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A Gringo’s Guide to Mexican Wiring

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1 Introduction

As an electrical engineer (now retired), I have always been interested in the reasons why residential electrical wiring was done the way it was in the US. Sure, the "Code" says so, but why exactly do we handle earth ground the way we do? And why is it still required when a GFCI breaker or outlet is used in the same circuit? After moving to Mexico, my interest became even greater because here I discovered that there is a whole new way of wiring things. Some of these ways were just different, but others were down-right dangerous.

Our first Mexican home had been built around 1987, and the visible wiring in the pool area was appalling. It worked, but I decided to fix it so it looked better. But the more I got into tracing the actual circuits, the more I discovered things in the way the circuits were connected that were just plain wrong, so I traced everything out and came up with a plan to redo it. This was so much fun that I decided to do the same thing with the wiring inside the house itself. Then it was on to the main circuit breakers and the meters. Thinking that what I was learning might be of interest to other gringos, I decided to keep detailed notes as I went along.

Then we bought another house that was newer (built about 2000) and which appeared to have more modern wiring. Before we bought the home, I had it inspected by a local professional home inspector, and I personally checked all the outlets for proper wiring using a simple 3-light tester. Everything checked out OK, but I soon discovered that it really wasn't. So I decided to repeat my tracing and rewiring on the second house. Again, the more I did, the more strange problems I discovered, corrected and documented.

Meanwhile, I had partnered with a local architect/contractor to build a new house as an investment. This provided an opportunity to see whether what I had learned could be applied to new construction. So together we wrote specifications for the electricians and provided them with a detailed electrical plan to use. The idea was to see if the standards used for residential wiring in the US could be easily adapted to Mexican construction. They can.

This book tells what I have learned after re-wiring the two older houses and wiring a new house using the specifications we developed. It is written for anyone who, like me, wants to live in a Mexican house that has reliable and safe wiring.

In places, I am critical of what I have found, because while the wiring "worked," it was often unreliable or even dangerous. But I do not mean to be too critical of Mexican electricians. Many of these men work with only on-the-job training and with a pair of pliers as their only tool. They work with minimal plans, no test equipment and no written specifications. The ones I have met are delighted to find someone who has an interest in their work, and they are willing to do whatever is wanted in whatever manner is requested. In other words, they are eager and willing to learn how to do things the "right" way.

Sections 9 through 13 of this book contain details of the modifications I made on the two houses we lived in and my experience with building the new one. They are worth reading if you intend to follow any of the techniques described for upgrading your house in the previous sections because they offer examples of what I found, what I decided to do about it, and how I did it.

Which brings me to an important point. While reading this book is safe, working with electricity can be dangerous. Anyone who is interested in understanding how Mexican homes are wired should find this book useful. But you need to know your own limitations when making any of the actual changes discussed. Anyone who has had previous experience wiring in the US or who has worked in construction should have no trouble as long as you are aware that things are not always as they appear. ***You cannot assume that a lighting circuit is unpowered just because the light is off or that a wire is not hot just because it is white or green.*** Please be careful, and try to find a local electrician who will work with you on the tricky stuff!

2 Similarities and Differences

2.1 Secondary Line Voltages and Phases

The voltages entering your home are called secondary, and they are either single (or two) phase 120/240 VAC as found in the US or three phase 127/220 VAC.

Single/two phase power is obtained from a single secondary winding on the power company's step-down transformer. The transformer is center-tapped to form two high side or line voltages along with the neutral that connects to the center tap. See Figure 2-1.

Figure 2-1 Two Phase Line Voltages

After passing through the circuit breaker panel, one line and one neutral form various branch circuits that are used throughout the house for lighting, plug-in appliances, etc. Regardless of whether line 1 or line 2 is used, these circuits provide 120 VAC. Larger appliances, such as an oven, operate from the 240 VAC provided by line 1 and line 2. The line to line voltage is 2 times the line to neutral voltage.

In the US, this is called single phase power, and both lines 1 and 2 are provided along with the neutral. In Mexico, smaller houses may receive only line 1, and this is called single phase power. When both lines 1 and 2 are provided, it is called two phase power.

In Mexico, the power company (CFE) also distributes three phase power. In this case, their transformers have 3 secondary windings. One side of each of these windings is connected together to form the neutral. With three phase power, the line to line voltage is $\sqrt{3}$ = 1.732 times the line to neutral voltage. See Figure 2-2.

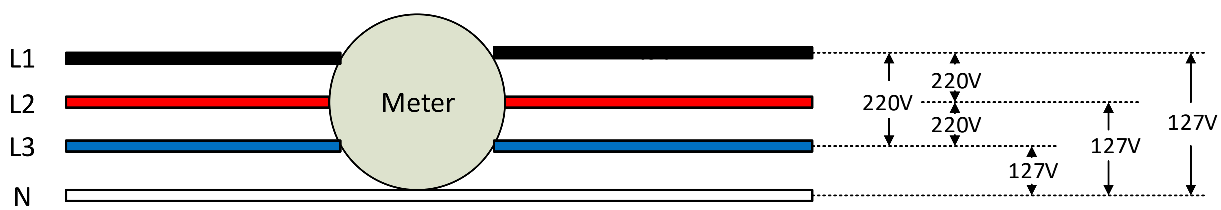


Figure 2-2 Three Phase Line Voltages

With three phase power, there can be three different line to neutral branch circuits providing 127 VAC, three different line to line circuits of 220 VAC, and a three phase 220 VAC circuit suitable for larger motors used for pool pumps, etc.

