United States Patent

Fredell

[15] **3,659,166**

[45] **Apr. 25, 1972**

[54] MULTI-SPEED DIAL CONTROL MECHANISM

[72] Inventor: **Gary D. Fredell**, East Moline, Ill.

[73] Assignee: **Gulf & Western Industries, Inc.**, New York, N.Y.

[22] Filed: **Nov. 13, 1970**

[21] Appl. No.: **89,359**

[52] **U.S. Cl.** **318/85**, 318/66

[51] **Int. Cl.** **H02p 5/46**

[58] **Field of Search** 318/85, 625, 66

[56] **References Cited**

UNITED STATES PATENTS

3,184,668	5/1965	Whitecar	318/85 X
3,428,877	2/1969	Campbell et al.	318/85
3,430,148	2/1969	Miki	318/85 X

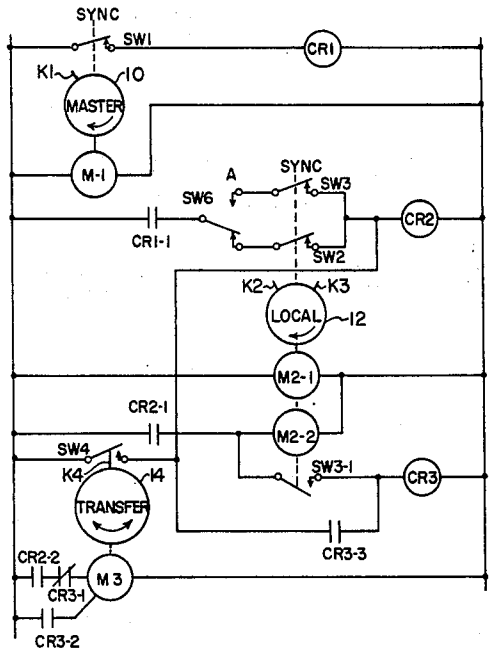
Primary Examiner—Benjamin Dobeck

Attorney—Meyer, Tilberry & Body

[57] **ABSTRACT**

Disclosed is a mechanism for controlling the relative positions of one or more rotating objects or local cams with respect to a master rotating object or cam. In addition, the mechanism also controls the rotating speed of the object or cams with respect to a master. Each local cam is normally driven by a motor which rotates the cam at the same speed as the master cam. A synchronization pulse is produced by the master cam and by each local cam, one pulse being produced for each revolution. When the synchronization pulses of the master and local cams are coincident in time, the cams are in their proper relative positions. When the synchronization pulses are not coincident, relay circuits are energized and, in turn, energize as second or third drive motor for the local cam. The second or third drive motor drives the cam at a greater or slower speed and overrides the normal local cam drive motor. The length of operation of the override motors is controlled by transfer cams which are also energized by the relay circuit. The mechanism may advantageously be incorporated in a traffic control system where the individual controllers are regulated from a master. The disclosed mechanism permits the smooth and rapid transistion from one control sequence to another depending on local traffic conditions.

