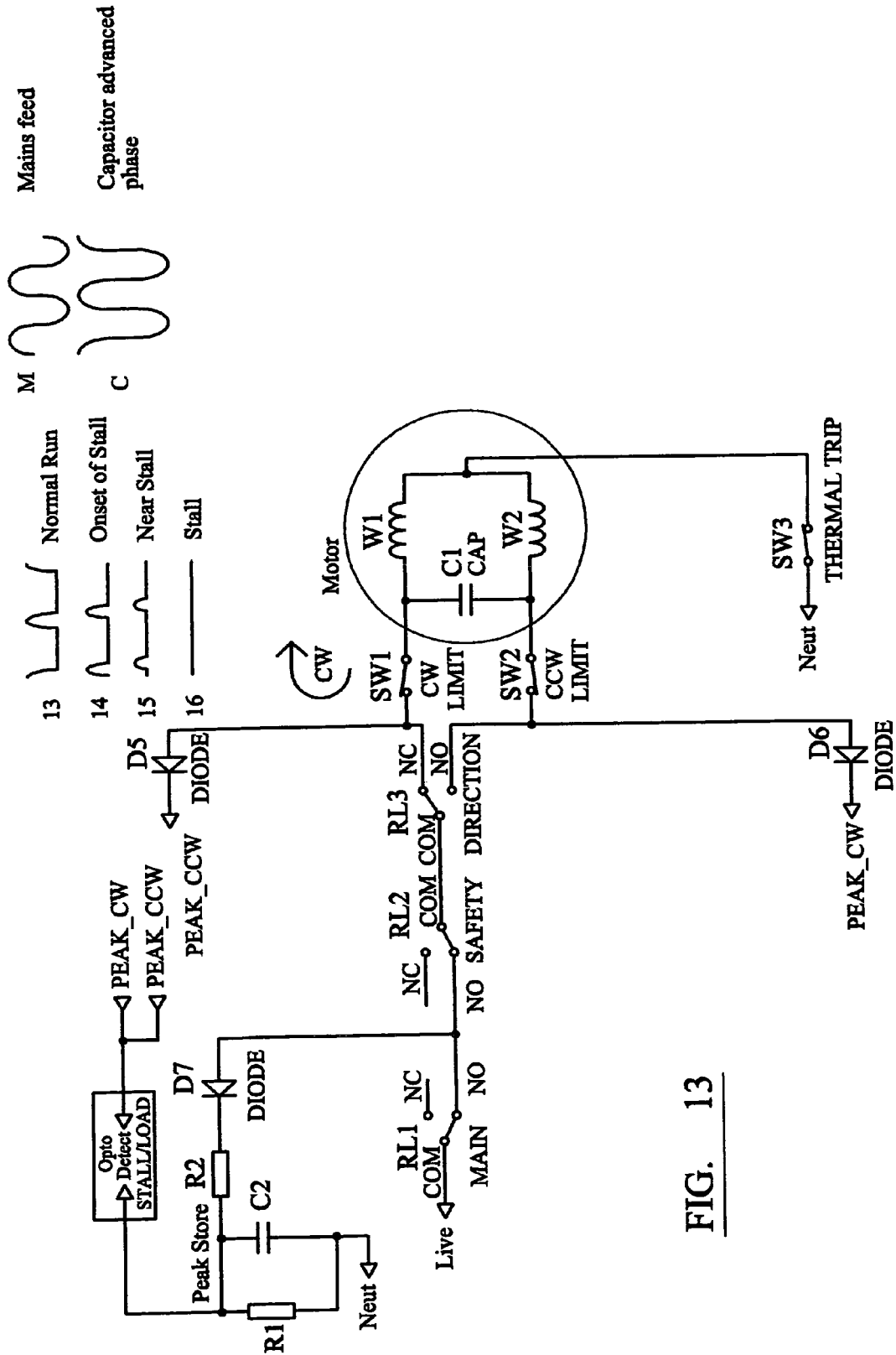


FIG. 13

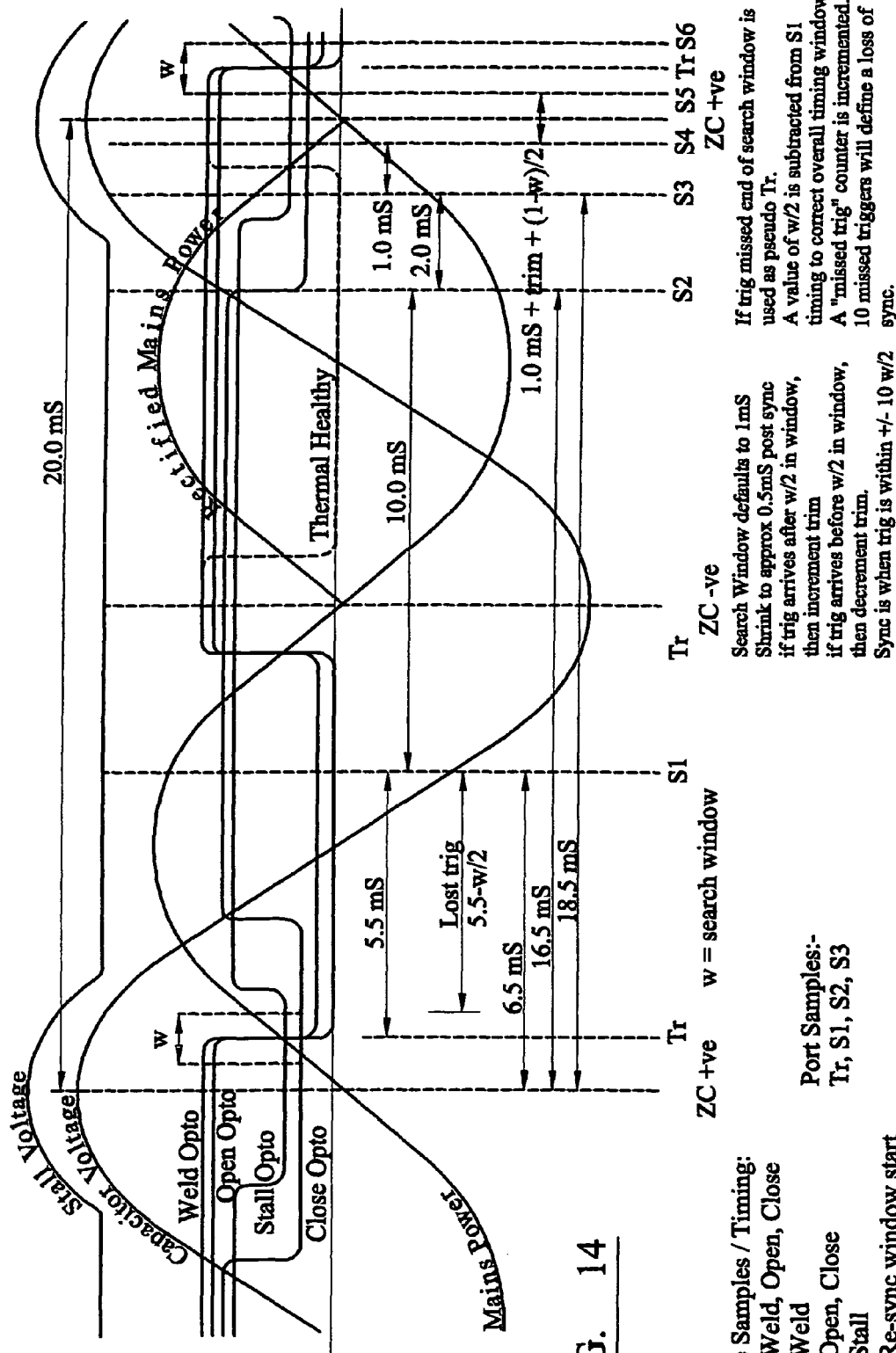


FIG. 14

Software Wave & Input Sample Timing

