Our good friend Russ Jensen was kind enough to not only write this Trouble-Shooting Guide was also kind enough to share it with the World in Coin Slot magazine!

One of the stories Russ liked to share was “his writing Bally and asking for a tour and some schematics of the pinballs” and how they

granted his wish and how it kicked off his whole interest in the games” _ Pretty Cool

~ Enjoy ~

PINBALL TROUBLE-SHOOTING

By Russ Jensen

Sometime ago one of your readers suggested that I devote an article or so to pinball repair and troubleshooting. Since troubleshooting of pingames is one of my favorite pastimes (next to pinball history research, of course) I have decided to do just that. This will be the first of several articles dealing with basic pinball circuitry and fundamental troubleshooting techniques.

In order to be able to track down and locate faults in a pingame's intricate wiring, an understanding of the following is required: 1) Basic electrical circuit theory, 2) The method of depicting pinball circuitry on a schematic diagram, 3) The basic circuit components employed in a pingame, 4) The types of circuit configurations used, and 5) A systematic method of fault localization using simple' test equipment. These articles will try to cover (at least in a superficial manner) these areas.

First, however, let me begin with a few introductory remarks regarding the scope of these articles. This discussion applies only to "electro-mechanical" games, and while I talk about "pinballs" much of the discussion could only apply equally well to other electro-mechanical coin machines such as "baseball machines," "shooting galleries" (and other arcade devices), and also to many "console slot machines" which use relay and stepping switch circuits. Secondly, this discussion applies in general to cases where one has available the manufacturers' schematic diagram for the particular machine. If you don't have one, your job is a lot harder but the basic principles discussed here should aid you greatly in trying to figure out "what is going on" in your machine.

Now to the basics! The fundamental electrical circuit consists of three parts; the 'power source,' the 'switch,' and the 'load,' each of which will be discussed in more detail. These items are connected in "series," that is, for an electrical current to pass through any one of them it must also pass through the other two. The circuit is said to have two conditions, or "states." The "open state" is when the "switch" is "open" and under this condition no current flows through the circuit and consequently nothing happens. The other condition is the "closed state" which occurs when the "switch" is "closed." In this state an electric current will flow from the power source, through the "switch," through the load causing something to happen, such as a light lighting, a relay energizing, a motor turning, etc. It should be noted that the term "switch" used above actually can be a simple switch or a combination of switches as will be discussed later. The important thing to remember is that the circuitry of an entire pinball machine can be considered as a group of many of the simple series circuits just described.

Schematic Diagrams

The fact that a game can be considered to be a group of individual series circuits is aptly demonstrated by the manufacturers' depiction of the circuitry on the schematic circuit diagram for the machine. First a word of caution; there is another form of diagram used with some machines (mostly older ones) called a "wiring diagram." This type of diagram bears little resemblance to the schematic diagrams being discussed here as it traces the physical wiring rather than the individual circuits. So if you have this type of diagram you may almost entirely disregard the following discussion of schematics.

The format of most schematics is similar and usually has the following characteristics: 1) The power source(s), usually transformer windings (more about that shortly), are shown on the left side with their outputs shown as horizontal lines extending the length of the diagram, 2) The "loads" are shown, usually in a row from left to right, with one side of each connected to one of the power source lines (power common line’) and, 3) The "switch" associated with each load is shown below that load with the "switches" other side connected to the other power source line (“return line”) Each load and the "switch" (which remember is generally a combination of switches) connected to it can be considered a separate series circuit as was stated earlier. Since pingames generally have lamps and coils operated from different voltages, these two types of loads will be shown separately, usually one above the other on the schematic, each with its own power source and power connection lines. The symbols generally used on most schematics are illustrated in Figure 1.

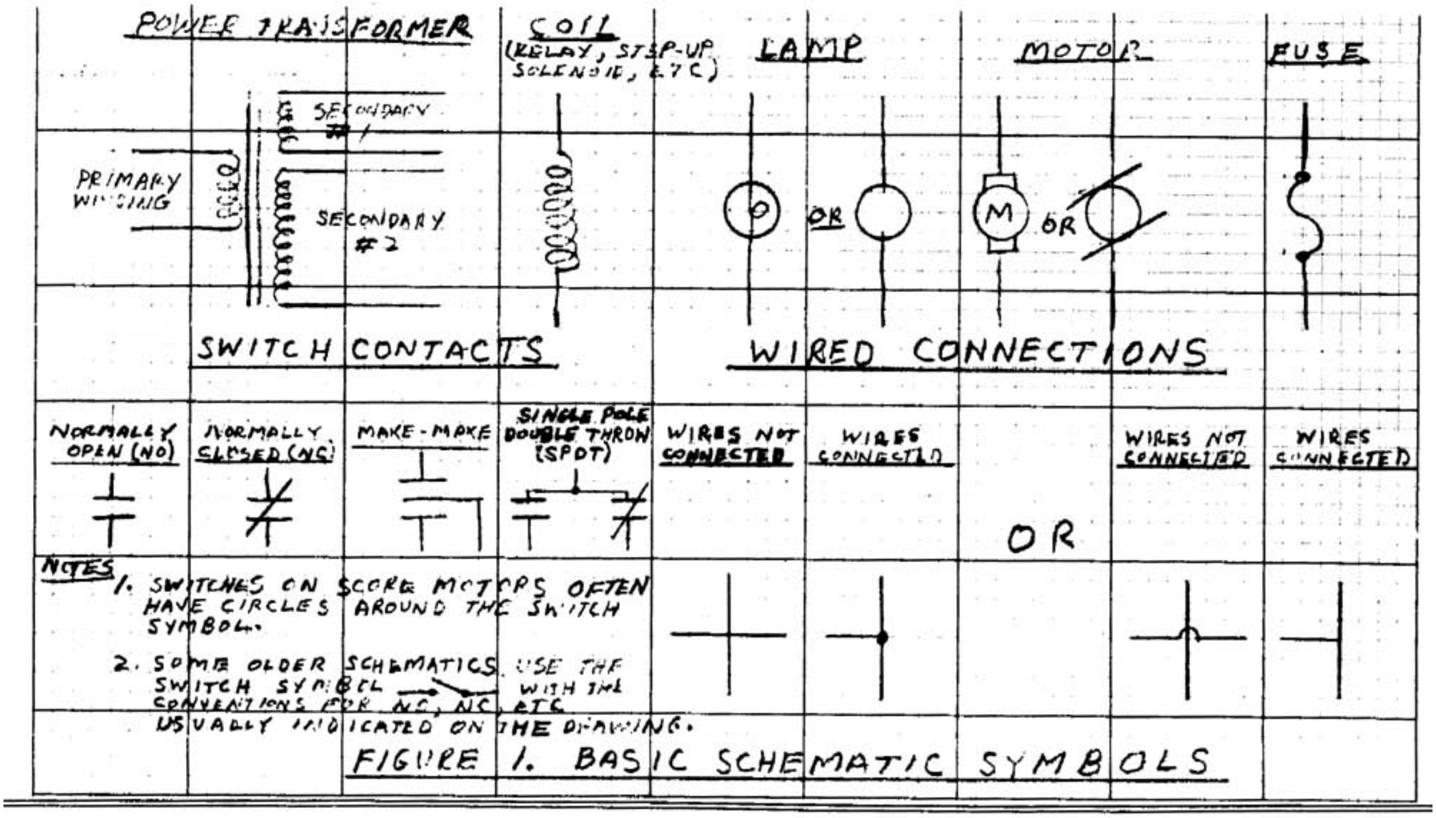


FIGURE 1. BASIC SCHEMATIC SYMBOLS

In order to better under understand schematics some additional points should be discussed. Each coil (relay, solenoid, stepping switch coil, etc.) will have a 'name' (or in some cases a 'code letter') associated with it. If a 'code letter* is used. the schematic will usually have a table giving the 'name' associated with each 'code letter.' This 'name' (or letter) will be shown next to the coil symbol on the schematic and also next to the depiction of any other items associated with that coil, such as relay contacts. It should be noted that the contacts for a given relay, even though physically located next to each other in the game, may be widely separated on the schematic because each contact will be shown near the load it controls, but more on relays later. This is a major difference between a schematic and a wiring diagram on which all contacts would be shown adjacent to the relay coil.

Another piece of information found on the schematic, which is of utmost importance during troubleshooting, is the wire "color code." Each wire in a game has one or two identifying colors associated with it. The wires insulation has a "base color" and in many cases a secondary or "tracer" color. In a few cases the wires two colors appear in a one-to-one ratio on the wire; these are known as "mottled" colors. The color (or colors) of each wire depicted on a schematic is indicated next to the line depicting the wire, either by words (ex: Yellow-Red), by abbreviations (ex: YL-RD) or by "code numbers" (ex: 76). When "code numbers" are used, reference must be made to a table somewhere on the drawing which cross-references each number to a color, a situation which is sometimes very frustrating and time consuming for the troubleshooter. When code numbers are used the first digit indicates the "base color" and the second digit the "tracer" color(a0 indicates no tracer). The color code for "mottled" wires uses an ampersand (&) rather than a dash between colors (ex: YL & RD). It should be noted here that the same wire color(s) is used for any wires which are electrically tied together with no intervening "switch" or load, even though many branches may occur. As soon as a circuit encounters a switch contact or load (lamp, coil, etc.) the wire color changes on the opposite side of that circuit element. Circuits which pass through connectors (such as those used for electrically connecting the playfield to the backbox), however, retain the same color on both sides of that connection. These connectors, by the way, will very seldom even be indicated on schematics but will on wiring diagrams.

We have now covered the first two items on our list of areas which must be understood to enable one to troubleshoot a pinball machine. Additional information in these areas, however, will be found in the discussions to follow. Next month we shall begin with a description of the basic circuit elements in a pingame and continue from there.

THE POWER SOURCE

The earliest electrically operated pingames used dry cell' batteries to operate their simple mechanisms such as electric'kickers' and 'guns.' The normal operating voltage for these games was usually 4V2 to 6 volts D.C. (direct current). The circuits in these games were very simple, consisting only of ball actuated switches and solenoid coils making troubleshooting quite simple. The next step in pinball power evolution was to replace these batteries with a 'power pack' which could transform the 110 volt A.C. (alternating current) 'house current' into a D.C. voltage equivalent to the batteries. These 'power packs' consisted of a transformer, to reduce the voltage, and a rectifier which changed the alternating current (A.C.) to direct current (D.C.). The output of this device was connected to the pingame's simple circuits in place of the batteries which had to be replaced frequently.

Electric pingames became increasingly more complex in the mid 1930's. Lights were added and the games contained more and more solenoids to provide action and later to operate score registering devices. The many coin payout pingames utilized motor operated payout devices which also required electric current. For this reason batteries and' power packs' soon gave way to multiple winding transformers. Games for the most part utilized AC. operated components, a practice which continued (on electromechanical games) until the mid 1970's when D.C. began to be used again to power some action components such as 'pop bumpers.' One exception to this was Genco which utilized A.C. for lamps and D.C. (using a rectifier mounted on the transformer) to operate solenoids and relays on 12 to 15 volts D.C. (NOTE: Some, (mostly payout), pingames in the mid thirties utilized 'power packs' putting out from 12 to 24 volts D.C. to operate the entire game including motor, relays, solenoids, and lights. Some of these games used higher voltage lamps (such as 18 volt) but many used 6 volt lamps and 'dropping resistors' to lower the voltage.)

The transformer, common to most games from the mid thirties until the 'solid state era', usually consisted of three 'windings'; a 'primary" and two (or sometimes more) 'secondaries'. The primary was supplied power from 110 volt A.C. power (house current). The primary produced a magnetic field in the transformer's iron 'core,' which in turn causes currents to flow in the secondaries, which were wound to produce lower voltages than that applied to the primary. One secondary produced the voltage for all the lights in the game (almost always 6 volts) while the other one produced a higher voltage (usually either 25, 30 or 50 volts) to operate all coils and most motors. The voltage produced by each secondary winding was almost always indicated next to the symbol for that winding on the schematic. Bally (and Williams, until the early 1960s) were about the only companies to use 50 volts for coils. Most of the others (except for Genco's D.C. power) used 25 or 30 volts. Most 1-ball 'horse race games' and 'bingos' however, usually used a third secondary on their transformers which provided 18 volts used to power some lamps and coils from the same power source where doing so greatly simplified the circuitry. A word of WA R N I N G! These types of games contain both 6 and 18 volt lamps, interchanging of which will result in either lamp burnouts or dimly glowing lamps.

As was mentioned last month in the discussion of schematics,the outputs of the transformer's secondaries 'feed' the 'power lines' to the other game components. One side of the secondary suppling the coil voltage feeds the 'coil common' line in the game which is connected directly,or occasionally indirectly (through a switch contact) to every coil in the game.

The other side of this coil voltage secondary is connected to the 'return line' to which is connected one side of the switch circuits controlling each coil. Actually this 'return line' consists of two sections, one of which is connected at all times when the game is 'on' and the other section which supplies power to certain coils only when the game is being played (i.e. not at 'game over" or 'tilted'). Contacts on the 'game over" relay (if there is one) and/or the 'tilt' relay(or some type of lock hold or anti cheat relay) are used to break the connection to this section of the 'return line' at the proper time. It should be noted that malfunctions in these contacts are a major cause of a game not working as will be discussed in a subsequent article.

Similar connections are made to the tranformer's other secondary (which supplies low voltage to light the lamps throughout the game) which feeds a 'lamp common' and a lamp return line. In some older games the two 'return' lines (coil and lamp) were connected together at the transformer thus creating one 'return' line common to both coil and lamp circuits. In these games a malfunction could occur which could result in burn out of a large number of the lamps in the game. When the game was tilted (or at 'game over' in some machines) two relay switch contacts would open the power circuits; one in the common 'return' line and the other in the 'lamp common' line. If due to contact wear or misadjustment, only the switch in the 'return' line opened (the one in the 'lamp common' line remaining closed) circuit paths would be created allowing a high voltage to be applied across some lamps, if the game were being played, causing these lamps to burn out. For this reason adjustment of all contacts which open transformer circuits to common power lines should be checked carefully.

The 'common' and 'return' lines are wired to many components in the machine. This is accomplished by wiring to a solder terminal of a component and then connecting another wire to the same terminal to go to the next component, etc. If any of these 'double connections' are ever broken (one wire disconnected) the power to one (or in most cases many) other components will be lost resulting in major malfunctions of the game. This situation frequently occurs when someone has removed a component which for some reason they don’t want to operate and did not reconnect the 'double circuit' which fed power to it. For this reason when such major malfunctions occur (i.e. several of the game's components not working at all) this power wiring should be checked carefully.

It should also be pointed out that each power circuit (coil power, lamp power and 110 volt power) will be separately protected by fuses placed in the circuit close to the transformer windings. These fuses are usually mounted on a fuse block' inside the front of the machine. The 110 volt line fuse is sometimes mounted separately near the transformer itself inside the game. On many later model machines, large current coils (such as relay bank reset coils) will be separately fused, the fuse mounted near the component it protects, The fuse sockets are usually labeled as to the size of the fuse (in amps) and the circuit it protects (6 volt, coil power, 110 volt line, etc). If one of these types of circuit is completely inoperative (i.e. no lamps light, no coils operate, or the game is completely 'dead) the fuses should be checked first. A burned out fuse can usually be spotted by eye looking to see if the small piece of' wire inside is broken. In some cases however a fuse may look O.K. but still be burned out. These fuses must be checked using an ohmeter or by trial replacement with a new fuse. When replacing or checking fuses, two cautions are strongly advised: 1) unplug the game when working near the 110 volt line fuse, and 2) always replace a fuse with the exact value indicated.

In addition to the components which operate from power supplied by the transformers' secondaries, a few components in many games operate directly from the 110 volt house current. These include some relays (generally in the game's 'start up' circuits), large solenoids, such as relay bank reset coils (more about those next month), and some motors (especially in 'bingos' and 'one-balls'). These circuits are usually shown on the schematic adjacent to the transformer primary winding. The wiring for these circuits in the machine can usually be spotted because a different type or size of wire is normally used than is used for the lower voltage circuits. Sometimes rubber or plastic insulated wire is used as opposed to cloth insulation used for the other wiring. In other games a much heavier cloth insulated wire is employed. In many cases the solder terminals where these 110 volt wires are connected to other components are covered by short 'slip-on' insulating sleeves to protect mechanics from inadvertently touching the wiring and getting an electric shock. These insulating sleeves are not always an indication of 110 volt circuits as some manufacturers occasionally use these on lower voltage circuits as well. In this respect a couple of words of warning are in order. These 110 volt circuits are generally the only ones in a game of which one should beware of touching, although 50 volt circuits can sometimes provide an annoying shock When working on these circuits, the machine should either be unplugged or extreme caution should be taken not to touch uninsulated connections. Most people do not realize that even if a game's 'on-off switch (if it has one) is off a shock is possible if 110 volt circuits are touched. So be careful!

This concludes the discussion of 'pinball power.' Next time we will start to discuss the other electrical components which make up an electromechanical game, such as relays, stepping switches, solenoids, and the like.

In the first article in this series on pinball troubleshooting we listed five areas of under- standing which were considered 'basic' to tracking down malfunctions in electro- mechanical games. The first two areas (the basic electrical circuit and schematic diagrams) were covered in that first article. In last month's article we began the discussion of the third area (pinball components) by discussing power sources and their associated wiring in the machine. This month we will continue the discussion of components by covering some of those which are the 'loads' in the basic circuit previously mentioned.

The 'loads' in pinball circuits are the components which utilize the electric current to provide some sort of' action;' not only action on the playfield, but also the operating of devices inside the machine that perform functions necessary to the game's operation. There are three basic types of loads in a game: lamps, coils, and motors.

I am sure that lamps are familiar to everyone so a detailed discussion of these is unnecessary. Lamps used in games are merely miniature incandescent light bulbs similar to the ones used in everyone's home except much smaller in size. When an electric current is applied to them they 'glow.' Lamps are used in games for illumination, score indication (in older games) and indication of certain conditions affecting the play of the game in the form of lighted panels on the back-glass, lighted bumpers or 'playfield inserts.