17 Claims, 8 Drawing Figures



Patented April 25, 1972 3,659,166

6 Sheets-Sheet 1

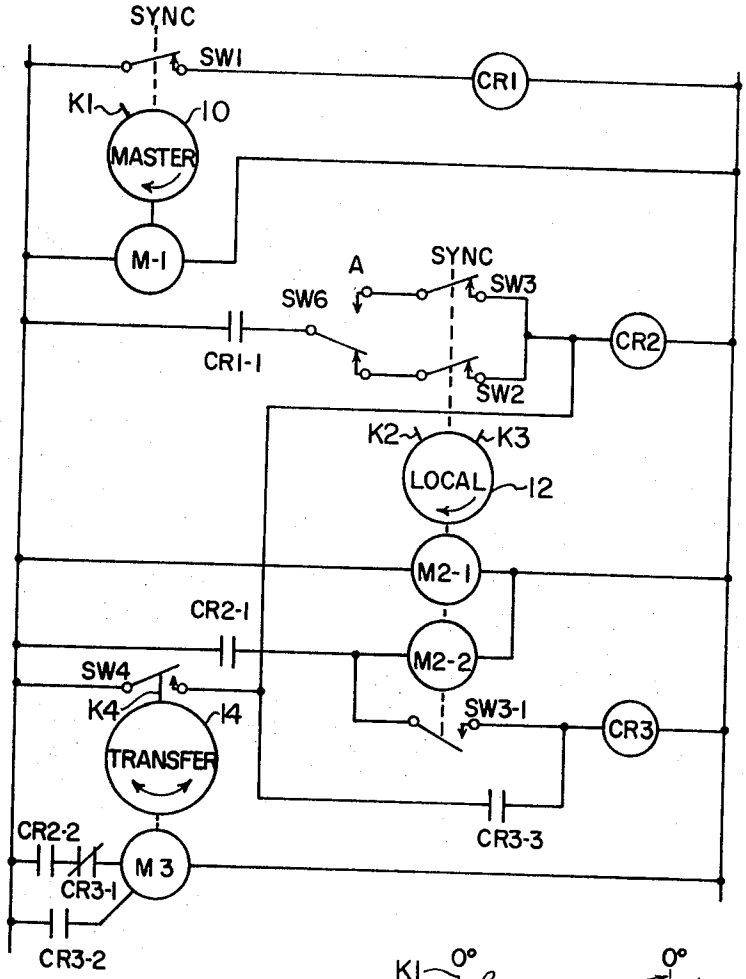


FIG.-1

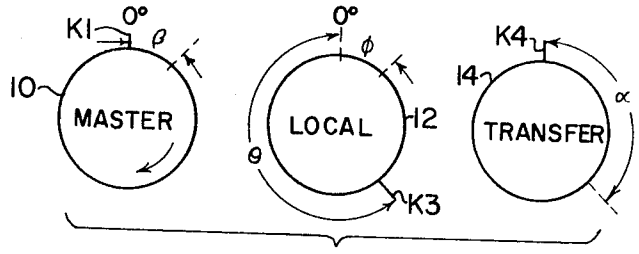


FIG.-2

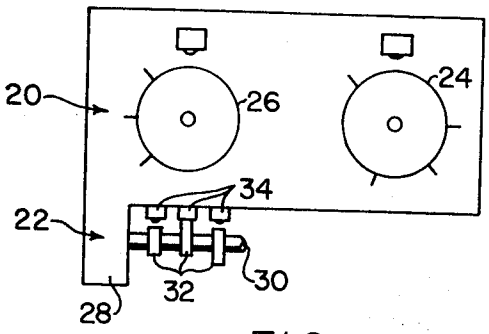


FIG.-3

INVENTOR.
GARY D. FREDELL
BY
Meyer, Tilberry & Body
ATTORNEYS

Patented April 25, 1972

3,659,166

6 Sheets-Sheet 2

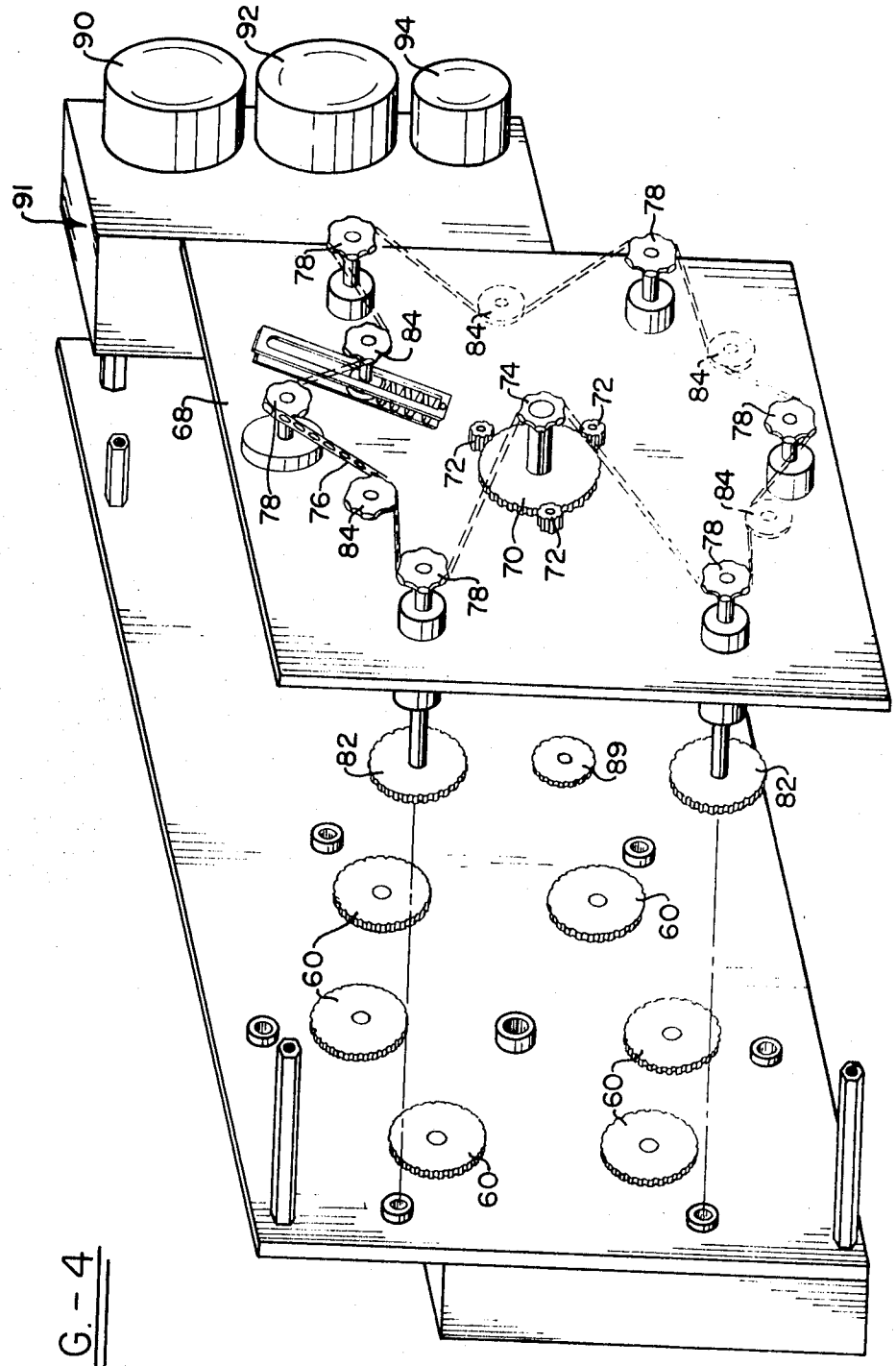


FIG. - 4

INVENTOR.
GARY D. FREDELL
BY
Meyer, Tilberry & Body
ATTORNEYS

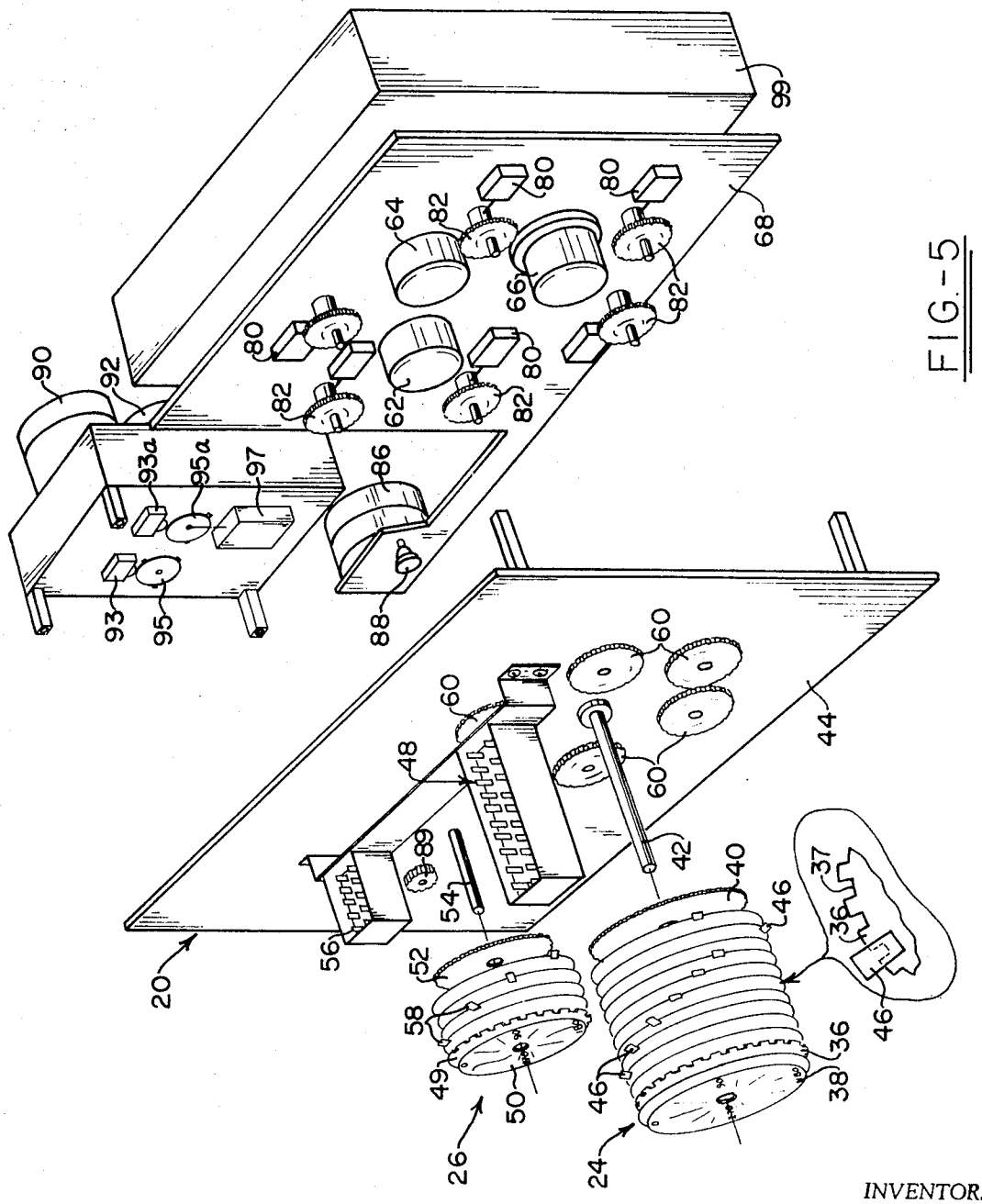


FIG.-5

INVENTOR.
GARY D. FREDELL
BY
Meyer, Tilberry & Body
ATTORNEYS

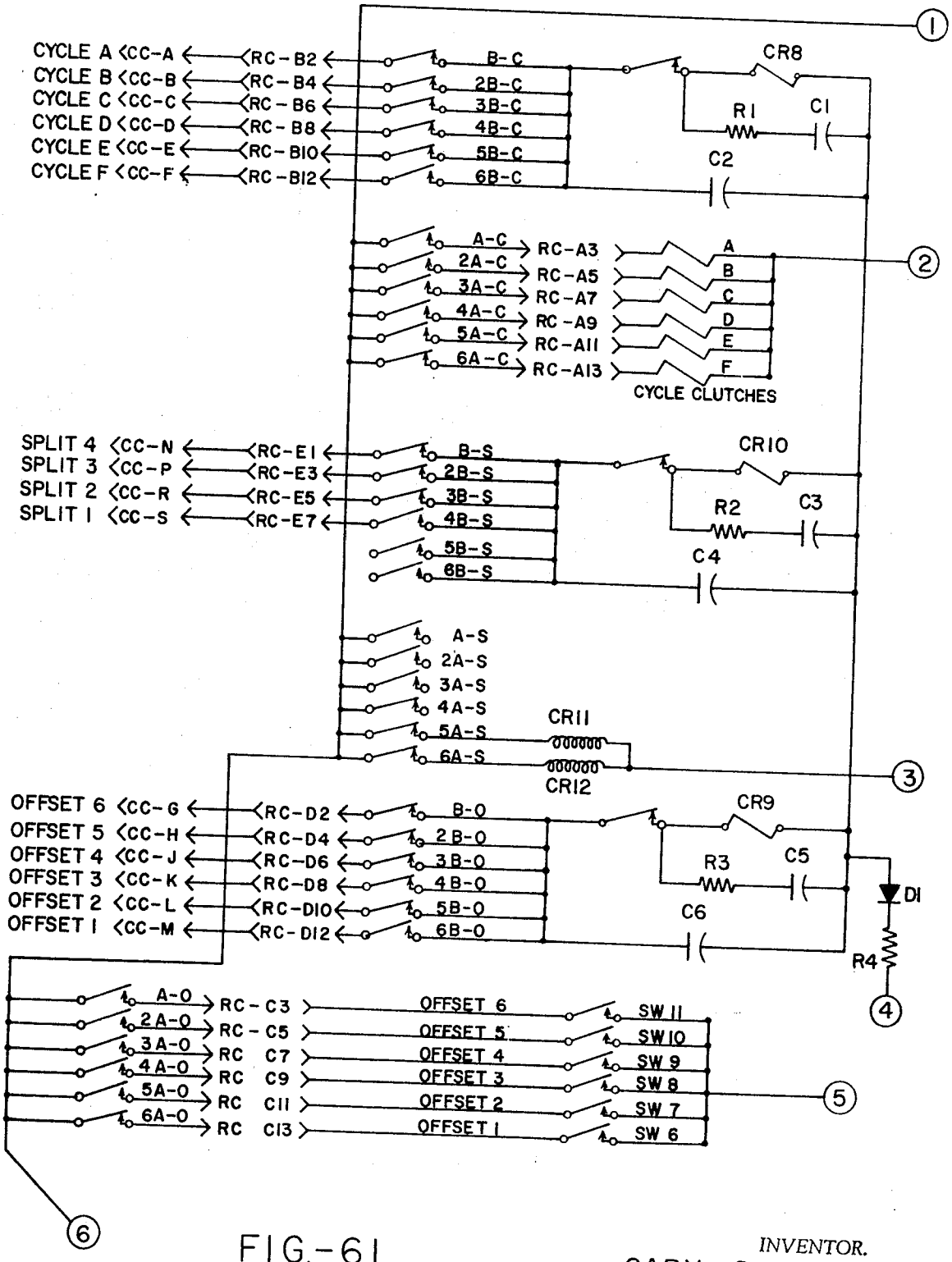


FIG.-6.1

INVENTOR.
GARY D. FREDELL

BY

Meyer, Tilberry & Body

ATTORNEYS

Patented April 25, 1972

3,659,166

6 Sheets-Sheet 5

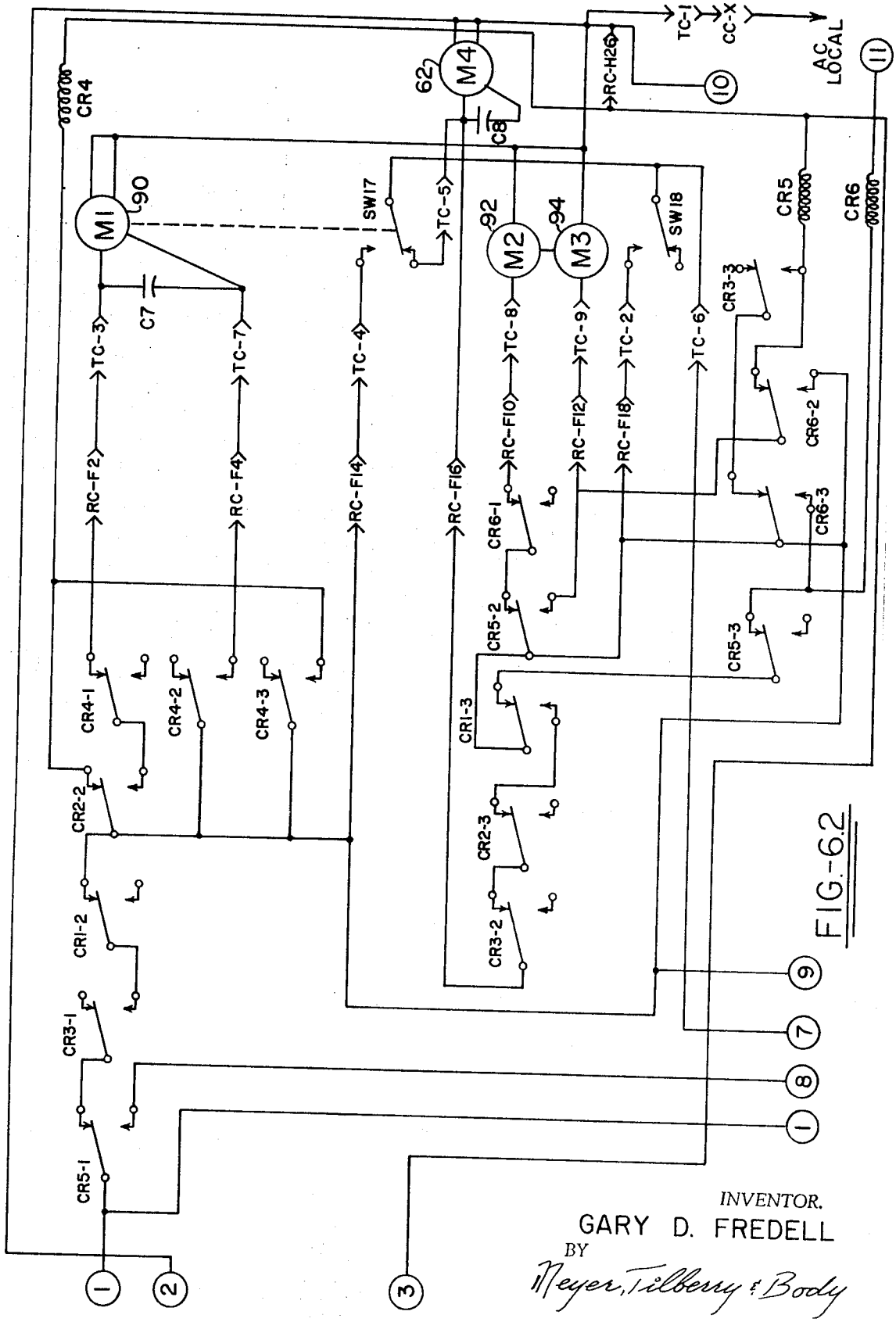


FIG-6.2

INVENTOR.
GARY D. FREDELL
BY
Meyer, Tilberry & Body
ATTORNEYS

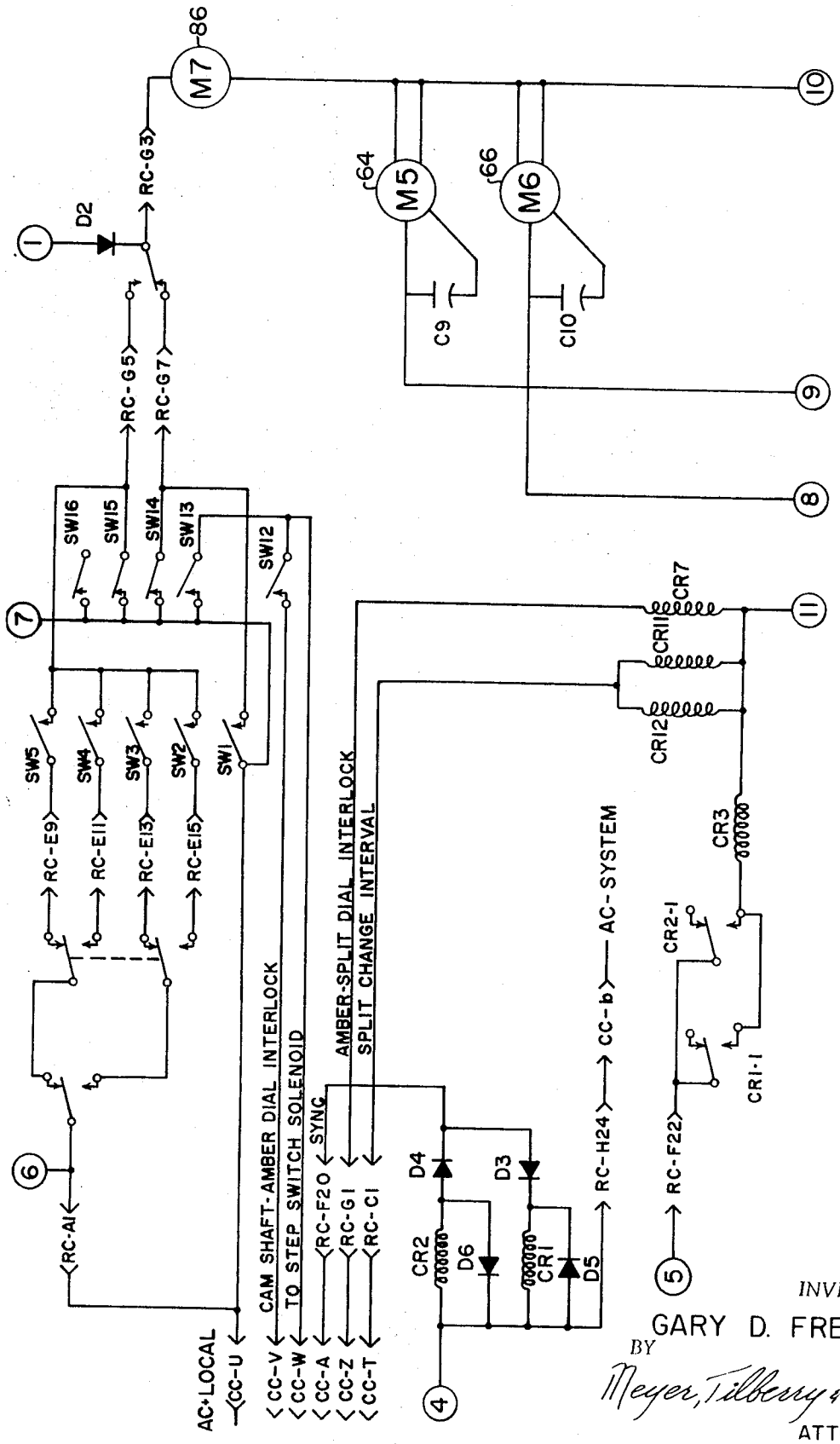


FIG-6.3

INVENTOR.
GARY D. FREDELL
BY
Meyer, Tilberry & Body
ATTORNEYS

MULTI-SPEED DIAL CONTROL MECHANISM

Various systems have heretofore been proposed for regulating the relative position of one or more rotating objects with respect to the position of a master rotating object. However, in these prior systems the respective positions of the master and the other rotating objects are achieved by stopping the local rotating object when it is out of phase with the rotating master and holding the local in its stopped position until the master has reached the corresponding position. Such stopping of the local is undesirable, however, where the local is employed as a control cam governing a sequence of operations since the operating sequence is interrupted during the time necessary for the local and master to again reach an in phase relationship. When the local is lagging only slightly behind the master, this delay may approach the time required for one full revolution of the master.

One arrangement for controlling the rotating speed of the master and local cams employs frequency responsive motors to drive the master and the local and is accomplished by varying the frequency to the motors. Such an arrangement, however, also possesses several disadvantages. These include difficulty of controlling the frequency responsive motors. An elaborate system of amplifiers is necessary to assure that the proper frequency from the master is supplied to the local frequency responsive motors. Such amplifier systems are very expensive and difficult to maintain. In a system using frequency responsive motors to rotate the local cams, the failure of power from the master causes the local to immediately return to a preselected speed, rather than maintaining the speed at which it was operating prior to the power failure.