"HALF" MOTOR EQUIVALENT CIRCUIT

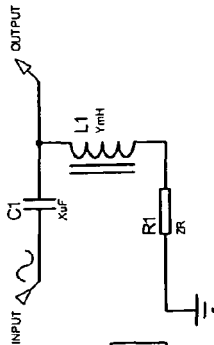
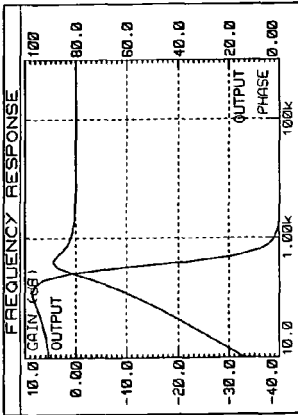


Fig 15a

HIGH IMPEDANCE MOTOR EQUIVALENT CIRCUIT

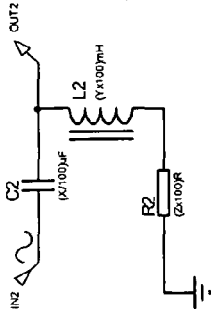
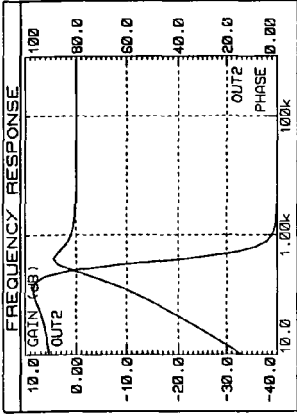