The load which does most of the 'work' in a game is the ‘coil’ or more properly 'electromagnet coil.' An electromagnet consists of many turns of thin wire wound around a hollow core ('bobbin'). When an electric current is pass- ed through this coil, a magnetic field is produced in the center of the core. There are three basic types of coils used in games. If the core is filled with iron, producing a solid core, the coil becomes a 'magnet coil' used in relays. If a small iron slug (commonly called a 'coil stop') is inserted in one end of the hollow core a 'solenoid' is produced. Solenoids are used in many pinball components such as flippers and stepping switches, as will be discussed shortly Finally, if nothing is inserted in the hollow core (other than a movable plunger) a 'bell coil' is produced.

In the case of the bell, when a current is applied to the bell coil, the movable iron plunger is repelled by the magnetic field produced by the coil and tries to 'shoot out of the coil.' The plunger strikes the bell's gong (which stops its movements) and falls back to its rest position when the current (and thus the magnetic field) is removed. The same principle applies to 'knockers' which are noise makers found in many games to signal the player that a free game has been won. In this case the gong is replaced by a wood block or metal 'stop' to produce the desired sound. The components which provide 'physical action' to the ball in play in most cases employ solenoids (with a 'coil stop') with a movable iron plunger placed partially inside the hollow core. When current is applied to the coil, the magnetic field produced causes the coil stop to become magnetized thus attracting the plunger toward it, stopping, of course, when they come in contact. The other end of the plunger is mechanically linked to the mechanism to which the motion of the plunger is transmitted. This can be the 'ball kicker* in a 'kickout hole,' a flipper, the 'kicker ring' on a 'pop bumper,' or the lever which strikes the stretched rubber ring in a 'rebound.' When the current is removed, the coil stop looses its magnetic attraction and the plunger returns to its original position, usually with the aid of some sort of ' return spring.'

The coil used for most flippers is somewhat different from other coils in that its winding is in two parts; a short winding which produces a large attractive force,, and a longer winding which produces a weaker field. When the flipper is' at rest' this latter winding is shorted out by a pair of electrical contacts which are part of the flipper assembly under the playfield. When the player pushes the flipper button all the current is applied to the other winding and the large magnetic force produced imparts a strong 'kick' to the ball. If this winding alone stayed energized for more than a second or two, it would get quite hot and eventually burn out. For this reason, as soon as the flipper has completed its forward action, the contacts in the flipper mechanism open (un-shorting the other part of the winding) allowing the current to pass through both parts of the winding 'in series.' This produces a weaker magnetic field, but sufficient enough to hold the flipper mechanism in its energized position. The cleaning and adjusting of these contact points are very critical and a frequent cause of flipper malfunctions^ If these contacts never open the 'strong' winding will soon burn out; if they never close extremely weak flipper action will result. Contact points (switches) will be discussed in greater detail in a subsequent article. The most common component in a game, other than the lamp, is the 'relay.' In its simplest form it consists of a 'magnet coil' (with a solid iron core), a hinged metal plate called an 'armature,' and sets of electrical switch contacts^ When current is applied to the coil, its core becomes magnetized, attracting the movable armature toward it. Attached to the armature is an 'actuator' made of an insulating material (usually containing horizontal slots) into which one blade of each set of contact switches is inserted. The movement of this actuator causes the contact points to either open or close depending on their configuration. Each relay can operate from one to several sets of switch contacts.

The purpose of relays is to allow the action of one electrical circuit to control one or more other circuits without an electrical connection between them. This even allows a circuit operating from one voltage to control another circuit which utilizes an entirely different voltage. Relays have a wide variety of uses in games and some specific applications will be discussed in subsequent articles.

The 'simple' relay just described will revert to its original state (due to spring tension on the armature) whenever the current to the coil is removed. There is however, another form of relay occasionally used in pingames which retains its state, due to mechanical latching of its armature, until a second coil (referred to as a ‘latch coil’) is energized. The first coil, incidentally, is called the 'trip coil.' These 'latch-trip' relays can easily be spotted by their two coil configuration and are primarily used as 'tilt’ or 'game over* relays in some later model machines.

Another relay configuration quite common in pingames is the 'relay bank,' sometimes called a 'trip bank' It consists of a number of relays (usually from 4 to 15 or 20) mounted on a common frame. Each relay has its own 'trip' coil, which acts in much the same manner as the 'trip coil' on the 'latch-trip' relay just described. When one of these coils is energized, its armature mechanically releases a metal plate connected to the actuator (which operates the relay contacts) which moves downward, thus opening and/or closing the switch contacts associated with that relay. When current is subsequently removed from the coil, the switch contacts will remain in their new position until the entire bank is later 'reset'

In the case of these relay banks, a method must be provided to later return all relays which have been ‘tripped' to their original condition. This is usually accomplished by a movable bar, running the entire length of the bank of relays, which can lift all of the contact actuator plates to their original position where they are again mechanically latched by the armatures returning (via spring tension) to their original positions. In older machines (generally before 1950) the resetting bar is moved (and thus the bank ‘reset’) mechanically as a result of the game being started when the coin chute is pushed in by the player. In most later machines, this resetting is accomplished by a large solenoid coil (commonly referred to as the 'bank reset coil and often operated by 110 volt power) the plunger of which is mechanically linked to the resetting bar. One exception to this is most later model Bally pingames which use a small electric motor to provide power to reset large banks of relays.

Relay banks are used where the conditions of several relays must be maintained until a specific event occurs such as the end of the game, the end of the ball in play, or the completion of a certain 'playfield objective' (i.e. the completion of a series of numbered bumpers). Some games have more than one relay bank, each being reset by a separate function. Relay banks are easily spotted by their common resetting bar and common mounting frame.

Next to the relay, probably the most common pinball component is the 'stepping switch.' It is in most cases the physically largest device in the game. It consists of a frame on which is mounted one or two (and in rare cases three) solenoid coils, a 'disc' made of insulating material and containing many metal 'contacts' (ar- ranged in a circular pattern), a rotatory contacting device, capable of completing electrical circuits with the contacts on the disc, and a ratchet mechanism to rotate the contacting device so it may make contact with successive disc contacts. The unit also has a number of solder terminals to provide connections for the many circuits it controls. Sometimes as many as 50 or more wires are connected to one stepping switch.

A common type of stepping switch found in games is the 'reset type.' It employs two solenoids normally referred to as the 'step-up coil' and the 'reset coil.' When current is applied to the step-up coil, its plunger

There are three basic types of loads in a game: lamps, coils, and motors. The load which does most of the 'work' in a game is the 'coil,' or more properly ‘electromagnet coil.' is pulled inward and causes the ratchet mechanism to rotate (advance) the contacting device to make contact with the next contact point(s) on the disc. Each sub- sequent 'impulse' applied to this coil advances the contactor to succeeding contacts on the disc until it finally reaches a mechanical 'stop' and can advance no further. When current is applied to the 'reset coil its plunger action causes the ratchet mechanism to be released The contacting device then quickly returns to its intial position ('zero position') due to a spring wound around its shaft which was 'wound up' with each upward 'step' of the unit.

These units have been widely used in games since the late thirties to advance score indicating lights. Each time the unit is stepped up, a circuit is completed (through the contacting device and the disc contacts) to light a different light indicating increasing score values on the backglass. In this manner the stepping switch 'counts' the number of score producing actions made by the ball in play. These units have also been used in later model games for a multitude of purposes such as 'ball counters,' 'advance units,' etc.

Another form of stepping switch is the 'continuous type.' It has only one coil, a 'step-up' coil. Its action is the same as just described for the 'reset type' with the following exceptions: 1) there is no 'stop' so the unit can be stepped completely around over and over again, and 2) since no 'reset is employed, there is no spring around the main shaft These units can easily be spotted because they have only one coil. (NOTE: A few pre-war machines employed 'reset type' stepping switches which had only one coil. They were mounted on the underside of the playfield and used the mechanical motion of the player pushing in the coin chute at the beginning of a game to actuate the resetting mechanism rather than using a 'reset coil.')

Continuous type stepping switches were used in applications where resetting was not necessary (i.e. 'match number1 units in games which included that feature). They were also widely used for the lowest value (i.e. 1000 or 10,000) score indicator light control in many games made between the end of World War II and the early sixties. In these applications, the game's circuitry provided a method of 'stepping' the switch around to 'zero' score when a new game was started.

A close cousin to the continuous stepping switch is the 'score reel' used to indicate the players' score on most later model (post 1960) games. These units can be considered as continuous stepping switches (in some cases without contact discs) which have 10 steps per revolution and with a rotatory disc attached displaying the numbers '0' through '9' through 'windows' on the backglass. Contact discs are employed on many of these units for 'number match' determination (on the lowest order digit) and for replay award determination (on higher order digits).

Most of these units employ three pairs of electrical contacts actuated by cams on the units main shaft One pair closes when '9' is indicated and is used to indicate a 'carry' so that the next higher digit can be incremented for proper counting. The second pair is closed at all times, except when '0' is indicated and is used to allow for resetting of that digit to '0' when the game is being 'reset to start a new game. The other contact pair either opens or closes at '0' (depending on the design of the game's resetting circuitry) and is used as part of the circuitry which determines when 'complete reset of all score reels has been accomplished. Malfunctions of these three contact sets are a major cause of malfunctions in games employing score reels, especially when a resetting problem appears.

Another type of stepping switch is the 'decrement’ unit. It is similar in appearance and operation to the 'reset type' with one exception. When the reset coil' is energized, the ratchet is released only momentarily allowing the unit to step backward one step (instead of going all the way to 'zero' as in the 'reset type' unit). These units are used in many games as 'bonus units’ which 'step up' when 'advance bonus' scoring devices are hit and 'step down' as the bonus score is being collected (added to the player's score).

A variation of the 'decrement' unit is the replay unit used to indicate 'free games’ on most machines made since the late forties. This unit has an 'indicator disc' (similar lot to those used on score reels) which displays the number for free game 'credits' through a window in the backglass. Each time a replay is awarded, the unit 'steps up' and each time a free game is 'played off the unit 'steps down' one step.

Another variation of the 'decrement type' stepping switch, found on a few machines, is a 'decrement type’ with a 'total reset.' These units have three coils, a ‘step up’ coil, a 'decremenf coil, and a 'reset coil. When the 'reset coil is energized, the unit resets to 'zero' in the same manner as the 'reset type' unit These units were mostly used as 'bonus units' with the 'total reset used at the start of a game. In some of these units to achieve a total reset both the 'decrement and the 'reset coils had to be energized simultaneously.

The ‘heart of any stepping switch is the contact disc and its associated contactor arrangement The disc is made of an electrical insulating material (usually bakelite) with metal 'contacts' embedded in it in a circular pattern. In most cases, there are two or more concentric circles of contacts on the disc. These contacts are usually in the form of brass rivets although some later model machines use copper 'printed circuit type contacts. Where rivets are employed, they are wired to the external solder lugs by small wires on the back of the disc. In many cases, several contacts are also wired together when the same circuit is to be energized at more than one 'step position' of the stepping switch.

The 'contactor' is generally in one of two forms. The most common type consists of one or more brass 'fingers' with a contact point at the end of each one. As the main shaft of the stepping switch is rotated (one 'step' at a time) these contact points make contact with the disc contacts in succession around the circle. The other form of contactor is a circular disc of insulating material with several 'spring loaded' contacts attached to it The rotation of the main shaft causes this disc to rotate, its contacts completing circuits in turn with the contact points on the stationary contact disc.

These stepping switch contact circuits are generally depicted on the schematic diagram as a rectangle containing a series of dots (representing the contacts on the stationary disc) and arrowheads (representing the movable contacts on the contactor).

In addition to the disc contacts, most stepping switches operate one or more sets of switch contacts of the type used on relays. Some of these switches may be operated by ‘pins' protruding from the ratchet wheel attached to the main shaft. These switches will normally be opened and/or closed by the stepping switch being reset' to its 'zero' position. In other cases, switches may be operated when the stepping unit reaches its 'top step' (in many cases these switches are used to open the circuit to the 'step up' coil when the stepping switch reaches its limit).

Many stepping switches (and score reels) also employ what are known as 'end of stroke' (abbreviated as E.O.S. on most schematics) switches. These switches are associated with one or both of the solenoids which operate the stepping unit when the solenoid's plunger is 'pulled in' (by current being applied to) these switches will be either opened or closed. They will then revert to their original condition when the current is removed from the coil. These end of stroke switches are often employed in circuits to assure that the solenoid has operated properly. An example of this type of circuit will be described in a subsequent article.

The final type of pinball 'load' to be discussed is the motor. Motors have been used in pin-games over the years for a variety of purposes but the most common use was the so called 'score motor' used in most post-war electro-mechanical machines Before we discuss these however, the other less frequent uses of motors will be described.

Late in 1933 Bally came out with a game called ROCKET which was the first game to have an electrically operated coin payout mechanism. This began a boom of payout pingames, which peaked in the mid thirties. Most of these payouts used an electric motor to power the payout device. Many of these devices had a rotating drum that had brass contact strips of various lengths around its periphery that completed circuits with contact 'wipers.' These contacts were part of the circuitry that controlled how many coins would be paid out for a particular 'win.' Most of the earlier payout machines were battery operated and therefore used DC motors, but later games used AC motors.

Another use of motors in pin- games was for 'animation.' An early example of this was Chicago Coin's DUX (in 1937) which had a small motor in its backbox which, through gearing, slowly rotated a disk with pictures of ducks painted on it. These pictures were alternately visible to the player through a window in the backglass painting. Other uses of motors to provide movement of objects on the playfield or behind the backglass can be found in later machines.

Another type of 'animation' using motors, found primarily on machines made in the sixties and early seventies, is the ‘moving target.' In this case a small electric motor beneath the playfield, by the use of a gear/cam arrangement, caused a playfield target to move back and forth across a small playfield area The motors used in these animations were generally small 'synchronous AC motors' of a type somewhat similar to those used in home phonographs.

The so called 'score motor' was first used in a few machines (primarily by Exhibit) around 1940/41, although a few earlier machines, such as the DUX game just described, used variations of the same idea. In the Exhibit machines, the earliest units consisted of a small AC motor, with a speed reduction gear train, which turned a shaft. Connected to this shaft were two metal disks (called 'cams') with indentations around their outside edges. These disks were mounted one above the other on the shaft and rotated with it when the motor was running. The lower disk had a series of 20 'hills' and 'valleys' around its outside edge. A 'cam follower' lever rode on this edge and therefore rose and fell 20 times for each complete revolution of the disk The follower on the 'impulse cam' operated an electrical contact set ('switch') which thus 'closed' and 'opened' 20 times per revolution. The other cam had 4 notches in its edge 90° apart. It also had a follower and a set of switch contacts, which were normally closed, but which opened whenever the follower fell into a notch (4 times per revolution of the disk).

The lower disk also had four 'slots' through it about halfway in from the outside edge and 90° apart in the disk's rotation. A solenoid coil was mounted on the unit in such a way that its plunger (with a rounded tip) protruded through one of these slots when the motor and the solenoid were both un-energized. When current was applied to the solenoid, the plunger was retracted and disengaged from the slot in the disk The movement of the plunger also operated a pair of switch contacts which applied power to the motor as long as the plunger was 'in.' This operation caused the disks to rotate and the end of the plunger 'rode' along the face of the disk (even though current was subsequently removed from the solenoid) until it encountered the next slot. At that point it dropped into that slot, opening its switch contact, and thus stopping the movement of the disk and the motor.

Each time the solenoid was energized the disks made a 1/4 revolution and stopped. During each of these 'cycles' the set of contacts operated by the cam follower on the lower disk closed ('impulsed') 5 times and the contacts associated with the upper disk 'opened' one time for a brief period. The notches on this disk were arranged in such a way that this latter action occurred just prior to the end of each 'cycle.'

The 'score motors' common to most pingames since World War II were somewhat similar to the early model just described. The motors, gear trains, and cam disks were essentially the same although some score motors had three or more cams instead of two. The use of cam followers to operate switches was also similar except that several groups of switches (mounted on brackets around the cams) were sometimes operated by the same cam. The switches were in 'stacks' similar to those used on relays. A detailed discussion of switches will appear in next month's article. Many times one or more of the cams also had 'studs' mounted at various locations projecting from the top and/or bottom surface of a cam disk. These studs also operated sets of switches that came into contact with them during the cam's rotation.

These later units did not employ the solenoid to start and stop the unit. One of the cam operated switches was used to keep power to the motor (once started by an external circuit) until the motor completed its 'cycle.' Some units were designed such that each 'cycle' was 1/4 revolution (as in the early unit previously described) and others made 1/3 revolution. In the latter case the lower cam had 15 'lobes' and the other cam(s) had only 3 notches. Still others made ^2 revolution per operating 'cycle.' The motors on these units were normally operated by the game's AC 'coil voltage' (usually 25 to 50 volts). Some units (primarily in 'one balls' and 'bingos') used 110-volt AC motors.

Some method was generally employed to identify the various cams and switch positions on schematic diagrams. Somewhere on the diagram, pictorial information was generally provided indicating the configuration of the score motor and the function of its various cams and switches, also providing a method of cross-referencing the switch symbols in the circuitry to actual score motor switches. In many cases pictorial views of each 'switch stack' and the functions of each of its switches were also indicated. Often pictorial drawings of each cam were also provided.

The switch 'numbering systems' generally employed used either a number or a letter to identify each cam. Letters were used in most cases where the cams were stacked vertically (as in Gottlieb machines) and this configuration usually also used ‛studs' mounted on the cams. The lower cam (which was the 'impulse' cam) was labeled ‛A,' the studs on its upper side 'B,' the next cam 'C,' and its studs 'D.' Some units employed a second set of studs on the top face of the top disc which were longer than the other studs and this level was labeled 'E.'

On this type of score motor the stacks of switches operated by the cams and studs were mounted on brackets at four or five locations around the cams. These locations were generally numbered '1,' '2,' ‛3,’ etc. and their actual position on the unit was depicted on a pictorial drawing on the schematic as were the 'levels' 'A,' 'B,' etc. It should be noted that these 'position numbers' normally had no particular significance as far as the order in which the associated switches operated in time during a motor ‛cycle.' Each bracket (at a particular position) could have mounted on it switch stacks which were operated by cams and/or studs at one or more levels. Any cam or stud could therefore operate switches at one to all of the positions ('1,' '2,' etc.); the 'cam notch' or stud thus operated switches at each position at a different time within the unit's 'cycle.'