It is the primary object of the present invention to provide a mechanism for controlling the position of one or more rotating objects relative to the position of a rotating master in which the change of position between the local and the master is accomplished without the necessity of stopping the local.

It is also an object of the invention to provide such a control system in which the amount of time required to effect a change in relative positions of the local relative to the master is accomplished with a minimum delay.

A further object of the invention is the provision of such a control system in which the synchronizing signal from the master is represented by the absence of power from the master so that the control will sense a synchronized condition in the event of a failure of power from the master and will thus maintain the local at its present operating rate.

A further object is to provide a better method of varying the rotating speed of the local and master cams.

The above and other objects of the invention which will become apparent in the following detailed description are achieved by providing a control mechanism in which the local cams are normally driven by motors rotating the cams at the same speed as the master cam and which includes additional motors for driving the local cam at a higher or lower speed, thereby overriding the normal drive motor. The speed-change motors are held in a de-energized state by the normally open contacts of relays which are energized only when the local cam is at its zero position while the master cam is in an out-of-phase position. The length of time during which the speed-change motors operate is controlled by relay circuits which employ transfer cams. The transfer cams rotate first in one direction at a uniform rate of speed, and then in the opposite direction at the same speed or a multiple of its forward speed. The transfer cams are rotated in their forward direction during the period of time between the point at which the master cam reaches its zero position and the local cam reaches its zero position. Reverse rotation of the transfer cams occur during the successive period extending to the point at which the master and local cams again reach synchronization.

For a more complete understanding of the invention and of the objects and advantages thereof, reference should be had to the following specifications and the accompanying drawings wherein there is shown a preferred embodiment of the invention.

In the drawings:

FIG. 1 is a schematic showing of the basic control mechanism of the concept of the invention;