Fig 15b

ELECTRONIC MOTOR EQUIVALENT CIRCUIT

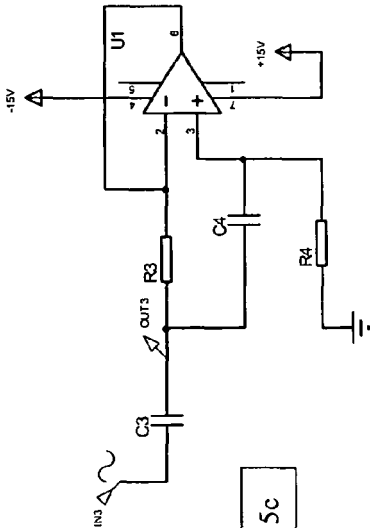
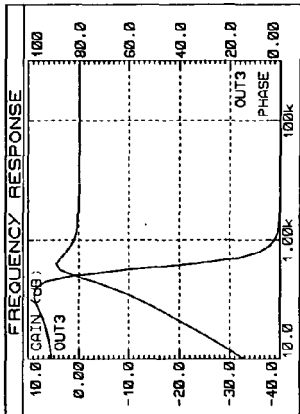
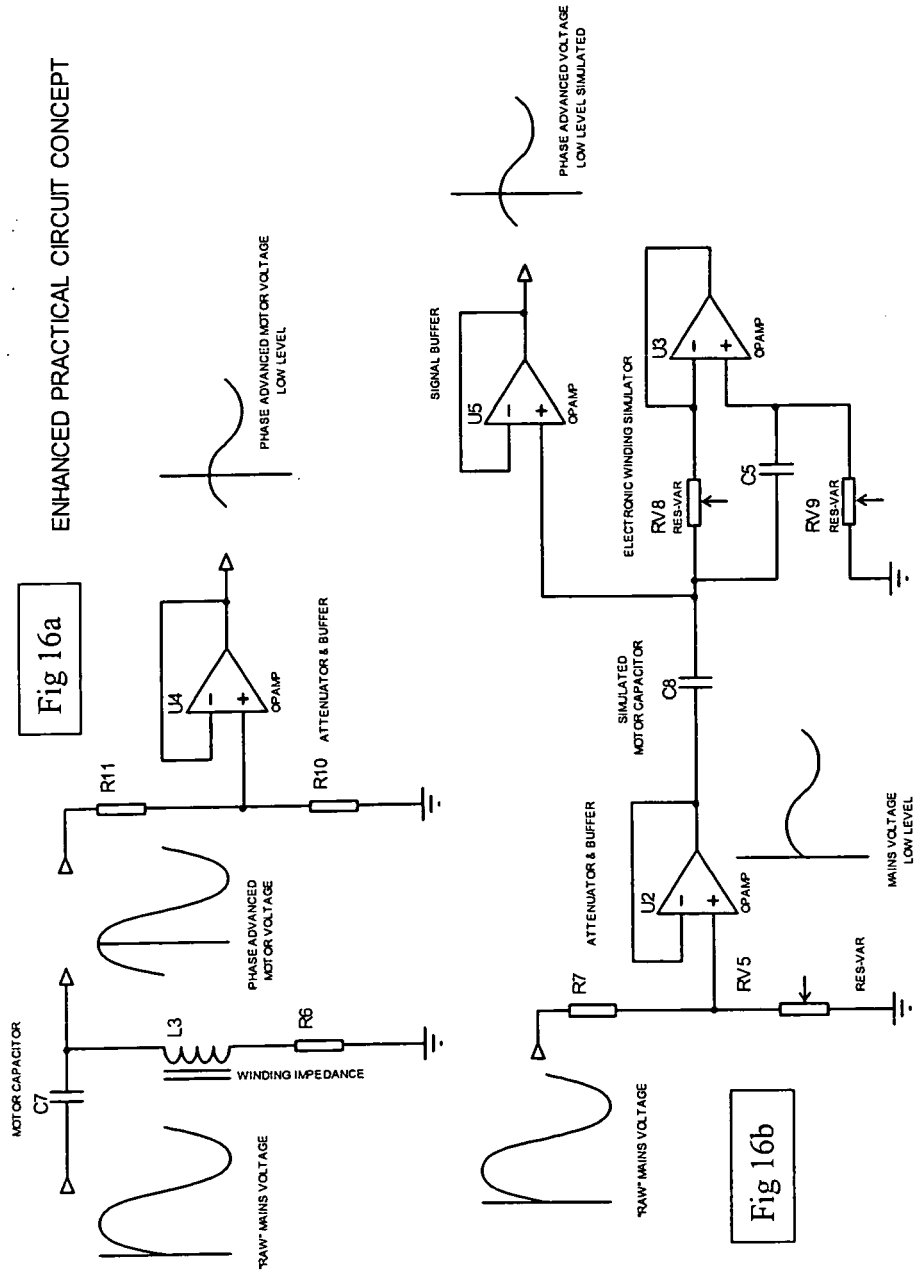
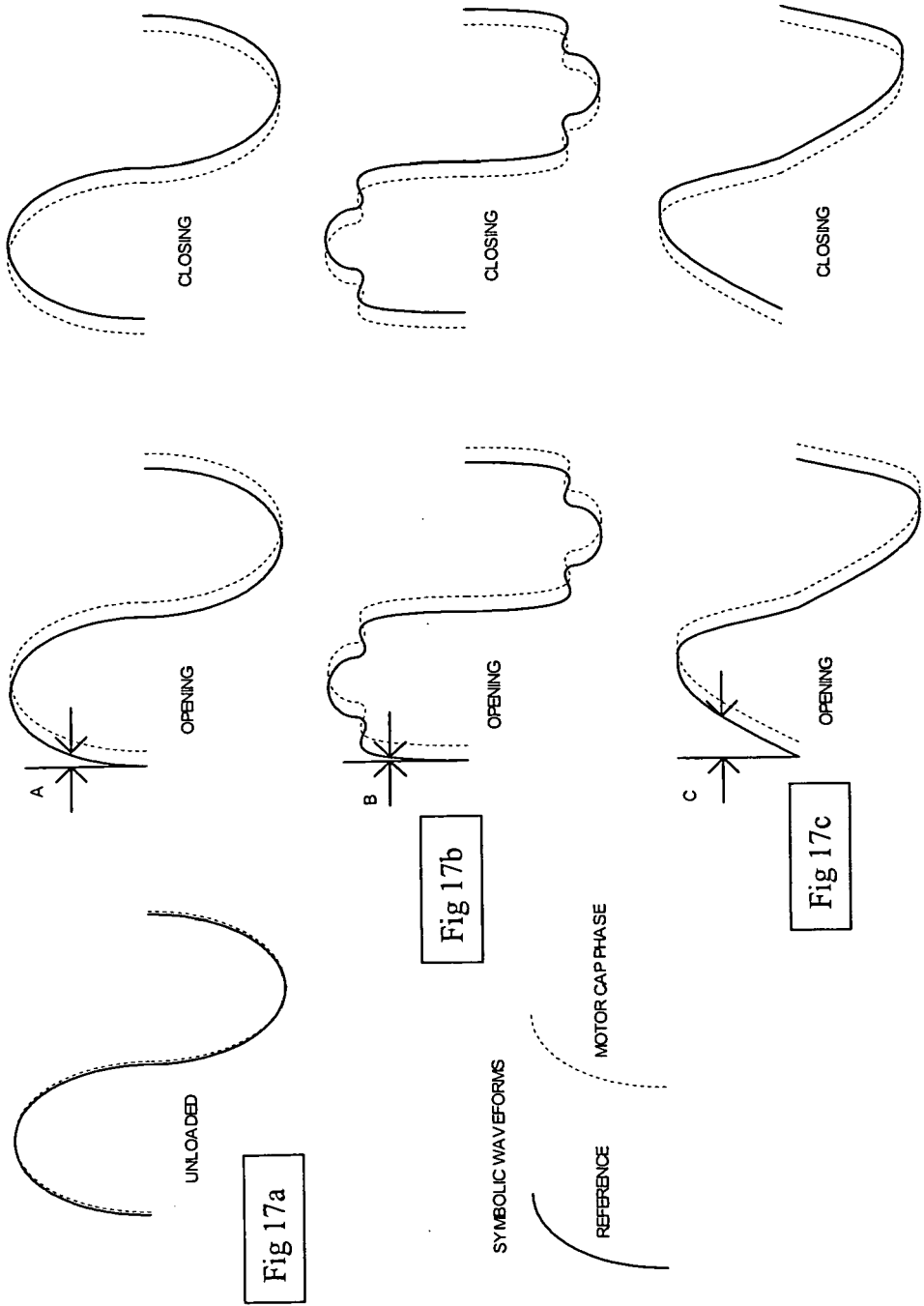