Each individual switch 'stack' could be called out on the schematic by a reference such as '1A' (switch at 'position 1'operated by the ‛impulse Cam’ at ‛level A') or '3D' (switch at 'position 3' operated by the studs at 'level D'). It should be noted that this numbering system made no distinction between multiple sets switches in the same switch 'stack.' This could only I done by noting the wire colors associated with each set of switch contacts.

Another common score motor configuration employed cams (usually 6 or more) mounted on a horizontal shaft turned by the motor and gear train. One cam ('impulse' or 'IMP') generally had ten lobes in ten groups of five. The other cams normally had ten notches, each on opposite sides of the cam. One these cams was referred to as the 'Index' cam (often abbreviated 'IND'). This cam was mounted on the shaft such that its notches lined up with the gaps between the groups of 5 lobes on the 'Impulse Cam.' The other cams, which were generally numbered '1,' '2,' '3,' etc., were each positioned on the shaft so that their notches occurred at various intervals after those on the 'Index Cam' ('1' occurring first, '2' next, etc.). Therefore when the motor was running the switches operated by these cams operated in sequence following each other in time according to their number. The 'cycle' for these units was 1/2 revolution of the shaft. (NOTE: This relationship between 'cam number" and timing does not apply to 'control units' on 'one-bell' and ‛bingo machines.)

In addition to the cam position notation (IMP, IND, 1, 2, etc.) the individual switch sets within the ‛switch stack’ operated by each cam were designated by letters with 'A' generally being the switch in the stack physically closest to the cam itself, 'B' next, etc. The notation to identify a particular switch on the schematic circuit for example might be' I ND A' (the switch operated by the 'Index Cam' and closest to that cam in the stack or '3B' (a switch operated by 'Cam 3' which is the second switch in that cam's stack). Cam '3' would be the third cam to reach its notch after the 'cycle' is started (the 'IND' cam being at its notch when the motor was stopped between cycles of the unit).

"The basic ideas presented here should enable a person to understand the operation of any such unit after carefully examining its operation and construction."

The purpose for score motor units in games was to provide 'timing' for operations which had to occur in a certain sequence with respect to one another. The switch contacts on the score motor unit were ‛opened’ or 'closed' at various times within the motor's operating 'cycle' as previously described.

Several types of timing functions were provided by these switches.

One function common to almost all score motor units (except some very early units as were previously described) was that of the 'motor run switch.' One of the switches was connected to provide electric power to the motor itself as long as it remained closed. This switch was 'open' when the unit was 'at rest' (the cam follower operating it being in a notch on one of the cams, often the' Index Cam'). When power was applied to the motor from any external source the motor operated and the cams began to rotate. As soon as the cam follower operating the 'run switch' left its notch the switch closed also applying power to the motor such that when the external source of power was removed the motor continued to operate until the 'run switch' was again opened by the next notch on the cam. This action thus established the operating ‘cycle’ of the unit.

Another switch function common to all score motors was the 'Impulse Switch (es)' which 'closed' and 'open- ed’ 5 times during each motor ‘cycle' thus providing 5 impulses to the game's circuitry. These were used to provide multiple scoring (ie 5,000 or 50,000) when certain playfield 'targets' or other objectives were achieved. If a score multiple other than five was desired then 'impulses' could be fed through contacts on one of the game's relays which would only be closed during the period of time in which 3 (for example) ‘impulses’ from the score motor occurred. Other motor contacts were used to accomplish this as described below.

Many switches on score motors were normally closed and opened only for one short period during a motor ‘cycle' (when their cam follower dropped into a notch on the cam). These could open at various times during a 'cycle' usually at the same time as the 'impulse' switches were going through one of their 5 impulses. One could call these five possible times during a cycle TIME 1,"TIME 2,"TIME3,"TIME4,'and 'TIME 5' (each corresponding to one of the five impulses from the impulse switches).

The purpose of these switches was to turn some device 'off at one of these particular times during a motor 'cycle.' If, for example, only 3 impulses were desired (to score 3.000) a normally closed switch which opened at 'Time 3' could be used to turn off a relay (as previously mentioned) after the 3rd impulse had occurred An example of this type of ‘relay hold on circuitry will be described in a subsequent article. These normally closed switches were sometimes used to 'eliminate' one of the 5 impulses. This was accomplished by wiring one of these switches 'in series' (more about that next month!) with the impulse switch such that the impulse occurring at the time this normally closed switch was open could not pass through, but passing the other four impulses.

The other common switch function on these motor units was a normally open switch, which would close one time during a motor cycle (when a cam follower was in a notch on a cam). These switches would usually close at the same time as one of the five 'impulses' from the 'impulse switch' as in the case of the normally closed switches just described except that the normally open switches would close at the same time, as a normally closed switch would open.

These switches were used to provide single impulses at specific times during a motor cycle and were often used to provide an electrical impulse to reset coils on a relay bank, stepping switch coils, etc. It should be noted that in some cases both these normally open and the normally closed switches were configured to operate slightly before or after one of the impulse switch closures by the 'impulse cam’ instead of exactly 'in time' with it.

The foregoing discussion of score motors attempted to describe the most common configurations of these units. Many variations however were used by various manufacturers over the past 40 or so years. The basic ideas presented here should enable a person to understand the operation of any such unit after carefully examining its operation and construction.

This concludes the discussion of the pinball components that act as 'loads' in the basic electrical circuit The third and final part of this basic circuit, the ‵switch,’ which has already been alluded to frequently in these articles, will be described in detail next month.

Russ Jensen discusses pinball components and their method of operation. Read his informative article on switches in the May issue of "The Coin Slot."

This month we will discuss the third and final type of component which makes up the basic electrical circuit, the 'switch' (often referred to as 'contacts' or 'points'). The switch provides the control of the operation of the circuit by turning on and off the flow of electric current from the 'power source' to the 'load.' Switch malfunctions probably account for 80 to 90 percent of the electrical problems occurring in games. Most of these troubles are caused by dirty or misadjusted switch contacts. Correction of these types of problems will be discussed on next month's issue.

Early electric games contained a small number of switches (some had only one) but as the complexity of electrical circuits in games increased the number of switches began to increase rapidly. Games of the sixties and seventies contained well over 100 sets of switch contacts each of which was capable of causing a problem

Basically a switch consists of two pieces of metal, each with an electric wire attached to it When these two pieces are touched together an electric current can flow between them, completing the electrical circuit to which the two wires are attached. The switches used in games generally consist of metal strips (called 'blades') with a solder terminal at one end (for connection of external circuit wiring) and small metal 'contacts' (often refered to as ‵points') embedded in the blade near the other end. Two of these blades generally make up a 'switch' although there are some exceptions which will be discussed shortly. The blades are separated from each other, at the terminal end by insulating 'spacers' (usually made of bakelite). Two or more of these switches may be mounted together, using additional spacers between them, to form a 'switch stack' An example of such a 'stack' (as used on a relay) is shown in Figure 2 A.

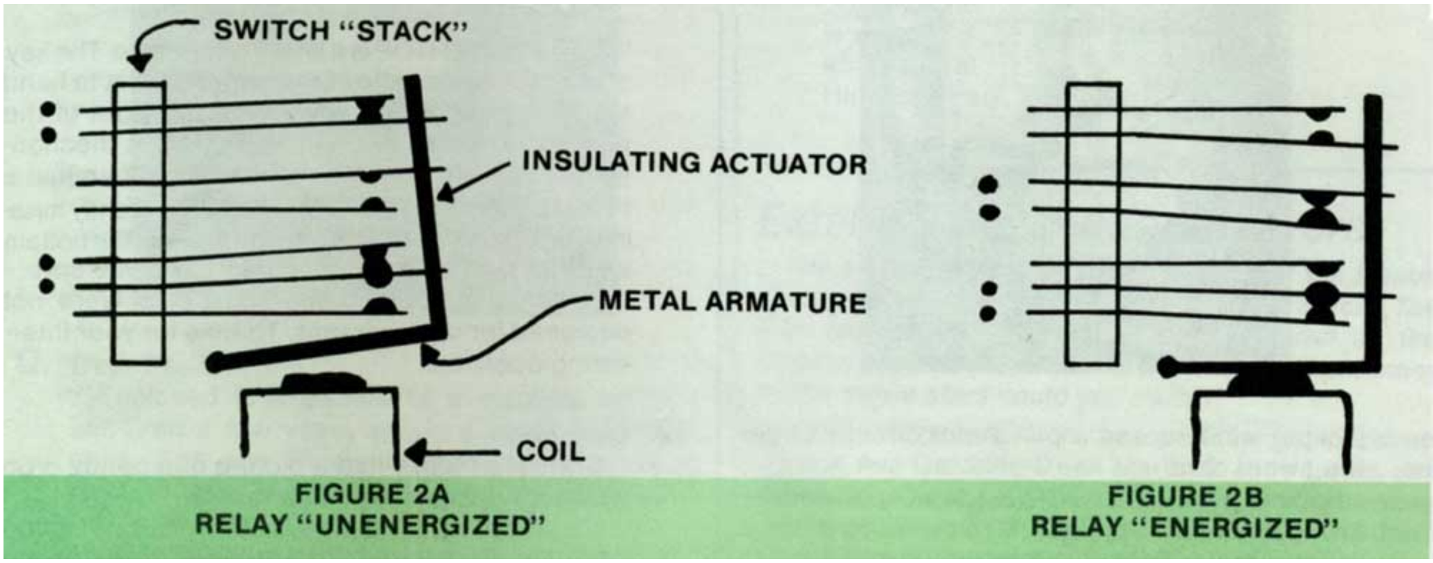


FIGURE 2A
RELAY "UNENERGIZED"

FIGURE 2B
RELAY "ENERGIZED"

One of the blades of each switch is slightly longer than its 'mate' and is the one which is 'actuated (moved) to cause the switch to operate. In most relay applications (and sometimes on score motors) the tips of these actuator blades protrude through slots in a non-metalic ‵actuator' attached to the relay armature. When the relay is energized this actuator is moved causing the actuator blades to move with it (thus operating their respective switches). This is illustrated in Figures 2A (relay unenergized) and 2B (relay energized).

In other switch applications involving a 'stack' of switches, one of the actuator blades is moved by the device operating the switch (e.g. score motor 'cam follower, 'playfield' rollover wire,' etc). Attached to the opposite side of this first actuator is a round fiber 'spacer" which pushes against the next actuator blade in the stack causing it to move as well. Two or more switches can thus be stacked in this manner such that moving the first actuator blade will move all others in the 'stack' thus 'operating' all switches in that stack

Each switch has two positions or 'states.' The 'normal state' is when the device actuating the switch (relay, cam follower, playfield bumper, etc) is in its 'normal or 'at rest' condition. The 'operated state' is when the actuating device has been activated (e.g. relay energized, cam follower moved by a cam, bumper struck by a ball in play, etc.). It is important to understand these states when working with switch circuits as most of the terminology involved with switching circuits is connected with these concepts.

SWITCH CONFIGURATIONS

The two most common switch configurations each involve two contacting blades and are referred to as ‘normally closed' and 'normally open.' Referring to Figure 2A, the uppermost switch (of the three switch -stack' shown) is a 'normally closed' switch. The relay is shown in its unenergized state, therefore its associated switches are in their 'normal state.' The upper switch can be seen to be 'closed' because its two contact points are touching (allowing current to flow between them.) This I have illustrated in the drawing by placing small dots to the left of all switches which are closed. When the relay is actuated (as shown in Figure 2B) the switch is in its 'operated state' and the upper contacts are 'open' and thus no current can flow between them. This type of switch is called 'normally closed' because its contacts are 'closed" (touching each other) when the switch is in its normal state.

Just the opposite is true of the middle set of contacts shown in Figures 2A and 2B. They are 'normally open' since, as can easily be seen, they are 'open' when the switch is in its normal state' (relay unenergized) and 'closed' when it is in the 'operated state (relay energized). Thus for this type of switch, current can only flow when the switch is operated as opposed to the 'normally closed' switch where current flows when the switch is not operated.

The other common switch configuration used in games involves three switch blades and is referred to as a 'Single-Pole-Double Throw' switch. This is most often abbreviated as 'SPDT’ and often also called a 'Form C' switch. Incidentally, 'normally open' switches are also referred to as 'NO' or 'Form A' and 'normally closed' switches as 'NC' or 'Form B.' The SPDT switch is actually a 'normally closed' switch and a 'normally open' switch sharing a common switch blade. It can easily be seen by referring to the lower switch (the one with three blades) in Figures 2A and 2B, that the center blade is the 'common blade,' and the upper blade forms a ‘normally closed' switch with this common blade, and the lower blade forms a 'normally open' switch with it. The dots placed to the left of the solder terminal end of the switches in the figures illustrate that when this switch is in its 'normal state' (figure 2A) current flows between the 'common blade' and the 'normally closed' blade of the switch. When the switch is in its 'operated state' (Figure 2B) that circuit is opened (no current flows) but current now flows between the 'common blade' and the 'normally open' blade. This illustrate the action of SPDT switches and should be thoroughly understood.

Another type of switch sometimes found in games is what I call the 'Normally Open-Normally Open' (or 'NONO') switch. It has three blades, the contacts on all of which are normally open. When the switch is actuated the contacts on all three blades touch thus electrically connecting all three circuits connected to them. This configuration was used on relays and some playfield switches on older (mostly pre-war) games and occasionally on playfield targets on later machines.

The symbols used on schematic diagrams for the various types of switches discussed above were shown in Figure 1, which was with Part 1 of this series of articles. Schematics often used abbreviated terminology such as NO, SPDT, etc. mentioned earlier. Often the abbreviations 'OWE' (open when energized) and 'CWE' (closed when energized) were used next to switch symbols This was normally used when a switch was operated by a solenoid coil, 'energized' referring to the condition where that coil had current applied to it The terms 'OWI' (open when in) and "CWF (closed when in) were used to refer to switches operated by the movable 'shuffle panel.' found on older games, which moves 'in' when the coin chute was pushed in at the start of a new game.

At this point, it should be pointed out that although I have used switches on a relay (as shown in Figures 2A and 2B) to illustrate switch operation, the exact same ideas apply to switches operated by any other device (such as score motor cams, playfield scoring devices, stepping switches, etc.) when you consider the 'normar and 'operated' states of these devices to be equivalent to the 'unenergized' and 'energized' states of the relay respectively.

SWITCH APPLICATIONS

Switches in games provide three basic functions. The switches which are operated by playfield scoring devices (bumpers, rollovers, etc.) act as 'sensors;' they sense the occurance of some playfield event (such as a ball striking a bumper) and pass this information on to the game's internal circuitry. Switches on relays provide 'control functions; they pass on information regarding one event to control another. The third basic switch function is that of' feedback.' The 'end-of-stroke' switches connected with some solenoids are a good example of this as they provide information to indicate that an action (the pulling in of the solenoids plunger) has been properly accomplished. Other examples of this function would be the 'zero switches' on stepping switches and 'score reels' which indicate that these devices have been successfully 'reset' to zero.

The applications of switches on 'score motors' were covered in last month's article. Switches on relays were also discussed in a previous article. The functions of these switches vary, but usually provide 'control' of other circuitry as mentioned above. The discussion of an example of typical game circuitry in a future article will provide a better understanding of the functions performed by relay and score motor switches.

This discussion of switches will be continued in the June issue covering stepping switches, playfield switches and switch maintenance.

PLAYFIELD SWITCHES

Switches connected with the playfield are found in several applications. Some switches are operated by bumpers when struck by the ball in play. In early games these were made up of a coiled wire •spring.' When this was struck by the ball its free end would make contact with another metallic object thus completing an electrical circuit. In most of these 'spring bumpers' contact was made with a metal ring, (sometimes surrounding a carbon ring) with a hole through it, embedded in the playfield, the free end of the bumper spring extending into this ring. In other early spring bumpers the free end of the spring was formed into a small circle. A small metal 'stud’ mounted on the playfield extended through this circle such that when the bumper was struck the two would make contact

The moulded plastic bumpers, which began to appear in the early forties, had a stiff wire extending below the playfield which would move to one side when a ball rolled over the bumper's plastic 'skirt' This wire was one ‘contact of the bumper's ‘switch.' The other 'contact' was some type of metalic object with a hole in its center through which this wire protruded and made contact when the bumper was activated by a ball. For this second contact many of these bumpers used a wire with one end wrapped around a doughnut shaped ring made of carbon.

Bumpers on later games (late fifties on) used an actual two blade type 'normally open switch mounted below the playfield. The 'actuator blade' of this switch had its movable end formed into a small metal 'cup.' A plastic rod extended downward from the bumper's 'skirt,' its lower end resting in the switch's cup. When the bumper was activated, this rod moved to one side pushing on the side of the cup, moving the actuator blade and thus closing the switch. The closing of this switch completed a circuit which indicated to the game's score-keeping circuitry that a 'point(s)' had been scored by the ball in play.

Another type of scoring switch on the playfield was the "rollover switch.' A ball rolling over a wire 'actuator,' protruding through a slot in the playfield, caused a switch (or small 'switch stack') to be operated. In other cases a small plastic 'rollover button' was used to activate a switch. Still another playfield scoring device consisted of a switch mounted vertically with its upper end protruding through a small hole in the playfield. A rubber ring, stretched between two 'posts' on the playfield, slightly touched the 'actuator blade' of the switch such that when this rubber was struck by a ball in play the switch would close thus scoring points. A variation of this idea was the 'rebound' or 'slingshot kicker.' A switch activated by a rubber ring was used, however, the switch in this case provided power to a small solenoid below the playfield which mechanically activated a 'kicker" which hit against the rubber ring from the reverse side, kicking the ball violently away into the playfield. In this case the scoring was provided by an ‘end-of-stroke' switch closed by the solenoid's action each time it 'kicked.'

Playfield 'targets' were also used on many later model games to operate scoring switches. In these cases the ball in play would strike (usually as a result of flipper action) a movable, vertical, circular (or sometimes square in the case of the so called 'roto targets') target, the movement of which would operate a switch behind the target to cause scoring. Some targets were capable of operating two separate switches (scoring two different values) depending whether the target was hit in the center (high score) or toward one side (low score.)