FIG. 2 is a diagram showing the rotation of the master and local dials and of the transfer cam and illustrates the principle employed to achieve the desired synchronization;

FIG. 3 is a front elevational view of a traffic system controller incorporating the mechanism of the present invention;

FIG. 4 is a rear perspective view of a portion of the controller of FIG. 3 with the rear panel removed therefrom;

FIG. 5 is a front perspective view of a portion of the controller of FIG. 3; and

FIG. 6 is an electrical schematic diagram showing of the circuits of the controller shown in FIGS. 3 and 5.

GENERAL SPEED-UP SYNCHRONIZATION SCHEME

Considering first FIGS. 1 and 2, the basic control mechanism of the concept will now be described. A master cam **10** is driven at a uniform speed by a motor M1. The cam **10** carries a key K1 on its periphery. When the key K1 is in the 12 o'clock position, the master cam **10** may be considered to be at its zero or reference position. A local cam **12** is driven by a motor M2–1 at the same speed as is the cam **10**. The local cam **12** is provided with one or more keys, as indicated at K2 and K3, on its circumference. The reference point for keys K2 and K3 is considered to be at the 12 o'clock position. A second motor M2–2 is also provided for driving the local cam **12**. This motor rotates the local cam **12** in the same direction as does the motor M2–1, but at a different speed, for example, eight times faster than the speed of the motor M2–1. A relay CR1 is normally energized through a switch S1. This switch S1 is opened once for each cycle of the master cam **10** by the key K1. The opening of the switch S1 de-energizing the relay CR1 provides the synchronizing pulse, as will be explained in more detail below.

Considering for a moment only the key K2 of the local cam **12** and the desire to synchronize K2 with K1, there is provided a normally closed switch S2 which is opened by the key K2 once during each cycle of the local cam **12**. The switch S2 is in series connection with a relay CR2 and with a normally opened contact CR1–1 of the relay CR1. The relay CR2 includes a normally open contact CR2–1 which is in series connection with the local cam drive motor M2–2. If the master cam **10** and local cam **12** are in proper relationship, that is if the keys K1 and K2 both reach the zero reference point in the rotation of their respective cams at the same time, the relay CR1 will be briefly de-energized by the opening of the switch S1 and the contact CR1–1 will close. However, the switch S2 will be opened at the same time by the key K2 thus maintaining the relay CR2 in its de-energized state. As a result, the motor M2–2 remains de-energized and the motor M2–1 continues to rotate the local cam **12**.