Fig 15c





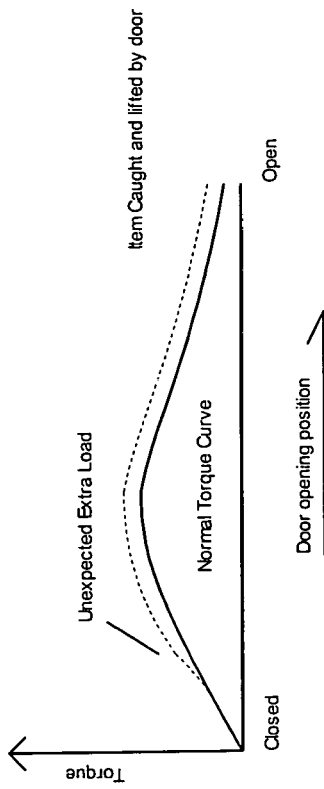


Fig 18a

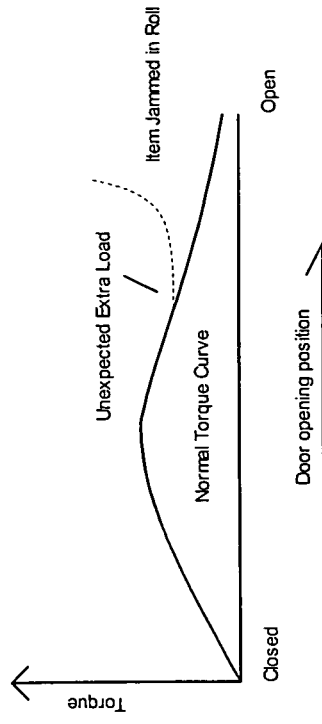


Fig 18b

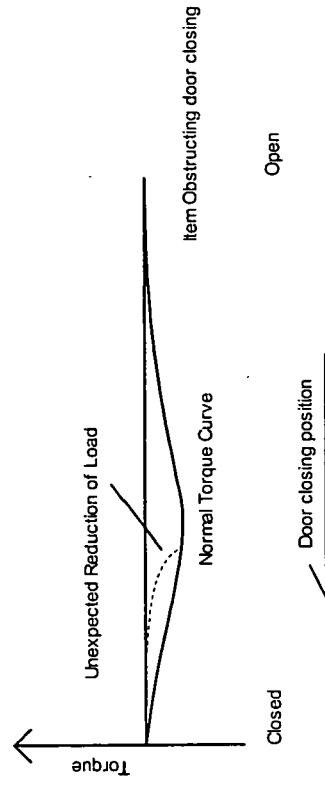


Fig 18c

Theoretical Torque Curves

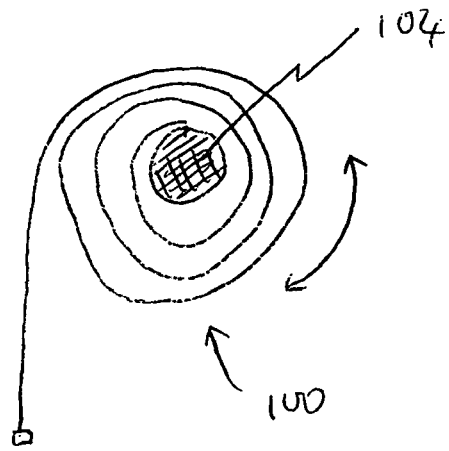


Figure 19a

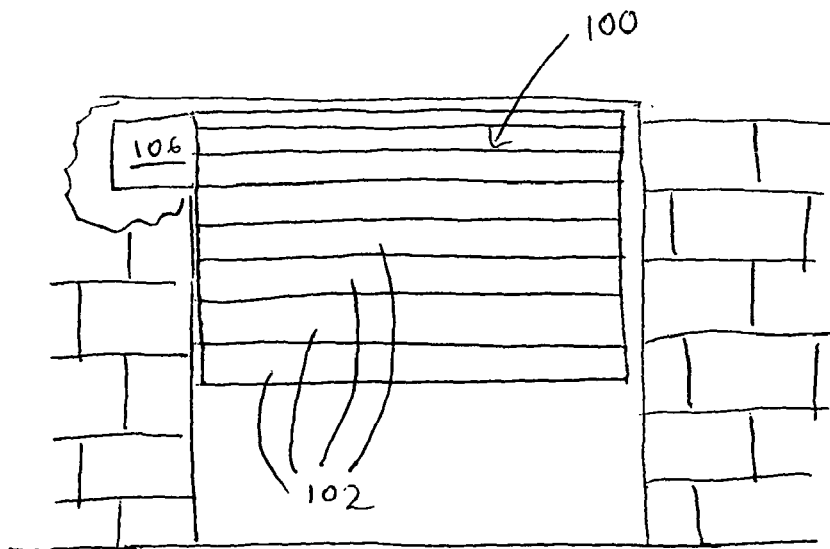


Figure 19b



European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 05 25 2835

DOCUMENTS CONSIDERED TO BE RELEVANT			
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			B66B H02P
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 6 September 2005	Examiner Kanelis, K
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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