The playfield switches described all have the 'sensor" function mentioned earlier. Older machines, having the movable 'shuffle panel' previously described, employed switches under the playfield which were operated by the shuffle's movement at the start of each new game. These switches provided a feedback' function to the game's other circuitry. 'Closed-when-in' switches were used to 'reset' devices such as stepping switches, while 'open-when-in' switches often were employed to disconnect the power to certain devices during the resetting to start a new game. Often the game's main power circuits ('lamp power" and 'coil power") were fed through these switches and therefore their operation should be carefully checked when power seems to be absent in a game.

STEPPING SWITCHES

The stepping switch unit was described in detail in Part 3 of this series. In that article the 'contact disk" and its associated 'contactor were described. These two items together form the equivalent of a series of switches which are in effect 'operated one at a time' each time the 'step up' coil is impulsed. In most cases these 'switches' are configured to be equivalent to 'normally open' switches with the 'contactor' being a 'common side' to all switches and the 'contacts' on the disk being the other side of each switch. In this configuration the contactor's 'wipers' are directly connected to an external circuit which can be accomplished in one of several ways.

In many units the wiper(s) on the 'contactor' are electrically connected to the unit's metal frame through the center rotating shaft on which the 'contactor' is mounted, the external wiring being connected to a solder lug somewhere on the frame. In other units one end of the wiper touches a circular metal ring which is wired to the external circuit. These are two typical methods of performing this connection but other methods are also used. When problems with stepping switches occur the method of connection to the wipers should be closely examined.

The other common type of switch configuration used with stepping switches involves closing a circuit at certain specific steps of the unit In this type of connection the wipers on the movable contactor are used as a 'cross-connection' to complete a circuit between two separate contact points on the disk, there being no direct external connection to the wipers involved. In these cases the particular wiper(s) involved is electrically insulated from all other wipers on the contactor. This type of connection is normally indicated on a schematic by two dots (representing the two disk contact points) and two arrowheads (representing the wipers) with a line connecting the latter together.

SWITCH MAINTENANCE

As was stated at the start of this article, switch malfunctions normally account for a major portion of the electrical problems occuring in games. For this reason the cleaning and adjusting of switch contacts may well be the most important topic in this whole series of articles on pinball troubleshooting.

Cleaning refers to removing dirt, grease, oxidation, etc. which builds up on the small contact points associated with every switch. (NOTE: The following discussion of switch cleaning does not apply to the gold plated contact points found in modern solid-state games.) The build up of dirt on contact points increases their electrical resistance which decreases the current flow to the' loads' controlled by the switch, causing the latter to operate marginally or not at all. The best method I have found for cleaning points is to use fine grain 'crocus cloth' which can be purchased at most hardware store& Use this lightly to remove the foreign material from the points until they appear metallic, but try not to remove any of the contact material itself (only the dirt).

In cases where the points are pitted a fine file, known as a 'burnishing tool’ may be used but one should file away only enough of the metal surface to make it smooth. I strongly discourage the use of spray type contact cleaning solvents on games for the following reason. These types of products loosen the 'dirt’ but often cling to the surface of the points as a mixture of dirt and solvent unless it is subsequently wiped off and this is difficult to do with most points. Alcohol can be used to clean stepping switch disk points if it is wiped off after application. After cleaning the stepping switch disk a thin coating of 'Lubriplate' ('white lube') should be applied to enable the wipers to pass smoothly over the disk

The purpose of cleaning contact points is to achieve 'metal on metal' contact between the two 'points' of a switch. Even perfectly clean contacts, however, cannot assure good switch operation. Another requirement, that of pressure between the points, is necessary to assure that the switch will operate correctly every time. As was mentioned earlier, a switch 'closes' when an 'actuator blade' is moved by an external device and its contact point comes into contact with a point on another blade ('non-actuated blade') of the switch. In order for a switch to make good contact, as soon as the two points touch each other further movement of the actuator blade is required which causes the non-actuated blade to itself move a small amount thus creating pressure (due to the spring nature of both blades' material) between the two contact points involved. This movement of the non-actuated blade is refered to as 'switch override.'

In addition to causing good contact between the switch points, this override causes the two mating points to rub slightly against one another providing a type of self cleaning action for the points' surfaces. A general rule for the proper amount of override would be that the actuator blade should continue to move, after the points first touch each other, by an amount about equal to its movement from its rest position to the position where this touching first occurs. For 'normally closed" switches the exact reverse of this should occur, the actuator blade moving by a small amount before the points start to open and by a similar amount after the points separate Reference to Figures 2A and 2B should help to illustrate override.

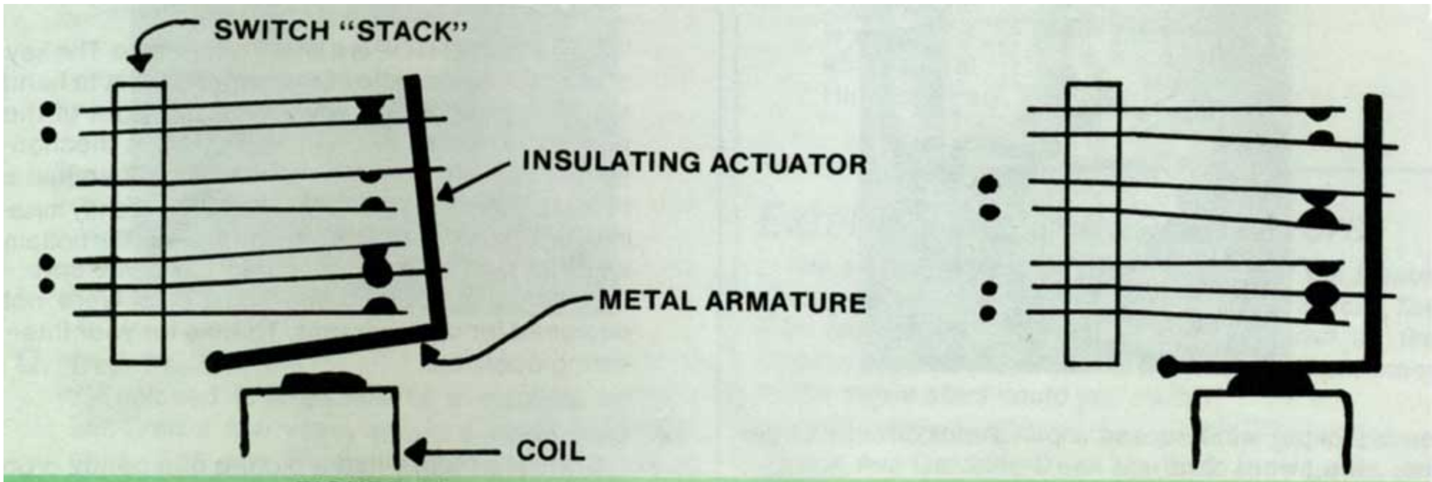


FIGURE 2A
RELAY "UNENERGIZED"

FIGURE 2B
RELAY "ENERGIZED"

Adjusting of switches for proper override should be performed by slightly bending the 'non-actuated' blade (the one not moved by the external device). The switch should be in its open position (for 'normally closed' switches the switch should be actuated by hand to open the points). The blade should be bent slightly in whichever direction is necessary to provide a small gap between the two mating points. This bending should be done using a special contact adjusting tool or a small pair of needle nose pliers gripping the blade immediately adjacent to its fixed end The switch should then be actuated by hand (or released in the case of a 'normally closed' switch) observing when the points first touch and then noticing if both blades continue to move a small distance further, as described above. If enough override does not occur readjust the blade until proper override is obtained.

It may take a person a while to develop this point adjusting technique (it is not easy) but once perfected it will be one of the most important skills in game maintenance One should very seldom have to bend the 'actuator blade' of the switch unless it has become bent itself. Also remember that an SPDT switch has both a 'normally open' and a 'normally closed' side, each of which should be treated as a separate switch. Once one side is adjusted the other side's adjustment should be rechecked since movement of the common actuator blade can occur during adjustment

This completes the discussion of pingame components. Next month some of the basic circuit configurations used in games will be discussed starting with connections of switches to perform complex switching functions.

The article you are about to read is highly technical and may bore you to tears. If, however, a person who is truly interested in understanding pinball circuitry reads it carefully enough to grasp its concepts, the results will phenomenally increase his ability to troubleshoot malfunctioning games,

When this series of articles on Pinball Troubleshooting was started, five basic areas of understanding were listed that are required to perform successful fault isolation in a malfunctioning game. The first three of these (basic electrical circuit theory, reading of schematic diagrams, and basic game components) have been covered in the past five articles, although more on basic circuit theory will be presented this month. We are now ready to start talking about the fourth item on that list, types of circuit configurations commonly used in games.

SWITCHING CIRCUITS

Last month the many types and uses of switches were discussed in detail. Since the switch is the control element in the basic electric circuit, its connections in the game's circuitry are very important to understand. Before discussing switch circuits, however, some basic concepts and terminology should be clarified.

As you will recall, each switch in a game is mechanically actuated by some device (eg., relay armature, score motor cam, bumper, etc.). The actuating of a switch by one of these devices can be considered as an event occurring (relay energizing, cam follower dropping into a notch, ball striking a bumper, etc.).

In a previous article it was pointed out that each switch shown on a schematic will have a label next to it (relay name or letter symbol, solenoid name, etc.) that indicates which device actuates that switch. The switch is thus actuated when the event corresponding to that label occurs. For example: a switch labeled "TILT' would be actuated when the game's tilt relay is energized, in other words, that switch will be actuated when the event "TILT' occurs.

As we also learned last month, all switches will, at any time, be either open (no current can flow through them) or closed (current can flow). If an event, "A," causes a switch to close (a normally open switch actuated by event "A") we can call this switch's function **A" (current will flow only when event A occurs). If, on the other hand, we have a normally closed switch, also actuated by event 'A," its function is said to be NOT "A," Since it can pass current only when event "A" is not occurring.

The function of a switch (or group of switches connected in a certain configuration) can be defined as that event (or combination of events) which must occur (or not occur, in the case of normally closed switches) in order that the switch (or combination of switches) will pass electric current. This will become clear when examples of specific switch connections are discussed. Let me also point out that in the discussions to follow, I will use letters to signify events, but each letter can represent any switch actuated event occurring in a game (eg., bumper "1" being hit, score motor switch "1 A" closing, etc.).

SWITCH CONNECTIONS

There are two basic methods of connecting switches together, these are known as "series" and "parallel." Any complex connection of switches can be broken down into combinations of these basic connections. In "series" connections an external circuit wire is connected to one side of a switch, the other side of that same switch is connected to one side of a second switch. If only two switches are connected, the other side of the second switch is connected to another external circuit connection. More than two switches can be connected in series" by connecting switch to switch as described above, with the second external connection being connected to the last switch in the "series.'

In a "series" connection, in order for current to pass through the series of switches, all switches must be closed. This means that all normally open switches must be activated and all normally closed switches must not be activated.

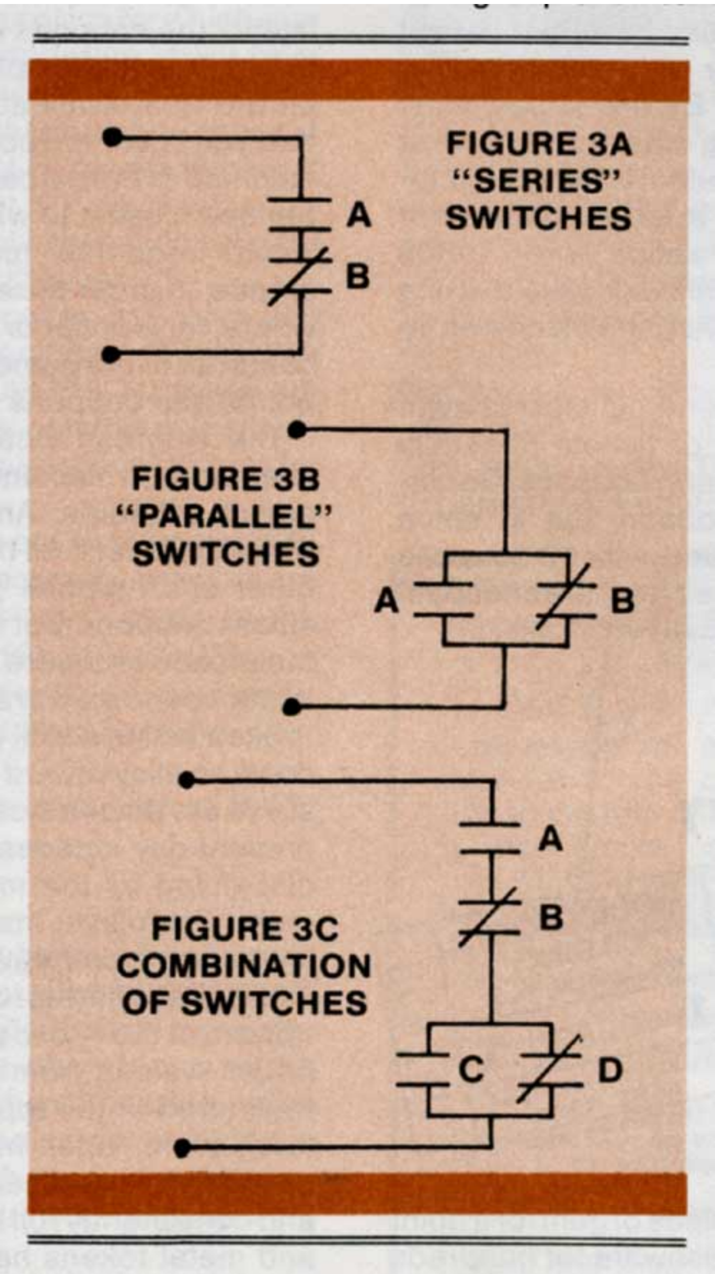


FIGURE 3A “SERIES” SWITCHES

FIGURE 3B “PARALLEL” SWITCHES

FIGURE 3C COMBINATION OF SWITCHES

An example of a two switch 'series" circuit is shown in Figure 3A. In this example, a normally open switch, activated by event "A" and a normally closed switch, activated by event "B," are connected in “series." It can easily be seen. that for current to flow through both switches, event 'A" must occur AND event "B" must not occur. The function of this series of switches (according to the definition presented earlier) would, therefore, be "A" AND NOT "B."

(NOTE: If more than two switches are connected in "series" their function would be the functions of each switch connected by AND. For example; three normally Open switches "A," "B," and "C," and one normally closed switch "D" connected in "series" would have the function "A" AND "B" AND "C" AND NOT D." This would seem reasonable, since for current to flow in a "series" circuit, the first switch AND all other switches must be closed.)

In "parallel" switch connections one external connection is connected to one side of every switch involved, with the second external connection being connected to the other side of all switches. In this type of connection, current can pass between the two external connecting wires when at least one of the switches connected in "parallel" is closed. It should be noted that more than one switch being closed will have no additional effect

Figure 3B illustrates an example of two switches connected in "parallel." In that example it can be seen that current will pass if normally closed switch "B" is not activated 0R if normally open switch "A" is activated. The function of these switches would, therefore, be "A" OR NOT"B." In other words, current will pass any time either event "A" has occurred OR event "B" has not occurred.

(NOTE If more than two switches are connected in "parallel," their function would be the functions of each switch connected by OR. For example: two normally open switches ("A" and "B") and one normally closed switch ("C") connected in "parallel" would appear to be reasonable, since for current to flow in a "parallel" circuit any one switch need only be closed.)

We have now seen that any single switch has a function equal to its actuating event if normally open, or NOT its activating event if normally closed. We have further discovered that when two or more switches are connected in "series" or in "parallel" the function of the combination of switches is the function of each individual switch connected by the logical connector AND or OR respectively. What this means is that a "series" or "parallel combination of switches can be considered to be equivalent to a single big switch, which will pass current only when its function occurs

The concept of the big switch can be carried one step further by connecting groups of "series" or "parallel connected switches in "series" or "parallel" with each other. The result would be equivalent to a big switch whose function would be the functions of each switch or group of switches connected by either AND or OR for "series" or "parallel" connections respectively.

To illustrate this idea, Figure 3C shows a combination of switches connected in both "series" and "parallel." A little study will show that for current to flow between the two external wires the following events must occur (or not occur, as the case may be): "A" must occur AND "B" must not occur AND either "D" must not occur OR "C" must occur. You can see that switches "C" and "D" are connected in "parallel" and these in turn are connected in "series" with "A" and "B" the function of this total combination is therefore: "A" AND NOT B" AND ("C" OR NOT "D").

(NOTE: The parenthesis in the function just cited is used as a grouping symbol indicating that the function contained in the parenthesis must be evaluated first before combining it with the other parts of the overall function. Had the parenthesis not been used the function could have been misinterpreted to mean that normally closed switch "D" was in "parallel" with the entire combination of switches A," "B," and "C" (instead of only with switch "C").)

In effect, the operation of every toad (lamp, coil or motor) in a game is controlled by either a single switch or a group of switches (which can be considered as a big switch having a complex function as described above). Remember, the load can only operate when its associated switch (simple or complex) is closed (allowing current to flow through it). The function of each load's switch (simple or complex) represents the conditions (events) required to energize that load.

In the proceeding examples, letters have been used to represent switch actuating events. When these letters are replaced by the names of actual devices in a game (such as "TILT," "GAME OVER," " 10 POINT RELAY," etc.) the functions which control a particular load begin to make sense and can relate to actual game operations. This will become clearer when actual circuits are discussed.

The switching circuit concepts just presented may seem a little difficult to grasp at first, but a little study should reveal that they are quite logical and actually relatively simple, when once understood Once a person understands these concepts, however, his ability to diagnose problems in a malfunctioning game will increase many fold.

Before leaving the subject of switching circuits one more point should be made. Some switches (normally those controlling the common power lines to different portions of the game) can be, in effect, in "series" with many of the games operating circuits. When analyzing one of these circuits, these common switches should be considered as if they were part of the function of each load that they affect.

This will be described and more circuit theory will be explained when Puss Jensen continues this very informative article in the August issue of The Coin Slot Learn how to troubleshoot for switch malfunctions and several tests to perform to isolate the various conditions in a game that cause unwanted problems.