Considering now the key K3 of the local cam **12** and assuming that the switch S6 has been turned to the A position indicating a desire to synchronize K3 with K1, an out-of-phase condition now exists since the key K1 of the master cam **10** will pass the reference point of this cam at a different time than will the key K3 of the local cam **12**. Thus, when the switch S1 is opened and the relay CR1 de-energized a circuit is completed through the contact CR1–1, the switch S6, and the switch S3 to the relay CR2. The relay contact CR2–1 is now closed energizing the speed-up motor M2–2 which drives the local cam **12** at a higher rotational rate.

The relay CR2 also contains a normally open contact CR2–2 which is in series connection with a contact CR3–1 of relay CR3 and a motor M3 which drives a transfer cam **14**. Closing of the relay CR2, while the relay CR3 is in its de-energized state thus completes the circuit to the motor M3. The motor M3 is a reversible motor which has a forward drive speed of a selected value and a reverse or counterclockwise speed of a different value, for example, seven times faster than the forward drive speed.

As the transfer cam **14** begins to rotate in a clockwise direction the key K4 carried by this cam moves from its zero reference point thus closing a switch S4. This completes a circuit to the relay CR2 holding this relay on after the relay CR1 has again become energized due to the continued rotation of the master cam **10**. The local cam **12** continues to rotate at the speed of the motor M2–2 and as the key K3 reaches its reference point a switch S3–1 is closed completing a circuit through the now closed contacts CR2–1 to a relay CR3. The contact CR3–1 now opens while the contact CR3–2 closes. As a result, the motor M3 is now reversed and drives the transfer cam **14** in the counterclockwise direction. As pointed out above, the motor M3 rotates faster in its counterclockwise direction. The relay CR3 also closes a contact CR3–3 to complete a holding circuit for the relay CR3 after the switch S3–1 has opened due to the continued rotation of the local cam **12**. When the transfer cam **14** has rotated back to its initial position with the key K4 in its reference location, the switch S4 is opened thus breaking the circuits to the relays CR2 and CR3. The contact CR2–1 now opens thereby de-energizing the motor M2–2 and returning the drive of the local cam **12** to the motor M2–1. At the same time the contacts CR2–2 and CR3–2 open so that the transfer cam drive motor M3 is de-energized. As will be seen in the following paragraphs, at this point the positions of the keys K1 and K3 will be exactly in phase.

PRINCIPLE OF OPERATION

Referring now specifically to FIG. **2**, the principle of operation of the circuit described above will now be explained. First let us consider the master and local dials in the positions shown in FIG. **2**, that is, where the key K1 of the master dial is in the zero or reference position while the key K3 of the local dial is offset from the reference position by an angle θ. The time required for the local cam **12** to rotate so that the key K3 is in the zero reference position is ($\frac{1}{8}$M) (θ/180) seconds where M is the number of seconds per revolution of the master cam or dial and presumably the local cam motor M2–1 drives at the same speed. The local cam motor M2–2 drives at a speed eight times that of the motor M2–1. When the local cam or dial **12** has rotated to zero, the transfer cam will have rotated through the angle α given by the equation

$$\alpha = (\tfrac{1}{8}M)\,(\theta/360)/T$$

where T is the seconds per revolutions of the transfer cam when driven in the clockwise direction. When the key K3 has reached the zero reference at the 12 o'clock position, the transfer cam drive motor M3 is reversed and, as explained above, drives the transfer cam in the counterclockwise direction at a speed seven times that of its clockwise direction. Thus, the transfer cam returns to its zero reference at the 12 o'clock position in (1/7 T) per revolution or in ($\frac{1}{8}M$) (θ/360)/T (1/7 T) seconds which also equals ($\frac{1}{8}M$) (θ/360) (1/7) seconds. Therefore, the total time that the local cam or dial **12** is rotated by the motor M2–2 is ($\frac{1}{8}M$) (θ/360) (1/7) + ($\frac{1}{8}M$) (θ/360) seconds. During this total time the local dial or cam **12** will have rotated

$$\frac{(1/8M)\,(\theta/360)+(1/8M)\,(\theta/360)\,(1/7)}{1/8M}=\theta/360 + (\theta/360)\,(1/7)$$

revolutions. The rotation of the key K3 beyond the reference point, that is the angle ϕ, is the total rotation of the local cam **12** less the rotation from the initial position of K3 to the zero reference. Thus,

$$\mathbf{100} = \theta/360 + (\theta/360)\,(1/7) - \theta/360 = (\theta/360)\,(1/7)$$

revolutions.

The master cam **10** will have rotated from the zero reference by an angular displacement β where

$$\beta=\frac{(1/8M)\,(\theta/360)+(1/8M)\,(\theta/360)\,(1/7)}{M}$$

Thus, β is equal to (1/7) (θ/360) revolutions and is equal to ϕ. It can thus be seen, that both the master cam and the local cam have rotated the same angular distance from the zero reference. The maximum displacement between the master cam key K1 and the local key K3 is 360°. Thus, the maximum time required to bring the master and local cams to an in phase relation is one-seventh of a revolution under these assumed relationships.

In the above-identified equations and relationships the following are assumed as parameters:

a. Master dial cycle—M seconds/revolutions
b. Transfer cam cycle—T seconds/revolutions
c. Return transfer cam cycle—1/7 T seconds/revolutions
d. Local dial transfer cycle—$\frac{1}{8}M$ seconds/revolutions
e. Offset "01" an angle θ from the zero reference
f. Offset transfer will not begin until the master dial is at the zero reference.

It should be understood that a definite relationship must exist between the speed of motor M2–2 and the reverse speed of motor M3 to satisfy the desired achievement of synchronism. Hence, if we substitute X for the difference in speed of the local cam motor M2–2 as related to the speed of the master cam motor M1, or M defined above, and Y for the change in speed of the reverse speed of the transfer cam motor M3 as related to the forward speed of motor M3, or T defined above, the following algebraic relation must be met to satisfy synchronism, regardless of the speed of master cam motor M1 or the first or forward speed of motor M3:

$$Y = X\,(1 + Y)$$

Using the equation defined above the following table represents typical speed arrangements for motors M1, M2–1, M2–2 and M3:

M1	M2–1	M2–2	M3Forward	M3Reverse
1 r.p.m.	1 r.p.m.	8 r.p.m.	1 r.p.m.	7 r.p.m.
1 r.p.m.	1 r.p.m.	9 r.p.m.	1 r.p.m.	8 r.p.m.
2 r.p.m.	2 r.p.m.	12 r.p.m.	2 r.p.m.	10 r.p.m.
1 r.p.m.	1 r.p.m.	½ r.p.m.	1 r.p.m.	1 r.p.m.

If a third drive motor is utilized for the local dial **12** which is capable of overriding the motor M2–1 and which drives the cam **12** at a lower speed than does the motor M2–1, the control arrangement described above can be adapted to slow the local dial to bring it into synchronization with the master dial following the same general scheme. If the signal from the master dial is one of positive polarity during a first portion of its rotation and of opposite polarity during the remainder of its cycle, polarity sensitive relays may be employed to select the speed-up motor or the slow-down motor to restore synchronization between the local and master dials in the shortest possible time. It should be understood, however, if two motors are used to drive the local dial at two different speeds, then two different motors are required to drive the transfer cam on its return cycle at the two necessary complementary speeds to achieve synchronization. Such an arrangement is illustrated in the traffic signal control mechanism described below.

Further, while specific rotative speed relationships are defined above between the motors, it is to be understood that various speed relationships may be utilized and still achieve the objects of the invention by simply following the algebraic relationship between X and Y or the relative speeds of motors M2–2 and M3 defined above.

Also, the disclosed mechanism operates on this same principle except the speed changes take place when the local dial or cam reaches the reference position (12 o'clock) instead of the master dial or cam.