MORE CIRCUIT THEORY

In the first part of this series the basic electrical circuit was defined. It was said to be a "series" circuit, in that electric current would flow from a power source, through a switch (either simple or complex, as we discussed last month) if it were closed, and finally through a load that would perform some function. All these components have been described in great detail in the past several months. It is now time to tie them all together in an actual circuit and discuss the basic electrical laws that govern the operation of any such circuit

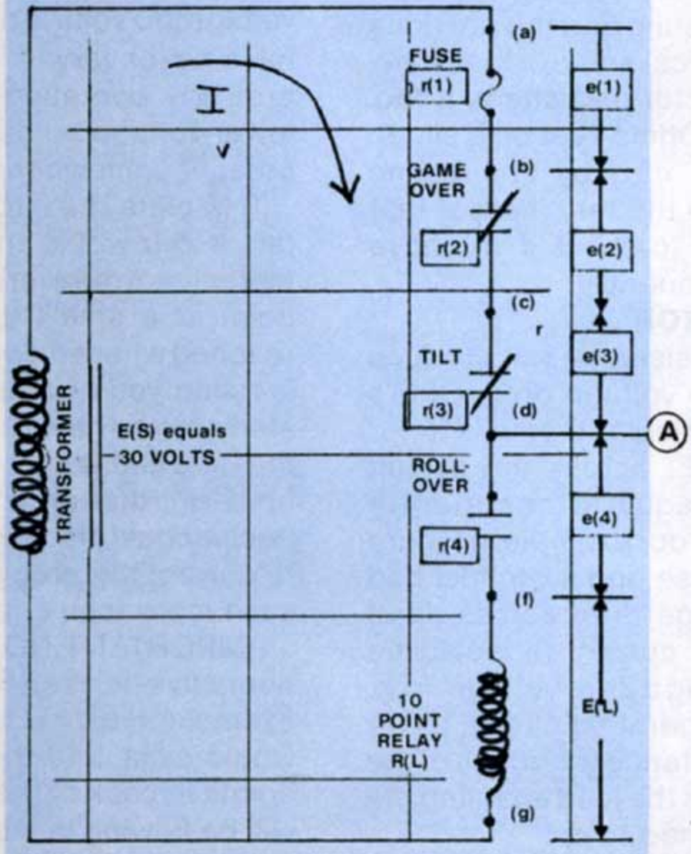


FIGURE 4
TYPICAL GAME CIRCUIT

Figure 4 represents a simple game circuit, in which a rollover switch (normally open) is used to energize a relay (10 Point Relay) in order to score 10 points. A portion of the common switches (the normally closed "Game Over" and "Tilt" relay switches), which control the application of power to some of the game's circuits are also shown as well as the fuse in the coil power line. All of these circuit elements are shown, because in order for electric current to get to the load (relay coil) it must pass through each of them.

Disregarding for the moment the notations in Figure 4 enclosed in boxes, you will notice that the coil power secondary of the game's transformer is shown. It is indicated that this produces a voltage of 30 volts, which I have labeled "E(S)" (more on notation shortly). A circular arrow is also shown, labeled I, indicating the flow of electric current through the entire "series" circuit (from transformer through the fuse, switches and load, and back, to the transformer). Finally, you will notice the notation "R(L)" next to the relay coil, which indicates the resistance of the coil to the flow current. It should be noted that no current will flow until the normally open rollover switch is closed, There is a fundamental law of electrical circuit theory, known as Ohm's Law, that can be represented by the formula I equals E/R. This says that the amount of current (I") flowing in any circuit is equal to the voltage ("E") of the source divided by the resistance ("R") to current flow in the circuit This law will be the basis for all the discussion to follow.

(NOTE: The notations "I," "E," and "R" (used for current, voltage and resistance respectively) may seem Strange but are traditional in Physics and Engineering. I have added (in parenthesis) additional modifiers to provide information about the quantities during this discussion For example: "E(S)" indicates source voltage and "R(L)" indicates resistance of the load.)

The Ohm's Law formula is presented here to illustrate the fact that two conditions can cause a decrease in the amount of current flowing in a circuit; a decrease in voltage supplying current to the circuit, or an increase in the resistance of that circuit to current flow. Of these two factors the latter is the most common in malfunctioning games. However, as will be pointed out later, an increase in resistance in one circuit can cause a decrease in voltage in another circuit fed by it

In a properly operating circuit, the current flowing will be determined only by the source voltage and the load's resistance (or impedance in the case of A.C. Circuits, see note below). In the example in Figure 4 this would be the case if there was no resistance presented by any of the circuit elements (fuse, switches, etc.) in the current path between the transformer and the load.

(NOTE: I have been using the term resistance generically to mean the resistance to the flow of current. Actually the resistance as defined in Physics and Engineering, refers to the property of circuit elements that resists equally both D.C. (direct current) and A.C. (alternating current). Certain circuit elements (in the case of games, coils and motors) have an additional resistance to the flow of A.C. only. which is due to their electromagnetic properties and is known as reactance. The sum of these two resistances (resistance and reactance) is called impedance. This impedance would be used in the Ohm's Law formula for coils and motors in A.C. circuits only, in place of "R(L)," and would be labelled "Z(L)" to differentiate it from other true resistances in the circuit

If any of the circuit elements (other than the load, of course) have resistance, this will add to the resistance of the circuit and thus decrease the current flowing, since in the Ohm's Law formula you are dividing the source voltage by a bigger "R" resulting in a smaller "I." If all these circuit elements (fuse, switches, etc.) are operating correctly they will have Zero (or close to it) resistance If, however, any of them are causing problems they can have some resistance, which I have denoted in Figure 4 by the small letters "r" (for example "r(l)").

The most common cause of unwanted resistance in game circuits is dirty or misadjusted switch contacts described in a previous article. A faulty switch can exhibit almost any resistance up to, of course, an open Circuit (infinite resistance). The possible resistances of the three switches shown in Figure 4 are indicated as "r(2)," r(3) and "r(4)." A perfect switch, when closed, would have zero resistance, although a properly operating switch can have a very small resistance because nothing is perfect!

Figure 4 also indicates (by "r(1)") that the fuse can have resistance. Actually, the fuse itself has a very small resistance that can be ignored, but what I intended to point out is that the fuse holder can exhibit a resistance if the fuse does not fit firmly into the metallic holding clips that provide its electrical contacts. This is often a problem in malfunctioning games and should be checked. The fuse clips should be cleaned and bent together so they make good, firm contact with the ends of the fuse.

While we're on the subject of poor contact causing unwanted resistance, a common and irksome cause of this phenomena should be mentioned, that of poor contact in 'quick disconnect" connectors. The typical circuit in a game usually involves components physically located in various areas of the machine (such as playfield, backbox and bottom of the cabinet). In order that the backbox and playfield can be removed, the manufacturers have provided' quick disconnect' connectors in the wiring for all circuits that go from one area to another (playfield to backbox, playfield to cabinet, etc.).

The wiring connecting a typical circuit, such as the one in Figure 4, may involve several of these connectors in order to connect all of the components together in a circuit. Although this wiring is somewhat difficult to trace (wire color codes must be used, and connectors are not indicated on most schematics) it must be done in many instances during troubleshooting a game. If a bad connection is found, the mating contacts must be cleaned and the socket adjusted for a tight fit with the mating plug pins.

THE ZERO OHMS TEST

Now that we know that various conditions in a game can cause unwanted resistance in a circuit, how do we detect it, and if it exists, isolate its cause(s)? One way (another method will be discussed later) is by what I call the Zero Ohms Test To perform this test you must have a Volt/Ohm Meter, which can be purchased at any electronics store for as little as $20. This is an essential tool in game servicing. When used as an Ohmmeter (one of its selectable functions) it measures resistance (the kind that affects both AC. and D.C. circuits, but not reactance, see note above) in units of Ohms.

(NOTE: Zero Ohms is a short circuit, meaning there is no resistance to the flow of current. Higher values indicate increased resistance to current flow, an open circuit having an infinite resistance, or no current flow.)

To use the Ohmmeter for measuring resistance you must first select the Ohms function and the lowest resistance scale (usually called "R x 1") meaning that the resistance in Ohms can be read directly from the meter's "Resistance Scale'). The needle on the meter should immediately go to the high end of the scale (infinite resistance) since you have an open circuit between the meter leads. Next, short the two leads together, and the meter should return to near Zero, since you now have a short circuit between the meter leads. Most meters provide an adjusting know, (usually labeled 'Ohms Adjust’), which can be used to place the meter exactly on Zero. If Zero cannot be reached, the meter's internal batteries should be replaced. You are now ready to perform the test on one of the game's circuits. (WARNING! the game should be unplugged when any Ohm-meter testing is being performed or damage to the meter may result)

Figure 4 will be used as an example of a typical circuit on which the Zero Ohms Test is to be performed. You would first attach one of your meter leads (using a clip lead) to the terminal on the fuse socket whose wire provides current from the transformer (wire color codes and the schematic must be used to determine this). This point in Figure4 is labeled "(a)." Next, you would attach the other lead of the meter to the relay coil terminal (point labeled "f” in Figure 4) This is the terminal on the coil that is not connected to the coil common power line. Your meter should read infinite resistance (top of scale) since the rollover switch is open. (NOTE: In this example the fuse is shown »n the side of the coil power line that feeds the switches. In many games the coil common line is fused instead. In these cases a separate Zero Ohms Test should be performed between that side of the transformer and the coil common side of the coil to test for unwanted resistance in the fuse socket and any intervening connectors.)

The rollover switch would next be closed manually, at which time the meter should go to Zero Ohms. As stated earlier, in a properly operating game a small resistance is normal, but anything over 1/4 Ohm should be suspect. If the meter indicates unwanted resistance, the meter lead attached to the coil (point “f”) should be moved to point "d." If Zero Ohms is then obtained your problem would be in the circuitry just eliminated (in this case either the rollover switch or any intervening 'quick disconnect' connectors).

If, however, you still did not get 'Zero, keep moving your meter lead back one point in the circuit (to point "c," then "b," etc.) until you locate the faulty part of the circuit. You should then correct the problem (clean and adjust the faulty switch or connector), and then retest everything as two faults could have existed, one masking the other.

A word of warning! Your test might seem to indicate a faulty switch yet the problem could be in a connector that is between the point you are testing and that switch. So if the point you are testing and the previous point tested are in different physical areas of the game, look for the intervening connector and check it too (HINT: You can perform a Zero Ohms Test on a single component (switch, connector, etc.) by connecting your two meter leads directly to the terminals of that component This is a good way to check if you have properly fixed a fault in a component.)

VOLTAGE DROP

The presence of unwanted resistance will produce an effect on a circuit known as voltage drop. Ohm's Law can also be stated by the formula "E equals l x R." This means that the voltage (E) across any circuit element will have a resistance (R) that is equal to the current (I) multiplied by the resistance. If, in our example in Figure 4, all of the circuit elements (fuse and switches) had Zero resistance then the voltage drop across all of them would be Zero since the current (I) would be multiplied by Zero, thus producing a Zero voltage drop. This means that in a properly operating circuit, all (or almost all, remember some resistance is normal) of the supply voltage will appear across the load enabling the load to operate as it was designed to do.

If. on the other hand, any or all of these components have unwanted resistance (denoted by the small "r" in the boxes in Figure 4) they will produce a corresponding voltage drop, "e(4)," across it, equal to the current, "I," multiplied by "r(4)." The same idea would hold true for any of the other circuit elements by multiplying their "r" by "I" to get their respective voltage drops ("e").

The result of all of this would be that the voltage appearing across the load ("E(L) in Figure4) would be the source voltage, "E(S)," MINUS the sum of all the individual voltage drops of the circuit components ("e(1)" plus "e(2)" plus "e(3)" plus "e(4)"). Thus the larger the voltage drops (produced by larger, unwanted resistances) the less voltage will be supplied to the load, causing it to operate marginally or not at all. This voltage drop is thus a symptom of the situation where unwanted resistance is present in a circuit

The phenomena of voltage drop provides the basis for another test to determine the presence of unwanted resistance in a circuit, the Voltage Drop Test. This test is similar to the Zero Ohms Test, except it is performed with the game's power on and voltages, rather than resistances, are measured with the Volt/Ohm meter.

The circuit of Figure 4 will again be used as an example. To perform a Voltage Drop Test on that circuit you would first start the game (so that the "Game Over" relay would be in its normal, unoperated, condition). Your Volt/Ohmmeter would be set up for the 'A.C. Volts' function and the lowest voltage scale selected that has as its maximum voltage reading a voltage over 30 Volts('50 Volt Scale,' for example). One of the meter leads would be connected to the side of the coil connected to the coil common power line (point 'g" in Figure 4). The other meter lead should be connected to the other side of that coil (point "f"). You would then be ready to perform the test.

Next the rollover switch must be closed by hand, at which time the meter should register a voltage. If the voltage registered is the same as the transformers coil voltage(30 volts in this example), or very close to if you have no (or very little) voltage drop and your circuit is probably operating properly. If, however, you get a lower voltage across the coil unwanted resistance is present somewhere in the circuit.

To isolate the circuit component causing the resistance you would then proceed by moving your one meter lead (the one on point "f) back in the circuit one point at a time ("d," then "c," etc.), until a point is reached where full voltage is obtained. When this point is found you have isolated the problem to the circuit element you have just eliminated, just as in the case of the Zero Ohms Test previously described. Don't forget, however, that an intervening 'quick disconnect connector could also bet he culprit The next step would be to correct the problem and retest the entire circuit in case more than one problem existed.

(IMPORTANT NOTE: While performing this test all normally open switches (only the rollover switch in this example) must be held closed. If not, an open circuit would exist and the full voltage would appear at all points in back of the open circuit because no current component had a fairly high unwanted resistance. This same condition can occur if a normally closed switch has a very high resistance or is completely open.)

COMMON POWER CIRCUITS

Mention has been made several times in this and previous articles of common power circuits, which feed more than one circuit in a game. An example of such a circuit could be that part of the circuit of Figure 4 between the upper side of the transformer winding and point "d" (including the fuse and the normally closed contacts of the "Tilt" and "Game Over" relays). You will notice that I have indicated a line, labeled "A," which represents the common point where other circuits fed by this common circuit would be connected. We shall now consider, using Ohm's Law, the effects on the game of malfunctions in this type of common circuit

If (in addition to the rollover switch and 10 Point Relay circuit shown) other circuits were attached to point "A" (in order to obtain power) each of these circuits would use a certain amount of current to operate. The behavior of electrical circuits is such that the total current flowing through the common circuit would be the sum of all the individual currents flowing in the circuits fed by it. You can also see, from the previous discussion of voltage drop, that the larger the current in this common circuit the larger the voltage drop between the transformer and point "A” resulting from any unwanted resistance in this common circuit. The resulting voltage at point "A" would be the transformer voltage, "E(S)," MINUS the voltage drop through the common circuit components.

The resulting voltage at point A" can be considered as the supply voltage to each of the individual circuits fed by the common circuit As you can see, the lower this supply voltage to a circuit the less chance that circuit has to operate properly. Now, since the individual circuits attached to point "A" are, for the most part, being turned on and off (sometimes drawing current and sometimes not) during operation of the game, the resulting current flow through the common circuit is hence the supply voltage to the individual circuits) is also changing. It should be plain to see that this condition can result in intermittent problems occurring in the game's operation.

It should be kept in mind that all these problems can only occur if there is unwanted resistance (caused by a malfunction) in one or more of the components in the common circuit If all components in this circuit had Zero (or very little) resistance, the voltage drop across them would be Zero (or very small) no matter how much current (Ie. one or many circuits operating) was flowing. A good test to see if this type of problem is occurring is to use a voltmeter to monitor the voltage at the common connection point (point "A" in the example) during actual playing of the game, to see if the voltage fluctuates to any great degree (say more than ten percent). If it does, then either the Zero Ohms Test or the Voltage Drop Test can be used to isolate the cause of the problem (the components) having unwanted resistance).