TRAFFIC SIGNAL CONTROL SYSTEM

Referring now to FIGS. 3 through 6, a traffic signal control system employing the principles of the above-described control mechanism is shown. Specifically, in FIG. 3 the controller consists of a timing unit assembly, indicated generally by numeral 20, and a cam shaft assembly indicated generally by numeral 22. The timing unit assembly 20 consists, essentially, of two main portions: a split dial assembly 24 and its associated drive and control mechanisms; and an amber dial 26 with its associated drive and controls. The split dial 24 controls the release time of the amber dial and determines the percentage split, that is, the time allotted for each phase of the signal operations. The amber dial 26 controls a ratchet motor 28 of the cam shaft assembly 22 to index a cam shaft 30 and respective cams 32. The cams 32 open and close contacts 34 to control individual traffic signal lights.

As best seen in FIG. 5, the split dial 24 consists of a series of discs 36 which are notched or slotted along their edges, as seen at 37 in the broken away enlargement, a front dial plate 38, and a gear 40 which are held together and rotate as a unit on a shaft 42 secured to a front plate 44 of the timing assembly 20. Each of the slotted discs 36 may be provided at any one of its slots with keys 46 which project outwardly from the discs. A switch assembly 48 is mounted on the front plate 44 immediately above the split disc assembly 24, and includes a separate switch corresponding to each of the slotted discs 36. As the split disc assembly 24 rotates the various keys 46 contact their associated switches as they pass through the 12 o'clock position, or any predetermined reference position.

The amber disc 26 is likewise composed of a number of slotted discs 49, a front dial 50, and a gear 52 which are held together and rotate as a unit on a shaft 54. A switch assembly 56 is provided on the front plate 44 immediately above the amber disc 26 and includes one switch for each of the slotted discs 49. Keys 58 may be provided on each of the slotted discs 49 for controlling the associated switches of the switch assembly 56.

Three motors 62, 64, and 66 are mounted on a backplate 68 which is carried in spaced, parallel relation to the front plate 44. The three motors 62, 64, and 66 each contain one-way clutches and drive a common gear 70 through drive gears 72. The common gear 70 is rotatably supported on the motor or backplate 68. Attached to and rotating with gear 70 is a drive sprocket 74. A continuous chain 76 passes around the drive sprocket 74 and around sprockets 78 carried by shafts extending through the back plate 68. Each of the driven sprockets 78 is connected through a solenoid clutch mechanism 80 to a gear 82. The solenoid clutches may be of the type shown in U.S. Pat. Nos. 3,340,975 and 3,355,602. The gears 82 drive idler gears 60 which in turn mesh with the gear 40 forming a part of the split dial 24. The idler gears 60 actually have gears on both faces of the plate 44 to engage on the rear with gears 82 and on the front with gear 40, respectively. A spring biased idler pulley 84 may be provided to take up any slack in the drive chain 76 and to permit different sized driven sprockets 78 to be employed, if desired.

A motor 86 also mounted on the motor plate 68 drives the amber dial 26 through a gear 88 meshing with an idler gear 89 engaging the amber dial gear 52. Three additional motors 90, 92, and 94 are also provided and these motors drive and comprise a portion of the transfer cam mechanism indicated generally by numeral 91. The mechanism 91 consists of two switches, switches 93 and 93*a* and two cams, 95 and 95*a*. The cam 95 is connected to the reversible motor 94 while the other cam 95*a* is connected to a differential assembly 97. The motor 94 will run in one direction at a fixed RPM and reverse at the same RPM. The differential cam 95*a* will run in one direction at a fixed RPM and reverse at one-fourth the fixed RPM.

Referring now to the circuit diagram of FIG. 6, the operation of the mechanism described above will be explained. The electrical control package is indicated by numeral 99 in FIG. 5. If the six driven sprockets 78 are each of different sizes, the selection of one of the sprockets as the split dial driving sprocket will permit the split dial to be driven at any of six different speeds thus giving six different cycle times for the mechanism. The selection of which one of the solenoid clutches 80 is energized, and thus which cycle is employed is determined by a stepper relay CR8. A signal from the master controller 99 to one of the contacts 1B–C to 6B–C determines which of the clutch mechanisms 80 will be energized and which cycle will be selected. If, for example, cycle B were called for from the master, power would be applied to contact B2 of relay CR8. This would cause CR8 to step around through its interrupter contact until contact 2B–C opened. At this time, contact 2A–C would close thereby energizing the respective clutch mechanism 80 of cycle B.

Six of the discs 36 making up the split dial 24 are used to provide offsets, that is the percentage of the cycle that the beginning of "main street green" is shifted from a reference point. The amount of offset is determined by the relative position of the key 46 of the particular disc selected. A stepper relay CR9 determines which of the offset discs 36 will be active in the circuit in response to a signal from the master. This stepper relay CR9 operates in the same manner as the stepper relay CR8.

In addition the invention contemplates, that four separate discs 36 in the disc stack making up the split dial 24 are employed to determine the split, that is the percentage of the cycle given to "main street green." The value of the split selected is determined by the position of the key 46 of each particular disc of dial 24. A stepper relay CR10 selects the one of the four splits to be controlling in accordance with a signal from the master to one of the contacts 1B–S to 4B–S.

A relay CR11 is a lock-in relay. That is, any power to the CR11 latch coil will not cause the CR11 contacts to transfer unless the release coil CR11 is energized. This is to prevent the transfer from one split to another except during a specific interval in the step switch mechanism. During that specific interval, generally referred to as "main street green," the CR11 and CR12 release coils are energized and only during this interval can the CR11 or CR12 latch coils transfer. Hence, as an example, when the coils of CR11 and CR12 are both de-energized number four split is in effect, when CR12 is de-energized and CR11 energized, number three split is in effect. When CR12 is energized and CR11 is de-energized, number two split is in effect. If both relays are energized number one split is in effect.

The amber dial motor 86 is normally driven through SW14 or SW15 contacts which are normally closed. When an appropriately positioned key 58 on the amber dial lifts the lever switch SW14 the amber dial motor 86 stops and waits until a split key closes SW2, SW3, SW4, or SW5 depending upon which split is in effect. Each time SW12 closes on the amber dial, the cam shaft assembly 22 advances one interval by driving motor 28 through connector CC–W. However, at a particular point in the operation of the cam shaft assembly 22, the power through connector CC–V is removed by appropriate action of one of the cams 32 cooperating with its respective switch 34. The only switch which may then advance the cam shaft assembly 22 out of its locked up interval is SW13. There is only one key 58 appropriately positioned on the amber dial that controls SW13. This relationship keeps the amber dial and the cam shaft assembly 22 in sequence.

Switches SW14 and SW15 are interwired through the contact CR7–1 of relay CR7. During all but one point in the revolution of the split dial switch SW14 of the amber dial drives the motor 86. During one interval of the cam shaft assembly, the relay CR7 is energized transferring the amber dial motor to switch SW15 on the amber dial. At this time only switch SW1 can release the amber dial motor and start it rotating again. This flip-flop action of CR7–1 insures that the split and amber dials do not get out of step or sequence with one another.

The synchronization pulse (referred to below as the sync pulse), which comes from the master and establishes a definite

relationship between the local controllers and the master, enters through connector RC–F20 to relays CR1 and CR2. The diodes D3 and D4 make one relay energize when a negative pulse is applied in the sync line and the other relay energized when a positive pulse is supplied in the sync line. Neither relay is energized in the absence of a pulse of voltage. The absence of voltage on the sync line is the true sync of the line.

The standard split dial drive motor **62** runs continuously through contact SW17. When the master dial approaches the 12 o'clock position or the sync point, the following sequence of events takes place. Relay CR2 is energized until the sync signal occurs. Just prior to synchronization; a pulse of continuous positive power is sent down the sync line thereby energizing relay CR1. Relay CR1 will therefore be held energized for one-third cycle of the master. During the cycle of the master, relay CR2 is held energized by supplying only negative power. Only during the sync point is CR2 released. If the split dial is not in synchronization with the master or if a new offset is called for by appropriate energization through the controller **99**, the sync pulse occurs and relay CR2 is de-energized. As soon as CR2 drops out, contacts CR2–3 close and power is transferred through SW17, contacts CR3–2, CR2–3, CR1–3 which is energized, CR5–2, and CR6–1, thereby turning on transfer motor **92**. As soon as motor **92** begins running it causes cam **95** to rotate actuating switch **93** (same as switch SW18) to supply power through switch SW18 to relay contacts CR5–2 and CR6–1 to maintain transfer motor **92** running even though relay CR2 has now energized and contacts CR2–3 have opened. Motor **92** will continue running in one direction at a set speed until one of the switches SW6–SW11 closes, depending upon the offset set-up of the controller. As soon as this happens, relay CR3 is energized through contact CR1–1 which is still closed. Relay contacts CR3–3 now close supplying power to relay CR5 which in turn energizes. The contacts CR5–2 now transfer stopping the transfer motor **92** and turning on transfer motor **94**. Also, the contact CR5–2 and CR6–2 provide a lock-up for relay CR5 and the contact CR5–3 locks out relay CR6. The transfer motor **94** reverses the rotation of the cam **95** and returns the cam **95** at one-fourth the speed that motor **92** rotated it according to this specific embodiment.