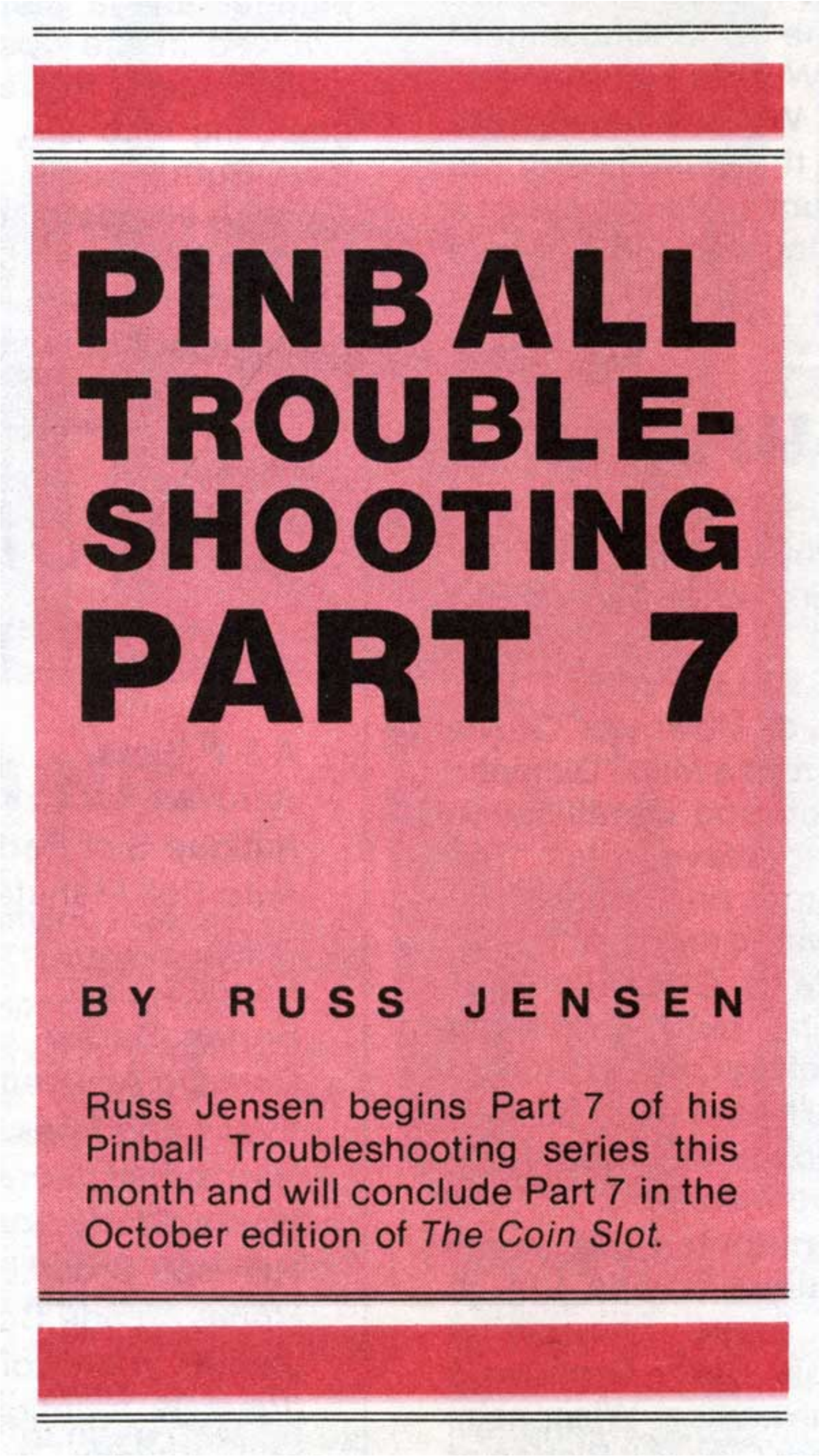
This concludes the discussion of circuit theory. While at first it may seem highly technical, the principles are really quite simple and logical and. when understood, are of great value in enabling one to understand why things happen as an aid to diagnosing malfunctions in a game. Next month some typical types of circuits will be described, and their operation will be discussed step-by-stepi

Correction

In the July issue of The Coin Slot an error was made in Russ Jensen's article, "Pinball Troubleshooting, Part 6, Basic Circuits." Some copy was inadvertently left out of the third paragraph, first column on page 39, the note about parallel switches. This paragraph should have read:

(NOTE: If more than two switches are connected in "parallel," their function would be the functions of each switch connected by OR. For example: two normally open switches ("A" and B") and one normally closed switch ("C") connected in "parallel" would have the function "A" OR " B" OR NOT "C." This would appear to be reasonable, since for current to flow in a "parallel circuit any one switch need only be closed.)

We apologize to Russ and our readers for this error and hope it has caused no inconvenience.



PINBALL TROUBLE-SHOOTING
PART 7

BY RUSS JENSEN

Russ Jensen begins Part 7 of his Pinball Troubleshooting series this month and will conclude Part 7 in the October edition of *The Coin Slot*.

PINBALL TROUBLE-SHOOTING

PART 7

COILS IN "SERIES"

Often in games it is required to have a series of playfield targets (bumpers, targets, rebounds, etc.)

that each perform two functions when struck by a ball in play. Typically, one function would be to add points to the score (a momentary function). The second function would often be to light a light, such as one of a series of numbers or letters on the backglass or in lighted bumpers (a sustained function). To implement this type of dual function game designers often resorted to the use of what were typically called "series" or intermediate relays.

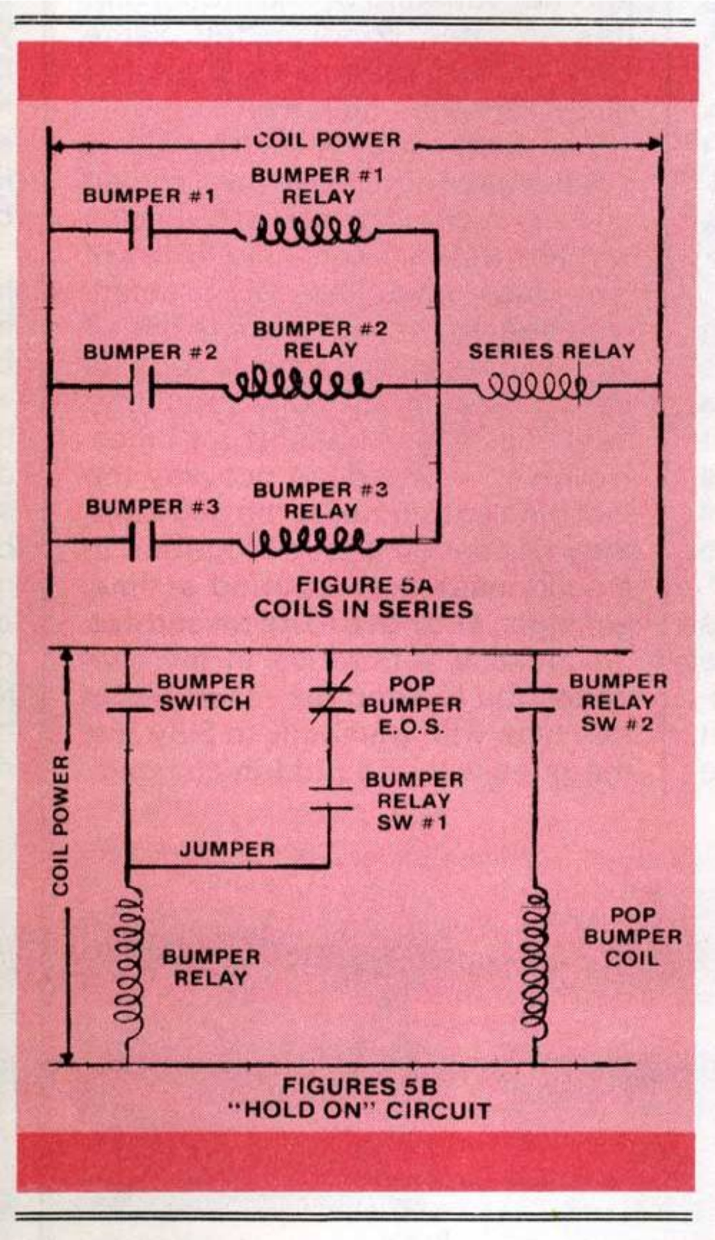


FIGURE 5A
COILS IN SERIES

FIGURES 5B
"HOLD ON" CIRCUIT

Figure 5A illustrates a typical circuit in which three bumpers (although any number could be used), labeled #1, #2, and #3, are shown. Each bumper has associated with it a bumper relay that would be on a relay bank, as described in the previous article on relays. An additional relay (labeled series relay) is of the simple type and is wired in "series" with a common connection to one side of every one of the bumper relays.

When any one of the bumpers is struck by a ball in play its switch is closed and a circuit is completed so current can flow through its corresponding bumper relay and through the series relay. The bumper relay is thus tripped, its switches providing a sustained function, since it will not be reset until the bank reset coil on the relay bank is subsequently energized by some other game function (such as the start of a new game or the completion of a series of events). The series relay will also be energized, (but only as long as the bumper switch remains closed) its switch(es) thus providing a momentary function, typically the scoring of points.

Two things should be noted about this type of circuit configuration. First, that subsequent hits of the same bumper (before the relay bank is subsequently reset) will cause current to flow in the same manner, however, only the operation of the series relay is significant since the bumper relay has already been tripped (current will, however, still flow through its coil although no mechanical action will result). Secondly, because the bumper relay coils and the series relay coils are operated in "series" with each other, these coils are designed to operate on lower voltages and cannot be interchanged with other coils in a game, which are designed to operate directly from the full coil voltage.

Finally, it should be pointed out that these circuits are designed to operate with only one bumper switch closed at any one time. If more that one is closed at the same time more current will flow through the series relay than it was designed for, and this could result in damage to that coil.

THE "HOLD ON" CIRCUIT

Probably the most common of all circuit configurations used in games is the so called "hold on" circuit used with relays. This idea has been used since the mid 1930s and is fundamental to game circuits. It must be thoroughly understood by anyone troubleshooting games. This type of circuit is basically used for one of two purposes, assurance or timing.

In the case of the assurance function, a relay whose operation is to cause an event to occur is "held on" until it receives feedback to indicate that the event has properly occurred. An example of this will be given shortly. In the case of the timing function,a relay is energized by one event and "held on" until a second event occurs. The relay's switches are thus activated for the period of time between these two events. An example of this will be shown later when typical complex game circuitry, to produce an entire game function, is described.

Figure 5B illustrates a typical example of a relay "hold on" circuit. It is one that provides the assurance function, yet its circuitry has the characteristics typical of all "hold on" circuits. The circuit in the example is the one commonly used in pingames having pop or thumper bumpers, which kick the ball away from them when struck. Before discussing how this particular application works, however, this illustration will be used to point out some typical characteristics of the relay "hold on" circuit.

You will note the relay coil, labeled bumper relay, has its top side connected (by a wire labeled jumper) to one of its own normally open switches (labeled bumper relay SW #1). This is the telltale sign of all "hold on" circuits; that is, that one side of a relay's coil is connected to one of its own normally open switches. I call this switch the relay's "hold on" switch. A relay wired in this configuration can usually be easily spotted by noting a short wire (jumper) connected from one of the relay's coil terminals to one of its switch terminals (usually the switch in the stack closest to the coil itself). Occasionally this connection may be made via a cable harness and is not as easy to spot.

It should next be noted that this "hold on" switch is wired in "series" with a normally closed switch (labeled pop bumper E.O.S in the example) to the other side of the coil power line. This is also typical of "hold on" circuits, in that the "hold on" switch is connected to coil power via a normally closed switch (or combination of switches that provide a normally closed function). This switch(es) I call the "drop out" switch. The entire circuit, consisting of the "hold on" switch and the "drop out switch, is referred to as the relay's" hold on" circuit

(NOTE: In some cases another normally open switch (or combination of switches) may be wired in "series" with the "hold on" and "drop off" switches. This would be used to open the "hold on" circuit under some condition when the game situation required the "hold on" function to be disabled).

Finally, note the other switch connected to the relay coil (labeled bumper switch in the examie). This is representative of the relay's energizing circuit, which is the switch (or combination of switches) that initially energizes the relay after which the "hold on" circuit keeps the relay energized for some period of time after the energizing circuit is opened. A discussion of how the particular circuit in the example in Figure 5B works should serve to illustrate how these circuits interact to produce the desired result.

When a ball in play strikes the bumper, the bumper switch is momentarily closed. This comletes the circuit, applying current to the bumper relay coil thus initially energizing the relay. The energizing of the relay then causes its two switches (bumper relay SW #1 and bumper relay SW #2) to close. Switch ^1 now provides current to the relay coil via the normally closed "drop out" switch (pop bumper E.O.S.) even if the bumper switch subsequently opens. The relay is now "held on."

The closing of bumper relay SW #2 applies current to the pop bumper coil, the energizing of which causes the metal ball kicker ring surrounding the bumper body to be pulled downward, repelling the ball from the bumper area The movement of this ring also causes the pop bumper E.O.S. (end of stroke) switch to open when the ring has been pulled all the way down, providing feedback indicating the pop bumper action has successfully occurred. The opening of this "drop out" switch removes power from the relay's "hold on" circuit and the bumper relay coil is de-energized. Both its associated switches then open, thus de-energizing the pop bumper coil as well. Everything is then back to its original condition until another ball strikes the bumper. (NOTE: The bumper relay typically has additional switches in its stack, which energize the other bumper functions (scoring of points, etc.).)

The circuit just described used the "hold on" circuitcto provide the assurance function previously mentioned. One characteristic of this type of "hold on" circuit is that if it is not operating (due to a defective"hold on" or "drop out" switch, etc.) it is sometimes difficult to notice, since the function it controls will still occur, but often not completely, In the above example, for instance, the pop bumper would still operate, but sometimes the ball kicker ring might not be pulled all the way down resulting in a weaker kick of the ball.

It is often useful in trouble-shooting a game to test a "hold on" circuit to be sure it is going to operate. Again using the example of Figure 5B, it can be seen that manually closing the "hold on" switch (bumper relay SW #1) should result in energizing its coil even without the closing of the energizing switch (bumper switch) provided that the "hold on" circuit is functioning properly. There are two easy ways to per- form this test. The first is to short the two blades of the relay's "hold on" switch (remember that is can usually be spotted by observing which switch has one of its contacts wired to one side of its coil) with a metallic object, such as a screwdriver blade or metal tip of a mechanical pencil. When this is done the relay should immediately energize. This tests all of the "hold on" circuit except the switch you have just shorted since you have bypassed its points with your shorting device.

The second method, which tests the complete circuit, is to manually move the relay armature slowly toward the coil. As soon as the "hold on" switch closes you should feel the magnetic pull of the coin on the armature as the relay energizes. If this is not felt, the "hold on" circuit is not operating. When the relay energizes let go of the armature, the relay should perform its function (operate the pop bumper in the caseof our example) and then "drop out." If it remains energized the "drop out" switch is not operating properly and should be checked. (NOTE: Sometimes in performing one of the above tests the relay will energize and remain so with nothing else happening. This means that the device that should be activated by the relay (such as the pop bumper in our example) is not operating at all, and thus never opening the "drop out" switch. If this occurs, that device, and the relay contact activating it, (bumper relay SW #2 in the example) should be checked.)

If either of the above tests are performed and indicate the "hold on" circuit is not operating at all, the "drop out" switch on the device activated by the relay (and any intervening quick disconnect connectors) should be checked until an open circuit is discovered.

The Zero Ohms Test, described in a previous article, is one way to isolate such a problem. Other useful test methods will be discussed in a future article.

(NOTE: The tests just described will not work if the "hold on" circuit contains a disabling switch(es) in "series" with it, as noted earlier. In these cases, that switch(es) must first be closed or shorted in some way prior to performing the tests.)

This concludes the specific discussion of the relay "hold on" circuit, however, other examples of such circuits (including one employing the timing function) will be illustrated when an example of circuitry performing a complex game function is discussed. The only major difference between "hold on" circuits providing the assurance function and the timing function is that the latter usually employ normally closed score motor switches as the "drop out" switch(es).

In October, Russ Jensen will continue his descriptions of the typical circuit configurations used in games and how they operate. He will discuss relays and their functions, and a complex game function to tie together what has been covered in the previous articles.

Correction

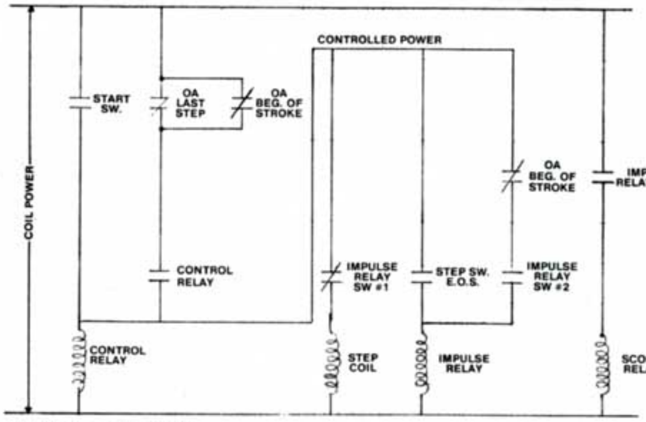
In the August Issue an error was made in Russ Jensen's article "Pinball Troubleshooting, Part 6 Continued." Some copy was inadvertently left out of the second paragraph under the heading "Voltage Drop," first column on page 46. This paragraph should have If, on the other hand, any or all of these components have unwanted resistance (denoted by the small "r's" in the boxes in Figure 4) they will produce a corresponding voltage drop (represented by the small "e's"). For example, if the rollover switch had a resistance "r(4)," it would have a corresponding voltage drop, "e(4)," across it, equal to the current, "I," multiplied by "r(4)." The same idea would hold true for any of the other circuit elements by multiplying their's" by "I" to get their respective voltage drops ("e's").

We apologize to Russ and our readers for this error and hope it has caused no inconvenience.

THE RELAY RACE

The term relay race refers to relay circuitry in which one relay, when energized energizes a second relay, which can then energize a third relay, etc. A relay, when energized, normally would de-energize the relay that energized it. A variation of this idea has been employed in games (mostly older games, before the introduction of the score motor) usually to provide multiple impulses for scoring functions.

(NOTE Genco used this type of circuitry in games up into the 1950s and, as far as I know, that company never used a score motor.)



NOTE: "OA" means "OPEN AT"

FIGURE 6
RELAY RACE

An example of a circuit employing this idea is shown in Figure 6. While this is a hypothetical and somewhat simplified example, the principles involved in the operation of this circuit are typical of those of this type of circuit. The example shows a circuit to provide multiple scoring (for example, scoring of 5 points by registering 1 point five times).

The circuit involves a "Control Relay" with a hold on circuit that, when energized by the closing of an external switch (labeled Start SW" in the example), will start the circuit in operation and keep it going until it has completed its job. A stepping switch is used to count the number of points scored and disable the circuit (by providing the drop out function for the "Control Relay") when 5 points have been scored. The timing of this circuitry is provided by a relay, (labeled "Impulse Relay") one of its switches energizing the "Score Relay" 5 times to provide the actual scoring. The step-by-step operation of this circuitry will now be described.

When the "Start SW" is closed (by some action in the game that entitles the player to five points) the "Control Relay" is energized. It is held in by its hold on circuit, via the normally closed switches (drop off switches) labeled "OA Last Step" and "OA Beg. of Stroke" (both of which will open when the stepping switch has completed five complete steps). This provides coil power to the line labeled "Controlled Power," which provides power to the other circuitry.

As soon as power is applied to this line the "Step Coil" of the stepping switch is energized via the normally closed switch, ("SW#1) on the "Impulse Relay" and the stepping switch starts to step to its first position. When the "Step Coil' plunger has completed its inward motion, its end-of-stroke switch (labeled "Step SW EOS") is closed thus energizing the "Impulse Relay."

The energizing of the "Impulse Relay" energizes the "Score Relay" by its normally open switch (SW#S) thus scoring one point and opening the circuit to the "Step Coil" by means of the normally closed switch (SW#1), which is in series with the "Step Coil," thus allowing its plunger to return to its normal at rest position. You will note that the "lmpulse Relay” has a hold on circuit utilizing the normally closed (drop out) switch, labeled "OA Beg. of Stroke," on the stepping unit. This switch closes as soon as the "Step Coil” is energized and remains closed until that coil is de-energized and its plunger has fully returned to its at rest position. This hold on circuit thus assures that the "Impulse Relay" remains energized during the time that the "Step Coil” plunger is returning from its end of stroke position to its normal at rest position.

At this point one cycle of this circuitry has been completed (one of the five points has been scored). As soon as the "Impulse Relay" opens (when the "Step Coil" plunger has returned to its at rest position) its normally closed switch will again close, energizing the "Step Coil" once more and the entire process will be repeated, thus scoring the second point. It can easily be seen that this will happen five times (scoring five points), but on the fifth cycle something else will also happen.

When the stepping switch makes its fifth step, the normally closed switch (labeled "OA Last Step"), which is in the hold on circuit for the "Control Relay," will open. This will not yet drop out the "Control Relay" however, due to the normally closed switch (labeled "OA Beg. of Stroke"), which is wired in parallel with this switch. This second switch (often referred to by game designers as a safety switch) will keep the "Control Relay" energized until the stepping switch plunger has fully returned to its at rest position after completing its fifth step. This ensures that the "Impulse Relay" will be held on for the same period as in the previous cycles to guarantee a good impulse to the "Score Relay" coil.

(NOTE: The circuitry shown in this example does not include a method for resetting the stepping switch after the fifth step This would vary depending on the type of stepping switch used. If a reset type were used additional circuitry would be required to energize its reset coil after the fifth step. If a continuous type was used the "OA Last Step" switch could either be implemented using contacts on the stepping switch disc or a cam could be attached to the rotatable shaft of the stepping switch with a notch at every fifth position to actuate the "OA Last Step" switch.)

It should be noted that in this type of circuitry, adjustment and proper operation of most of the switches is extremely critical. One malfunction or misadjusted switch can cause erratic operation of the entire circuit, and if more than one is bad. Watch Out! For example, the adjustment of the "Step SW EOS" and "OA Beg. of Stroke" switches control the timing of the entire circuit; the former determines when the "Impulse Relay" will be energized and the latter determines when it will drop out.

This concludes the discussion of typical circuit configurations used in games Although this discussion was by no means exhaustive, some of the most commonly encountered, difficult to understand, and important circuits have been discussed. The important thing, as far as troubleshooting is concerned, however, is the understanding of the principles involved. To tie up the discussion of game circuits an example of a complex game function will now be discussed.

A COMPLEX GAME FUNCTION

Since we have now examined all the basic game components and many of the basic and typical game circuits, we are ready to examine an example of a complex circuit in which several circuits acting together produce a game function. In this case, the multiple scoring of points You may notice that this is a similar function to that used to illustrate the relay race, but this repetition serves several purposes. The present example shows everything associated with this function including the control of the score indicating lights. In addition, it illustrates the uses of the "Score Motor" while providing an example of the timing function application of the relay hold on circuit (as well as the assurance, or feedback, function). In short, this example will tend to tie together most of what has been covered by the previous articles in this series.

(NOTE: The circuitry in this example will also be used in connection with the discussion of troubleshooting techniques to be presented in the final part of this series)

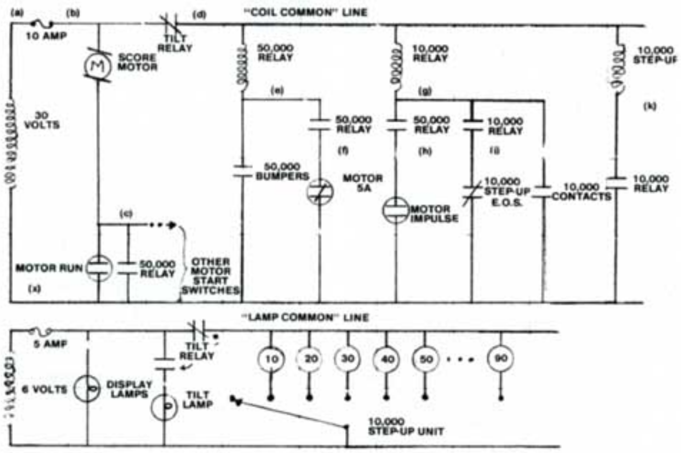


FIGURE 7
COMPLEX GAME CIRCUIT

Figure 7 illustrates the basic circuitry required to score 50,000 points (in increments of 10,000 points) such as would be found in a typical 1950s pingame. Basically, the ball in play would strike a bumper or target whose value was 50,000. This would initiate the action of the circuitry and cause the "10,000 Step-up Unit" to advance five times, displaying the changing score (in units of 10,000) on lighted panels on the backglass. The step-by-step operation of this circuitry will now be described.

First, note the switch labeled "50,000 Bumpers" to the lower right of the "50,000 Relay" coil When a ball strikes one of these bumpers this switch (actually it may be several switches wired in parallel) would close, thus energizing the "50,000 Relay" coil. Once energized, this relay is held in by its hold on circuit via its normally closed drop out switch labeled "Motor 5A."

(NOTE: This relay and its hold on circuit is a good example of the timing function of hold on circuits previously referred to. This will become more apparent as this discussion progresses.)

The energizing of the 5O,OOO Relay" closes the switch by the same name, which supplies power to the "Score Motor," starting the motor unit rotating At the beginning of the motor cycle, the switch labeled "Motor Run" will be closed by one of the "Score Motor" cams. Since this switch is in parallel with the "50,000 Relay" switch, the motor will continue to rotate until the end of the motor cycle after the "50,000 Relay" is de-energized.

(NOTE: You will notice the notation "Other Motor Start Switches" to the right of the "50,000 Relay" switch that starts the motor. This is to indicate that in all games there are many switches in parallel with the "Motor Run" switch, each of which will start the "Score Motor" for one of the game functions requiring motor action, such as game resetting, multiple scoring, kickout hole operation, or any other operation requiring events to occur in a timed sequence.)

As you will recall from the discussion of "Score Motors" in Part 4 of this series all "Score Motor' units have 'Impulse Switches," which normally close and reopen five times for each motor cycle. One of these switches, labeled "Motor Impulse" can be seen in Figure 7 to be connected in series with a switch labeled "50,000 Relay" and supplying power to the "10,000 Relay" coil. Since the "50,000 Relay" is held on (and hence its switches are closed), as soon as the "Motor Impulse" switch closes the first time, the "10,000 Relay" will be energized. You will notice that that relay has a hold on circuit utilizing a normally closed switch labeled "10,000 Step Up E.O.S." This circuit provides an assurance function to assure that the "10,000 Step Up Unit" steps before the "10,000 Relay" is allowed to drop out. This hold on function also is necessary to keep the relay energized after the "Motor Impulse" switch reopens.

(NOTE: You will note the switch labeled "10,000 Contacts" also capable of energizing the "10,000

Relay." This represents any other circuits in the game that can score 10,000 points such as rebound rubbers, "10,000 Bumpers," etc. While this switch symbol actually represents several switches wired in parallel, schematics will often illustrate these as one switch, appropriately labeled, to save space on the drawing.)

The energizing of the "10,000 Relay" energizes the "10,000 Step Up" coil on the "10,000 Stepping Switch" via the switch labeled “10,000 Relay." The stepping switch will thus advance one step. One of its wipers would then make contact with the disc contact wired to the 10,000 score lamp (shown as the number "10" enclosed in a circle In the figure) thus supplying lamp power to light that lamp behind the backglass. During this operation (when the plunger of the "10,000 Step Up" coil has been completely pulled in) the ”10,000 Step Up EQSL" (end of stroke) switch opens thus dropping out the "10,000 Relay." This feedback provides the assurance function mentioned earlier.

During all this time (actually only barely a second) the "Score Motor" is rotating and shortly after the scoring sequence just described is complete, the "Motor Impulse" switch will close for the second time The 10,000 Relay" will again be energized and 10,000 more points will be scored. This sequence will occur a total of five times (once for each closing of the "Motor Impulse" switch) thus scoring 50,000 points. At that point the stepping switch wipers will have reached the disc contact connected to the 50,000 lamp behind the backglass, thus illuminating it.

(NOTE: If the "10,000 Step Up Unit" had been at some score other than zero at the start of the sequence (say 20,000) then it would be 50,000 higher (70.000 in that case) when the scoring sequence is completed).

Almost immediately after the "Motor Impulse" switch reopens for the fifth time the motor switch labeled “Motor 5A" will open. You will recall that this switch is used as the drop out switch for the "50,000 Relay" and has been holding that relay energized since the start of the sequence of operations being described. When the switch opens, the "50,000 Relay" will immediately drop out (become de-energized), thus opening its switch, which was used to allow motor impulses to energize the "10,000 Relay." Remember, however, that the "10,000 Relay's" hold on circuit will keep that relay energized until the last 10,000 points have been scored.

Shortly after the "Motor 5A" switch opens the "Motor Run" switch will open and the "Motor 5A" switch will again close. You will note that since the "50,000 Relay" is no longer energized, the motor will stop (when the "Motor Run" switch opens) and the "50,000 Relay" will not be energized by the closing of the "Motor 5A" switch since its hold on switch ("50,000 Relay Switch") is now also open. This completes the operation of the 50,000 scoring sequence. A subsequent closing of one of the "50.000 Bumpers" switches would, of course, start the whole sequence again scoring an additional 50,000 points.

The sequence just described includes a good exam pie of the timing function of a relay hold on circuit in the operation of the "50,000 Relay." This relay was energized at the start of a motor cycle (before the first impulse) and was held on until the end of the cycle (after the fifth impulse) allowing all five impulses to reach the "10,000 Relay." Had this relay been dropped out earlier (say after the third impulse, for example) a fewer number of impulses (three in this case) would have been allowed to energize the "10,000 Relay" thus scoring fewer (30,000 in this case) points. This type of circuitry is abundant in games where scoring of some multiple number of points (or other situations requiring multiple impulses) is desired.

We have, at this point, concluded the discussion of game components and typical circuitry.

Well, what do you know! Many months ago we started a series of articles called "Pinball Troubleshooting" and we are now up to Part 8 and finally getting around to the actual business of "troubleshooting." Well, that's not exactly the case. Before anyone can troubleshoot anything they must be able to understand basically how it works. For this reason we have spent the bulk of this series describing all the basic game components, how they operate, how they are used, and the basic circuits by which they are connected to perform actual game functions.

It is also not true that trouble-shooting has not yet been described. Two very useful and basic techniques, the Zero Ohms Test and the Voltage Drop Test, were described in a previous article. In addition, a simple method of testing relay hold on circuits was also described, as well as other miscellaneous troubleshooting hints scattered throughout the previous articles. In the final part of this series other important fault isolation techniques, and associated test equipment, will be described. First, however, the concept of trouble-shooting (or fault isolation as it is sometimes called) will be discussed.

The first step in fault isolation is to determine what is wrong. To do this you must ask the question, "What doesn't the game do?" This is the first question I ask of anyone who tells me of a malfunctioning game. The answer to that question should provide the clues to the source of the problem. When troubleshooting, all clues are important and should be considered, no matter how insignificant they appear to be.

The next step is to use the clues (symptoms) to help locate (on the schematic first, and then in the game) the circuit components that are involved in performing the game function(s) that are not being properly performed. For example, if the symptom is the game's bonus feature is not scoring properly, the bonus scoring circuitry (relays, bonus step up unit, etc.) is most likely at fault. But if there is an additional symptom in which other scoring (in addition to the bonus) that occasionally malfunctions, you must consider that a malfunction in the basic scoring circuitry (score relay, score step up, or drum unit, etc.) could be interfering with the proper operation of the bonus circuitry. The point to be emphasized here is that all symptoms must be considered collectively in trying to isolate the cause of a problem. Of course, you must also allow for the possibility that more than one (sometimes many) problems can exist at one time.

The next step is to perform organized tests on the suspect circuitry to try to locate the faulty components). The test methods to be described shortly, as well as those described in previous articles, can be used for this purpose. After a little experience you should be able to more easily decide what tests to perform under what conditions.

NOTE: There are two general types of malfunctions, intermittent and sustained. The latter type is much easier to troubleshoot because the failure is always there and all you have to do is systematically track it down. The intermittent failure, on the other hand, represents the most difficult (and sometimes seemingly impossible) type of malfunction to track down. This is true of intermittent in not only games, but any other device for which servicing is required (automobiles, TV sets, computers, etc.). There are two possible situations involving intermittents. Hopefully the problem will eventually worsen and become a sustained problem, thus simplifying troubleshooting. If not, you must very carefully study all clues and try to make a logical guess as to the possible causes of the problem, and check these out one by one.

Game troubleshooting requires certain test tools to aid the "mechanic" in fault isolation. One of the most important of these, the Volt/Ohmeter, was mentioned in "Part 6" of this series, when the Zero Ohms Test and Voltage Drop Test were described. Other simple home made devices will be described in conjunction with the test methods describedin this article.

Test Light Techniques

Probably the handiest tool a game troubleshooter can have is a home made gadget I call the test light.

While it is true that any test using the test light can also be made with a voltmeter, the test light is, in general, more convenient and easier to use, because it provides an easy visual indication of the presence of electric power without requiring one to look away from the area being tested to observe a meter reading. I will first describe the construction of this simple device and then present some examples of how it can be used for fault isolation in a game.

NOTE: The examples of various testing techniques will often refer to Figure? (Complex Game Circuit), which was included in "Part 7" (the September and October issues of The Coin Slot of this series.

The test light simply consists of a miniature lamp with suitable socket, with two wires connected one to each side of its two connections, each terminating in an alligator clip a spring loaded electrical clip on connector available at most electronic supply stores). The lamp should be chosen with a voltage rating consistent with the voltage in the circuit being tested. I have found that a 50 volt lamp is suitable for testing game coil circuits with supply voltages between 25 and 50 volts (the lamp glowing at about half brilliance at the lower voltages). For testing 6 volt lamp circuits, a 6 volt lamp should be used. When using any test light one should be keenly aware of the voltages present in the circuits being tested so as not to burn out the test lamp (50 volt lamps are fairly expensive and will be destroyed by 110 volt circuits). For testing these circuits use either a 110 volt lamp or your voltmeter.

NOTE: The alligator clip used should have insulated grips to prevent electric shock when connecting them to higher voltage circuits. The schematic diagram for the game (if you have one) can be used to determine the voltages in each circuit. If you do not have a schematic, a volt-meter should, at least initially, be used to determine circuit voltages.

The purpose of the test light is to detect the presence of voltage at any point in a circuit. For this to be done, the game must first be turned on (and normally a new game started, if possible), of course. If the game shows no sign of being energized, the 110 volt power circuits supplying the transformer's primary must be checked using a voltmeter, and any problem found corrected so that power is supplied to the transformer.

Since most test light testing is done on the game's coil circuits, examples of this type of testing will be given utilizing the typical complex game circuit, illustrated in Figure 7 in last month's article. All references to circuit points by letters will refer to the lower case letters in parenthesis shown on that figure. Similar testing can, of course, be performed on lamp circuits using a 6 volt lamp.

Normally during testing one side of the test light would be connected to some common circuit point (usually a power return line) and the other side moved from point to point to detect the presence of voltage. Since the object of most testing is to determine why voltage is not being applied to one of the loads (coils in the examples to be given) this common point is usually the game's coil common line (point "d" in Figure 7). This can easily be accomplished by clipping one lead of your test light to the coil common side of one of the game's coils. The proper coil terminal can be determined by the color of the wire corresponding to the color code indicated for this line on the schematic diagram.

As you can see from Figure 7, the coil common line in this example is not connected directly to the transformer, but through the fuse and a normally closed switch on the "Tl LT' relay. (In some games utilizing a "GAME OVER" relay, a normally closed switch on that relay would also be in series with this line.) In addition, there are quite possibly one or more intervening quick disconnect connectors in this line.

Any one of these circuit elements could have a problem itself (open circuits or unwanted resistance) preventing the coil common line from getting the proper voltage. So, before you use this line as a reference point for testing, the coil common line itself should be tested.

This can be accomplished by connecting the other side of your test light to the opposite side of the transformer's secondary (point "x" in the Figure). If the light lights you know the coil common line is receiving voltage from the transformer, and hence the fuse, "TILT' relay contacts, etc., are all operating properly. If the lamp fails to light you have a problem in one of those components (or there is no 110 volt power to the transformer's primary). A check of these circuits can quickly be made using your test light. Since this itself is a good example of test light testing techniques, this procedure will be described.

NOTE: Unless the game has a major malfunction, one symptom ofwhich is most of the game's coils are not operating at all, this coil common line would most likely be operating properly, therefore the tests of the circuit to be described would normally not be necessary unless that symptom existed.

Leaving one lead of your test light connected to point "x" (one side of the transformer winding), move the other lead from point "d" to point "b." If the light now lights, you know you have a problem in the normally closed "TILT' relay switch (or possibly an intervening quick disconnect connector). If the light still fails to light, move your lead to point "a" (the transformer itself). You now have your test light connected directly across the transformer's secondary (point "x" and point "a"). If the light now lights, your problem must either be a blown fuse, a bad connection in the fuse socket, or a faulty contact in a quick disconnect connector.

If the light still fails to light, you either have a bad transformer (very unlikely!) or most likely no 110 volt power to the transformer's primary. Get out your voltmeter and check the voltage across the primary terminals, and if none is present determine why and correct the problem. If voltage should be present on the primary, then you have a bad transformer. (In all my work with games I have never found a faulty transformer.)

After you have located and repaired any problems in the coil common circuit (your test light lights when connected between points "x" and "d") you are now ready to use your test light to find further faults in the game.

NOTE: The example used here shows the fuse and "T l LT' relay connected in series with the coil common line. This is not always the case. In some games the coil common line may be connected directly to one side of the transformer and the other coil power line (labeled "x" in the Figure) may be fused and/or broken by the "T l LT' and/or "GAME OVER" relay switches. Consult your schematic to determine your configuration, modify the test just described to suit it in order to determine if your coil common line is receiving power from the transformer. You should also be sure that the coil you use to make your coil common test light connection is one whose common power is broken by the "TILT'(and/or "GAME OVER") relays, if your circuit is so configured.