When relay CR5 energizes, contact CR5–1 closes turning on the split dial drive motor **66** which overrides the standard dial drive motor **62** and drives the split dial at 1-¼ times its original speed. If the relay CR1 drops out during the speeding up sequence opening the contacts CR3–1, the transfer motor M3 and relay CR5 are still held energized through the contact CR5–2 which is still receiving power from switch SW18. The split dial **24** will thus continue rotating at its higher rate of speed. When the transfer cam **95** driven by the motors **92** and **94** reaches its reference position the switch **93** (same as SW18) opens. The relay CR5 is now de-energized and the split dial returns to its original speed. At this time the dial is in synchronization with the master all according to the synchronization scheme defined with reference to FIGS. **1** and **2** above.

If none of the switches SW6–SW11 had closed, the split dial would be in a position where it was to slow down to get into synchronization with the master dial. In this case when CR1 de-energized, power would go from SW18 which is closed through the contacts CR1–3, CR5–3, and energize relay CR6. CR6 would now lock up through contacts CR6–3 and would lock out relay CR5. This would shut off the motor **92** and turn on the motor **94** through CR6–2. Motor **94** would then return the cam **95** to its reference position until switch SW18 opened. This sequence will result regardless of any other sequence because CR6 is dependent only on SW18.

Assuming now that the split dial was not in synchronization with the master and the best method of getting the dials into synchronization would be to slow down the split dial. In this case, CR1 is not energized, and CR2 is energized. Should a split key close one of the switches SW6 through SW11, the relay CR3 is immediately pulled in through the CR2–2 and CR4–1. Motor **90** drives cam **95***a*. Switch SW17 (same as switch **93***a* of FIG. **5**) is thus actuated to provide a holding for the motor **90** through these contacts. Also when CR3 is energized, motor **64** which is the half-speed motor is immediately turned on through CR5–1, CR3–1, and CR1–2 and motor **62** is turned off by SW17. When the dial of the master controller comes into synchronization, the relay CR2 is momentarily released. Even if relay CR1 should pull in during the slow-down cycle the motor **64** will continue to run through SW17. When the sync point appears and CR2 drops out, CR4 will be energized through the contacts CR2–2 and SW17. CR4 now locks itself closed through its own contact CR4–3 and turns off the motor **90** operating in the first direction and, through the contact CR4–2 causes the motor **90** to operate in the opposite direction. The motor **64**, the half-speed motor, will continue to run until contact SW17 again transfers turning on the standard speed motor **62**. CR4 now drops out and the motor **64** is turned off. Synchronization has again been accomplished.

If for some reason there is a power failure from the master, there will now be no voltage in the sync line and the relays CR1 and CR2 will both be de-energized. This is sensed by these relays as a sync point at all times and as a result, no changes in the operation of the motor **62** will occur.

When the local split dial and the master dial are in synchronization, the relay CR3 energizes at the same time relay CR2 de-energizes. As a result, the transfer motors remain inactive and no change will occur.

It will be noted that since the slow-down and speed up motors **64** and **66**, respectively, drive the split dial **24** through the same sprocket chain and clutch combination that is used by the standard drive motor **62**, the reset transfer time is always a percentage of the split dial cycle and this percentage is independent of the cycle selected. The use of the two relays CR1 and CR2 which are sensitive to opposite polarity signals, provides a means for selecting the most advantageous arrangement for bringing the split dial into synchronization with the master dial and for most rapidly effecting a desired offset. Thus, if the offset key sees positive power when it reaches its reference position, it will trigger the speed-up mechanism of the controller to accelerate the split dial. If the offset key sees negative power, it will drive the split dial at one-half speed until synchronization is achieved. With the speed ratios of the described embodiment, the maximum transfer time necessary to achieve a transfer or to bring the master and split dials into synchronization is 1-⅓ cycles.

The relationship between the speed-up and slow-down speeds of the local dial should be such that both the speed-up and slow-down maximum times to achieve synchronization with the master dial should be equal. In this specific embodiment this is the one-third to two-thirds relationship for controlling the positive (1-¼ speed) negative (one-half speed) signals respectively as defined above.

Hence, it should be understood that in the specific application of the invention to a traffic control system described above, the main parts of the timing unit assembly are, the split dial assembly **24**, the amber dial **26**, and the six offset discs **36** which make up a portion of the split dial **24** used to provide offsets. The split dial and the amber dial are each made up of a series of round discs which in a preferred embodiment of the invention have 100 equally spaced slots punched in the discs around their peripheries. This type of construction enables the dial to be built up to any number of discs or switch positions that are desired. In the mechanism set forth above, there are 11 such positions on the split dial **24** and five positions on the amber dial **26**. The switches **48** and **56** mounted above the split dial and amber dials **24** and **26**, respectively, are preferably of the enclosed snap type as these switches require much less space than open type contacts.

In the past, separate offset mechanism has been utilized, but as now defined, this has been replaced and put directly on the split dial **24**. This eliminates much gearing from the offset dials to the split dial which has been a problem heretofore.

A fixed speed-up and slow-down range has been selected where the speed-up range is 1-¼ times faster than the normal cycle and the slow-down is one-half times the normal cycle. Therefore, for a maximum reset transfer time or the time to go to a new offset to be equal for both the speed-up and the slow-down, the mechanism is speeded up for one-third of a cycle and slowed down for two-thirds of the cycle. The amount of time of speed-up or slow-down is accomplished by the three reset transfer motors **90**, **92**, and **94** cooperating with their respective cams and switches and the circuit of FIG. **6** to achieve the reset transfer time. If a new offset is called for, when that particular offset key reaches the 12 o'clock or reference position and actuates a switch, the split dial **24** then either speeds up or slows down, depending upon that offset key position with respect to the master. This position is determined from the master by transferring positive power during the first one-third of the cycle. Should the offset key see positive power when it reaches the reference position, it will trigger the speed-up mechanism of the controller and drive the split dial at 1-¼ times its normal speed until the system is in sync. On the other hand, if the offset key sees negative power, it will drive the split dial at one-half speed until it is in sync. Thus, maximum transfer or the time to get the sinc from the point where the offset key starts from the 12 o'clock position will be 1-⅓ cycles maximum. Therefore, it would be understood that the faster the cycle length the faster the reset transfer time.

A further advantage of the structure described above is that of speed selection or cycle length selection. The six electric clutches positioned around the periphery of the split dial **24** provide six different speed availabilities at the split dial which can be selected from the master or at the local controller. Which six speeds are available at the split dial depend upon the six sprockets which are placed on these clutches, but the drive motors **62**, **64**, and **66** for the split dial **24** drives an appropriate chain device around the six clutches by use of cooperating sprockets. The cycle length of each clutch is dependent upon which size sprocket is placed upon that clutch. In the proposed preferred embodiment of the invention, there are 21 different size sprockets, and therefore the total number of combinations available is 21 × 21 or 441. This is feasible due to the fact that a sprocket drives the other six clutch sprockets. Therefore, by changing the drive sprocket, one can alter the timing of all six sprockets accordingly. Since there is no differential from the speed-up or slow-down motors **64** and **66** to the split dial **24**, the speed-up and slow-down will always be at the 1-¼ or one-half rate regardless of which cycle length is being used.