There are two initial choices that can be made prior to performing a test light test; whether to test from the load up or from the power down. Both methods provide the same end result (finding the source of the problem), the difference being in the amount of time it takes to find the fault. Some examples should clarify what is meant by these two types of testing. In the example to follow it will be assumed that one lead of your test light is connected to the coil common line (point "d" in Figure 7), unless otherwise noted, and that this point has the proper voltage applied to it

Load up testing is generally chosen when you suspect a bad load (burned out coil, lamp or motor). Assume, for example, that the symptom of a malfunctioning game is "10,000 points" are never scored. You might therefore suspect a bad "10,000 step up" coil. To test for this clip the other lead from your test light to point "k" (using the coil terminal) and operate the "10,000 relay" armature by hand so as to close the "10,000 relay" contacts, which energizes the "10,000 step up" coil. At this point three possible results can occur.

First, the coil might be energized and the light will glow, which indicates that that circuit is operating properly. The second possibility is that the light glows, but the coil does not energize. This indicates a bad coil and your problem has been found. The third possibility is that nothing happens, which indicates that either the "10,000 relay" switch is malfunctioning or that an intervening quick disconnect connector (or a broken or loose wire) is the culprit. To check for this, move your lead from the coil terminal to the solder lug on the "10,000 relay" switch, itself connected to the wire of the same color as that connected to the coil terminal you were just connected to (you are still connected to point "k," only at a different place to check intervening wiring and connectors).

Again operate the "10,000 relay" by hand. If your test light now lights, the "10,000 relay" switch is OK and the problem lies in the wiring (including any quick disconnect connectors) between that switch and the "10,000 step up" coil. If the light still fails to light, you would move your lead to the other solder lug of the switch (connected to point "x"). You now have your test light connected across the power supply lines to the circuit If it now lights the problem must be a faulty "10,000 relay" switch. If it still doesn't light, power is not being supplied from the transformer(point "x") to the "10,000 relay" switch (we are, of course, assuming that the coil common line (point "d") has been tested as described previously). You should then check all wiring and intervening quick disconnect connectors between the transformer (point "x") and the "10,000 relay" switch.

NOTE: In the proceeding example, it was assumed that you knew the "10,000 relay" coil was not the problem because it operated when energized and therefore the "10,000 stepup" circuitry was suspect.

Power down testing is generally employed when you have reason to believe that the load itself (lamp, coil or motor) is functioning properly and you suspect one of the switches controlling it to be faulty. For example, lets say you know the "50,000 relay" coild is alright because it energizes when you hit one of the "50,000 bumpers," but the hold on circuit does not seem to operate on that relay. You would first connect your test light to the power supply to that circuit (points "d" and "x"). If the light lights, you know power is being supplied to the circuit

The test light lead originally connected to point "x" should now be moved to point "f." If the light still lights, you know "Motor Switch 5A" is operating properly. If the light fails to light that switch is either not making good contact, or there is a problem in the intervening wiring or connectors.

If the light lights when connected to point "f," move your lead to point "e" and operate the "50,000 relay" by hand. If the light now fails to light, the problem must be in the "50,000 relay" hold on switch (or intervening wiring or connectors). NOTE: As was pointed out earlier in this series, all points on the schematic, such as point "e" in the above example, actually have two or more connections in the game (i.e. both ends of the wire plus any terminations at intervening quick disconnect connectors). Point "e" terminates at both the "50,000 relay" hold on switch and the "50,000 relay" coil. If current is found to be present at one of these points and not the other, a problem must exist in the intervening wiring or quick disconnect connectors This is a very important point to keep in mind and often overlooked by inexperienced troubleshooters.

The examples given above should give the reader the basic ideas of test light troubleshooting. Once one becomes familiar with these techniques, he should realize that they are a quick and easy way to track down most game malfunctions.

Before leaving the subject of test light testing two points should be made. Several times during the above discussion I have referred to operating relays by hand. By this I mean pushing the armature against the coil (or tripping by hand a latch-trip or relay bank relay), so that the switch(es) on that relay will operate. In the above examples only one relay was involved, but sometimes it becomes necessary in testing a series circuit to operate more than one relay simultaneously. In these cases you may want to short out a switch using a clip lead (more about these later) rather than physically operating the relay. To do this, you would simply clip the two ends of the clip lead to the two solder lugs of the switch you wish to close.

NOTE: The clip lead method is fine when you just need to operate one normally open switch on a relay, but you should keep in mind that other switches on that relay (and the normally closed side of a single pole double throw switch) are not operated by this method, which could cause abnormal circuit operation. An alternate method would be to place some object between the top of the armature and the metal stop (which keeps the armature from coming up too far when the relay is not energized), such that all switches of the relay are operated as if the relay were energized).

The final point to consider is the major weakness of test light testing. Testing circuits using a test light is similar to the Voltage Drop Test, described in a previous article, with one major difference. In the Voltage Drop Test the actual voltage of each point in the circuit is measured rather accurately. In test light testing the light merely gives an indication of the presence or absence of a voltage. If the voltage is less than it should be, the lamp will glow somewhat dimmer, but it will take possibly a 20% decrease in voltage before most people might notice the difference. The point to be made is, even if the lamp test seems to indicate that a circuit is operating properly, if problems still exist double check that circuit using your voltmeter.

PART 8 CONTINUED

Clip Lead Testing

One ot the simplest, and almost foolproof methods of troubleshooting game circuits utilizes a simple clip lead (sometimes referred to as a jumper wire). This is used to by-pass suspected circuit elements, in a systematic manner, in order to locate faulty components. As early as 1937. Bally described this method quite well in a small pamphlet provided with a game called LINE UP (and most likely others as well).

The only tools required to perform this test is one (or occasionally more) clip leads. A clip lead is simply a length of electrical wire terminated at each end with an alligator clip (see the previous discussion the November issue of the construction of the test light). These leads can be purchased at most electronic supply stores or home made. I have found it very convenient to have one clip lead at least three feet long that you would almost have to make yourself.

The basic principle of this method of testing is really quite simple. One end of the clip lead is connected to the power source and the other end used to apply power directly to various points in a circuit. This. In effect, bypasses all circuit elements between the power source and the location where your clip lead is connected.

Generally, the lead would first be connected to the load (lamp, coil. or motor) in the circuit being tested (the other end of that lead must, of course be connected to the proper power source for that load: six volts, coil voltage, 110 volt line. etc.). If the load now operates, you know it is good, and the problem is in either a switch or wiring (including connectors) that have been by-passed by the clip lead. If the load fails to operate it is the problem.

NOTE: It is assumed you know that the power source to which your clip lead is connected is providing the proper voltage, and that the other side of that power source is supplying power to the common line to which the other side of the load is connected. If there is any doubt about this you should first test for voltage between these two points using a voltmeter or test light.

If the load operates when connected to the power source via the clip lead, the next step is to move the clip lead back one point in the circuit 'unbypassing' one of the switches in the series circuit, if that switch (or parallel combination of switches) has a normally closed function the load should still operate. If the switch is normally open it must be closed by hand first. If the load still operates you know that switch is operating properly, and the problem must be in the rest of the circuit that is still bypassed. If the load does not operate, you have isolated the problem to the switch (or switch combination) just 'unby-passed' (or any intervening wiring or connectors).

NOTE: If you are dealing with a parallel combination of two or more switches, each switch must be operated by hand separately to insure that all are operating properly (each should energize the load when Closed). If any of these parallel switches are normally closed all of these should be first opened, as any closed switch in a parallel combination will operate the load such that the other switches) cannot be tested. A simple way to open these switches is to place a piece of paper between the two closed mating contacts, pulling the paper out to again close the switch. Remember, only one switch in a parallel combination should be closed at a time during testing of that combination.

You should continue to move the clip lead back one point in the circuit at a time, (closing all normally open switches in the circuit between the point to which you are connected and the load) until you find a point where the load fails to operate (when all switches are closed). At this point you have isolated the problem to the switch (or parallel combination of switches) you last 'unby-passed' with your clip lead (or any intervening wiring or connectors). You should then check these elements to find the problem. The Zero Ohms Test, described in a previous article, or the Continuity Test. to be described shortly, are good test methods to use for this purpose.

NOTE: If intervening connectors are present in the circuit, you may consider them as series circuit elements (equivalent to a normally closed switch) and test them by clipping your clip lead first to one side of the connector pair of mating contacts and then to the other. If the load operates in one case and not in the other the problem must be in the connector.

Test example

An example, Figure 7 from the article in the October issue, should serve to clarify the test method just described. Suppose you wish to test the energizing circuit for the "10,000 Relay." You would first connect your clip lead to point "x" (assuming you have already determined that the full coil voltage is present between that point and the point "d" coil common line). The other end of your clip lead should then be clipped to point "g" (the coil terminal on the "10,000 Relay" not connected to coil common). If the coil now operates (i.e. the relay pulls in) you know that the coil is all right; if not, your problem is a defective relay coil.

Assuming the coil is found to be operational, you should next move your clip lead from point "g" to point "h�even on the switch stack of the ‘50,000 Relay." Since the switch involved in the circuit on that relay is normally open you must next close it by hand. If the "10,000 Relay" now operates you know the switch just tested is operating properly. If not, your problem is either in that switch or in the wiring between that switch and the ‟10,000 Relay" coil. The latter possibility can quickly be eliminated by moving your clip lead to the other solder lug on the switch you have just tested (which is also point ‟g"). If the"10,000 Relay" now operates the problem is definitely In the switch. If it does not operate there is a problem in the point "g" wiring between the "50.000 Relay" switch and the "10,000 Relay" coil.

Now, assuming you have determined that the ‟50,000 Relay" switch is operating properly, your problem has been isolated to the "Motor Impulse" switch (or the point "h" wiring between it and the "50,000 Relay" switch).

This wiring can, of course, be checked by moving your clip lead to the solder lug on the "Motor Impulse" switch, which feeds point "h," and closing the "50,000 Relay" switch by hand. If the " 10,000 Relay" coil does not operate the problem is in the point "h" wiring (including any connectors).

The testing just described tests the "50,000 Relay" energizing circuit for the "10,000 Relay" coil.

Similar testing can be performed on its hold-on circuit (utilizing point "j" in lieu of point “h"). This example, plus the general principles previously described, should give a person a reasonable idea of how to apply this useful testing technique.

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Continuity Testing

The final testing technique to be discussed is called continuity testing. Continuity testing is, in reality, another form of the Zero Ohms Test (described in a previous article), only using a visual indication from a lamp in lieu of reading an ohmmeter

For this reason no specific examples of actual circuit testing will be given here as the reader can refer to the discussion of the Zero Ohms Test. The test device itself will be described followed by a discussion of a few instances where the use of continuity testing is sometimes desirable over the use of the Zero Ohms Test

NOTE: When continuity testing is used in lieu of Zero Ohms Testing one important point must be kept in mind. Zero Ohms Testing actually performs two functions that are related. One is to detect open circuits (infinite resistance) and the other to detect unwanted resistance. The continuity test, for all practical purposes, can only detect open circuits since the presence of unwanted resistance (unless that resistance is fairly high) would only result in a small decrease in brilliance of the test lamp, which normally could not be noticed by the eye.

The continuity tester is actually a simple series circuit consisting of a battery (power source) and a lamp (load) with two clip leads to complete the circuit To construct one you need a lamp (with socket), a suitable battery(ies) with some means of holding them (and connecting the batteries in series when more than one is used), and two wires with alligator clips on one end of each wire.

The lamp chosen should be either 1 1/2 or 6 volts A 1 1/2 volt lamp requires only one 1 1/2 volt flashlight battery, a 6 volt lamp requires four such batteries connected in series (that is the positive terminal of each battery connected to the negative terminal of the next, etc., leaving one of each type of terminal available for external connection). Battery holders made to hold four batteries and connect them in series, are available at most electronic supply stores.

One terminal of the battery (or series string of batteries) must be wired to one connection on the lamp socket. The other battery terminal and the other lamp socket connection should each have a wire, terminated by an alligator clip connected to it When the two clip leads are then touched together a complete circuit should be made thus lighting the lamp.

NOTE, ready-made continuity testers can be purchased at some electronic stores. If you decide to buy one, get one that uses batteries and an incandescent lamp. Some solid-state units are available but these should be avoided, as they will indicate continuity even though a coil might be in the circuit. An incandescent lamp will generally glow noticeably dimmer if you're in series with a coil so you know you do not have a circuit of zero ohms or there-abouts. Some testers use batteries and a buzzer (in lieu of a lamp). These will generally be acceptable but less desirable.

Before discussing the uses of the continuity tester, a word of caution should be given. As was the case with the Zero Ohms Test, all continuity testing must be performed with all power off on the game being serviced. This means that the machine should be unplugged from 110 volt house current before attempting any continuity testing.

There are three types of tests for which continuity testing is quite useful because it gives a quick visual indication as to whether or not a closed circuit exists. These are: wire tracing, testing of quick disconnect connectors, and testing of switches (on relays, etc.). Always keep In mind, however, that the continuity test only gives an indication of an open or closed circuit and Is not a reliable substitute for the Zero Ohms Test in detecting unwanted resistance. In this same light, it should be pointed out that if continuity testing seems to indicate that a circuit is alright, but that circuit still does not seem to function properly, use the Zero Ohms Test to check for unwanted resistance in that circuit

Wire Tracing

Wire tracing is checking a wire, either run directly or through one or more quick disconnect connectors, to determine if it has continuity (i.e. makes a complete zero ohms circuit). The wire to be traced will have the same colors) wherever it appears in the game, even though it may pass through one or more connectors, One should beware, however, that some color code combinations are used for more than one wire. For this reason you should make sure that each circuit point you test is connected to the wire you are testing by making reference to the game's schematic.

NOTE: The wire we refer to may actually consist of more than one physical length of wire, as long as each of these wires is electrically connected together at solder terminals or by quick disconnect connectors. A wire Is represented on a schematic by a line connecting two or more circuit elements together and may have several branches as long as there are no intervening circuit elements other than connectors.

Before beginning any continuity test, check your tester by touching the two clip leads together causing the lamp to light. Now connect one clip lead to one connection point (solder lug on any component connected by the wire being tested) of the wire. Touch the other clip lead to each of the other connection points (circuit element solder lugs) for the wire being tested as shown on the schematic If the lamp fails to light when connected to any of these points an open circuit exists somewhere in the wire being checked.

If, when your lamp fails to light, the two points you are connected to are in different areas of the game (i.e. one end in the backbox and the other on the playfield) then the wire you are testing goes via one (or more) quick disconnect connectors, which could be the source of the problem. To check for this remove one of your clip leads from its connection point remembering where you had it. Now go to the connectors in the game area where your other lead is still connected and look for a connector terminal with a wire connected to it of the same color(s) as the wire being tested.

Next, touch the free clip lead to the solder terminals for that wire on each of the mating connectors. If the lamp lights each time, the connector is fine. If the lamp lights on one side of the connector only, the connector must not be making a good connection. If the lamp does not light on either side of the connector, there is either a problem somewhere else in the wiring, or you are testing a different wire on the connector with the same color(s), so look to see if there are any more wires on the connectors in that area with the same color(s) and test them also

The above discussion should give one the basic principles of wire tracing using the continuity tester. Once an open circuit is found you must next determine the cause. It could be a connector (as just described), a loose wire (unsoldered from a terminal or a poor solder connection), or even possibly a broken wire (the conductor severed inside the insulation). The latter condition is rare but I have seen it several times. Once the problem has been isolated to a particular section of the wire you must systematically check for all possible causes

Switch Testing

Another common use for the continuity tester is to test a particular set of switch contacts or a pair of mating elements of a connector. In both cases the two clip leads of the continuity tester are connected to the two solder lugs of the switch, or pair of connecting elements of a connector that you wish to check In the case of a connector, or a normally closed switch, the lamp on the continuity tester should glow indicating the element being tested is alright if the lamp glows dimly (dimmer than when the two clip leads are directly shorted together), or not at all, the element being tested is making a poor connection (unwanted resistance) or no connection at all (open circuit). If you are testing a normally open switch you must first close the switch by hand before the lamp will glow.

This completes the discussion of continuity testing (and all testing for that matter). As was implied previously, continuity testing can be used in lieu of Zero Ohms Testing to test for complete series circuits. Remember, however, the warning (which applies to all tests using lamp indications in lieu of a meter) that if the circuit being tested seems to check out, but still does not operate properly, double check using your meter.

Closing Comments

Whew! This is it! What I originally envisioned as a two or three article series on pinball troubleshooting has ended up in eight parts, taking twelve issues to publish. What happened, actually, is that I just can't knowingly leave anything out I try to tell everything about everything, which of course is impossible, but I gave it a shot

I have tried to gear this series primarily for the person who has never worked on a game before. This is why I spent a lot of time describing game components in detail and very basic electrical circuit theory. I hope, however, that some of what I have said can also be of help to the more advanced troubleshooters as well, since much of it has come from things I have encountered in working with games over the years.

I have also tried to make this series applicable to both old and more modern machines., The basic circuit theory is the same, of course, and many components are almost identical, the later ones being a little more sophisticated perhaps and possibly better designed. The basic components (relays, stepping switches, etc.) have actually changed very little over the years, other than in the construction.

Before closing one important point should be made. There is no substitute for experience! I am constantly amazed at the new things I discover while working on games. New troubleshooting techniques are developed by necessity when trying to solve a particular problem. New circuit configurations are discovered when working on some more sophisticated game circuitry (those pinball designers were no dummies). You never stop learning. That old adage, "experience is the best teacher" is certainly true when it comes to pinball troubleshooting.

What! No Game?

What if you don't have a malfunctioning game to work on right now? Here are a few suggestions on how to make the information presented in this series more relevant First, copy all of these articles and bind them together like a booklet Next. Read them over again trying to absorb more from each subject When reading descriptions of components, open up a game and look at a typical component as your read the description. Operate It by hand when ever possible. When reading descriptions of circuit configurations, get out a schematic and find a similar circuit. Try to follow the actual circuit while reading the description. You may also perform tests (Zero Ohms Test, continuity, clip lead, test lamp, etc.) on operating circuits to gain familiarity with performing those tests as well as seeing what the indications should be on a properly Operating circuit.

These techniques should greatly help to strengthen your understanding of this subject until you have the opportunity to troubleshoot a real game problem. Good Luck!