Also, as more fully described above, no problems occur if there is a power interruption between the master and the local controllers, since all local controllers remain in the same cycle, split, and offset in which the mechanism was operating prior to power failure, because the power supply to these three items is supplied at the local intersection and not from the master since the sync pulse is the absence of power.

While in accordance with the Patent Statutes, only the best known embodiments of the invention have been described in detail, the invention is not so limited and reference should be had to the appended claims in determining the true scope thereof.

What is claimed is:

1. Apparatus for controlling the position and speed of one or more local rotating objects relative to the position or speed of a master rotating at a substantially constant RPM, comprising:

a first motor for rotating the local object at substantially the same speed as the master;

a second and third motor capable of overriding the first motor to rotate the local object at a second or third different speed;

first means for indicating when a fixed point on the circumference of the master passes a stationary reference point;

second means for indicating when a fixed point on the circumference of the object passes a stationary reference point;

control means responsive to the first and second indicating means to operate the second or third motor for a period of time determined by said control means to bring the fixed point of the local object into rotational synchronization with the fixed point of the master.

2. Apparatus according to claim **1** wherein the local object has a plurality of fixed points in spaced relation on its circumference and the control means includes switch means for selecting the one of the plurality of points to be brought into synchronization with the fixed point of the master.

3. Apparatus according to claim **1** wherein the control means includes a reversible motor having a reverse speed different from its forward speed, a cam driven by the reversible motor, a switch controlled by the cam and closing when the cam rotates from its at-rest position, relay means controlled by the position of the rotating object for controlling the reversible motor to rotate the cam in one direction from the beginning of operation of the control means until the fixed point of the rotating object passes the stationary reference point and in the reverse direction thereafter until the cam returns to its at-rest position whereby synchronization of the object with the master is achieved.

4. Apparatus according to claim **3** wherein the control means further includes a first normally closed switch which opens when the fixed point of the master reaches the corresponding stationary reference point, a relay in series connection with the first switch and having a normally open contact, a second normally closed switch which opens when the fixed point of the object passes its corresponding stationary reference point, the second switch being in series connection with the contact of the first relay and with a second relay, the second relay having a first contact in series connection with the second motor and a second motor and a second contact in series connection with the forward drive of the reversible motor, and the relay means controlling the reversible motor including a normally open switch which closes when the fixed point of the object passes its corresponding stationary reference point, a third relay in series connection with the normally open switch and the first contact of the second relay, the cam controlled switch being in series connection with the second relay and, through a first contact of the third relay, with the third relay, the third relay also including second and third contacts in series connection with the forward and reverse drives of the reversible motor, respectively.

5. Apparatus according to claim **4** wherein a plurality of fixed points are provided at spaced locations on the circumference of the rotating object, a normally closed switch being associated with each of the fixed points, and an additional switch being provided to determine which of the normally closed switches controls the second relay.

6. Apparatus according to claim **3** wherein the control means includes means to provide a signal pulse as the fixed point of the master passes its corresponding reference point, a normally closed switch opening when the fixed point of the object passes its stationary reference point, a first relay energized by the signal pulse when the switch is closed, the first relay energizing the second motor and the forward drive of the reversible motor, the cam controlled switch providing a latching circuit for the first relay, a normally open switch closing when the fixed point of the object passes its stationary reference point, and a second relay controlled by the normally open switch to reverse the reversible motor, the cam controlled switch also providing a latching circuit for the second relay.

7. In a traffic signal control system including at least one local controller for operating the signal lights at at least one intersection and a remote master for regulating the controllers, a mechanism for synchronizing the master and local controllers, comprising:

a rotating dial in the master driven at a uniform speed;

a rotating dial in the local controller;

a first motor driving the local rotating dial at a uniform rate of speed;

at least one additional motor means capable of overriding the first motor to drive the local dial at a different speed than the driven speed of the rotating dial in the master;

means for detecting an out-of-synchronization condition between the master and local dials; and

control means responsive to the detecting means for operating said additional motor means for a period of time determined by said control means to achieve synchronization.

8. The mechanism according to claim 7 wherein the local dial is provided with at least one reference point on its circumference, where said additional motor means including a second motor driving the local dial at a higher speed than the first dial, and the detecting means includes a normally closed switch which opens as the reference point rotates past a fixed point relative to the local dial.

9. The mechanism according to claim 8 further including means to transmit a signal of one polarity from the master to the local controllers during one portion of each cycle of the master dial and a signal of opposite polarity during the remainder of the cycle, said motor means including a third motor capable of overriding the first motor and driving the local dial at a slower speed, the control means energizing the second or third motor in accordance with whether the local dial is following or leading the master dial, as determined by the detecting means.

10. Apparatus according to claim 9 wherein the detector means includes first and second relays sensitive to opposite polarities, one or the other of the relays being energized depending on whether the reference point of the local dial leads or follows the synchronization pulse a predetermined amount.

11. Apparatus according to claim 9 wherein the control means includes a transfer cam, a reversible motor rotating the cam, the motor having a reverse speed faster than its forward speed, and a normally closed switch opening when the cam rotates from its at rest position, the cam being rotated in a first direction for the period of time required for the reference point of the local disc to rotate to its corresponding fixed point and in the reverse direction for the additional period of time required to achieve synchronization, the control means energizing the second or third motor during the period of time in which the cam is rotated from its at rest position.

12. Apparatus according to claim 8 wherein the local dial is provided with a plurality of reference points, a normally open switch being provided in connection with each of the reference points, the master including selector means for determining the one of the plurality of points to be used, and the local controller including relay means for selecting the corresponding switch in accordance with the selector means.

13. Apparatus according to claim 7 wherein the first motor drives the local disc through a chain and sprocket arrangement which includes a plurality of sprockets of different diameters each connected through an electromagnetic clutch to the disc driving gears, the master including means to select the one of the clutches to be energized and the local controller including relay means responsive to the selector to energize the one clutch, whereby the cycle of the local dial may be varied.

14. Apparatus according to claim 13 wherein the motor means drives the local disc through the chain and sprocket arrangement utilized by the first motor.

15. A mechanism according to claim 16 where said means to control actuation of said third motor comprises:

a transfer cam, motor means to rotatively drive said cam, said means to actuate said third motor simultaneously actuating said fourth motor means to drive said transfer cam in one direction, at a predetermined speed, means to determine an initial stopped reference position of said transfer cam, means to change the driving rotative speed of said fourth motor means upon said local dial passing its selected reference position, and means to simultaneously stop the transfer cam when it returns to its initial position and return the rotative drive of the local dial to the second motor under the conditions where X equals the change in rotative speed of the local dial by the third motor means and Y equals the change in rotative speed of the transfer cam upon change in driving rotation of the fourth motor means and the equation $Y = X(1 + Y)$ is satisfied.

16. A multi-speed dial control mechanism which comprises:

a master dial, first motor means to continuously rotate the master dial at a predetermined speed;

at least one local dial, second motor means to continuously rotate the local dial at substantially the same predetermined speed as said first motor means;

a third motor to selectively override said second motor and effect rotation of said local dial at a speed different from said predetermined speed;

means to determine when the master dial passes a predetermined fixed reference during each revolution;

means to determine when the local dial passes a selective fixed reference during each revolution;

means to actuate said third motor whenever said master dial passes at reference position and said local dial is at a different position than its reference position, and

control means to actuate the third motor for a period of time determined by said control means based upon the time differential between means to determine when the master dial passes a predetermined fixed reference and a means to determine when the local dial passes a selective fixed reference to achieve coincidence of said reference positions of both dials in time.

17. A multi-speed dial control mechanism which comprises:

a. at least one local rotatable object;

b. a master rotatable object;

c. separate drive motor means to effect rotative drive for each of said local object and said master object at substantially the same speed;

d. means to determine when each rotating object passes a predetermined initial reference point;

e. means to change the rotative speed of the local object when the times of reference point passings do not coincide between the local rotatable object and the master rotatable object, and

f. control means to compare the times of reference point passing of each rotating object and actuate last said means a time period determined by said control means by said time comparison, and to shift the rotative speed of the local object back to its original speed when said time period has passed.

* * * * *