Our first house in Mexico (Casa Erres) was in a neighborhood that had three phase power. All the houses used two phase or multiple single phase meters except ours which had a monstrous three phase meter. At one time, all three phases may have been used for the original pool equipment, but one of these had since been abandoned, and only two of the three phases were wired to the house. In general, it is difficult to tell whether power is coming from a two phase or three phase transformer without measuring the line voltages, because the wiring will appear the same.

Any decent appliance in North America will operate from a voltage of 120 +/- 10% or 240 +/- 10%. The 127 and 220 volts found in three phase Mexican power are within these ranges, so using US appliances in Mexico should work just fine.

2.2 Earth Ground Wiring

In the US, a separate earth ground wire connects to all exposed metal surfaces in the electrical system. In Mexico, the use of a separate earth ground is typically limited to the wiring for major appliances (washing machines, refrigerators, etc.) and to kitchen appliance outlets. Newer houses have all outlets wired with an earth ground, but unlike the US, the earth ground is usually not connected to metal switch boxes, junction boxes, etc. If the outlets in your home have 2 prongs, this is a sure sign that there is no earth ground on that circuit, but if they are 3 prong outlets, there is no guarantee that the third prong is actually grounded.

A very simplified diagram of a (correctly) wired house is shown in Figure 2-3 below. There are many similar diagrams in this book so it is worthwhile pointing out that black horizontal and vertical lines represent wires with their color and size indicated in red above them. The red dots indicate an electrical connection. Where wires cross without a red dot, they are not connected. The diagram below shows just one subpanel and one branch circuit. The colored rectangles represent the "buses" inside the breaker panels used to distribute line 1 (black), line 2 (red), neutral (white) and earth ground (green). The terms "line", "hot" and "high" are used interchangeably. "Neutral" always refers to the return circuit and "Ground" or "Earth Ground" to the non-current carrying conductor. The Main Service Panel provides a means to disconnect the entire house and should be located very close to the meter(s).

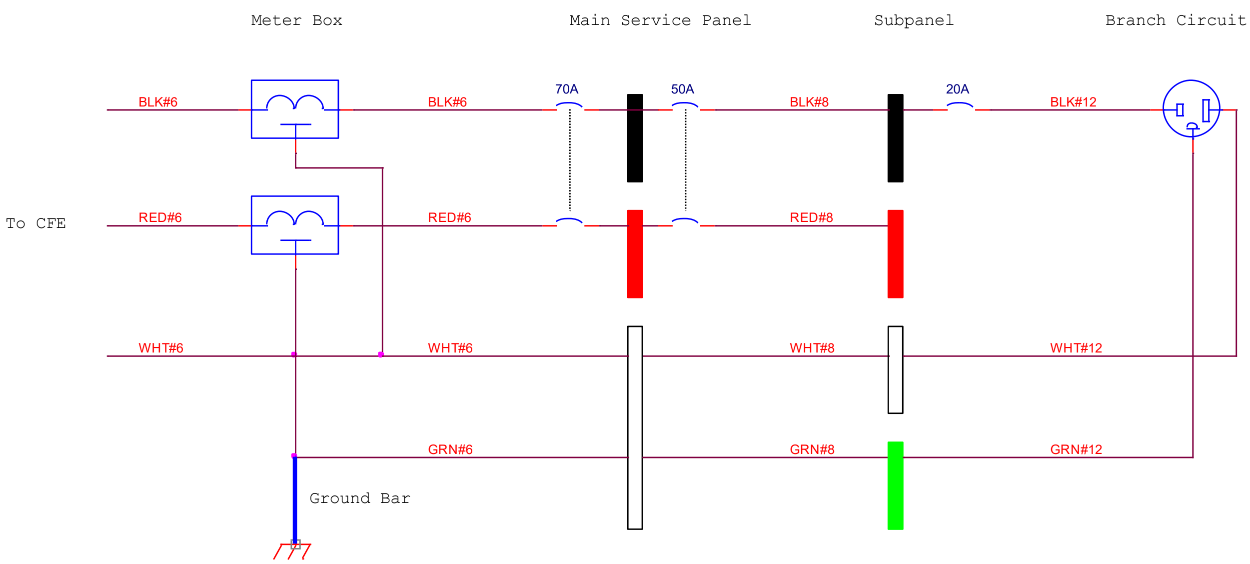


Figure 2-3 Simplified Power Distribution Showing Connection between Neutral and Earth Ground at Meter and Main Disconnect Panels

Under normal (no fault) conditions, the earth ground conductor never carries any current. At the main service panel and/or meter only, it is connected to the neutral wire. (At any subpanel, the neutral and earth grounds are not connected together). Also at the service panel/meter the earth ground conductor is connected to a large conductive stake driven into the earth. It may also be connected to the cold water plumbing to provide a low resistance connection to the earth. The earth ground conductor may also be connected to the plumbing at appliances such as washing machines from branch circuits inside the house.

The reason for not connecting the earth ground to the neutral at the subpanels is so the earth ground does not become part of the neutral circuit. If the two were connected at a subpanel, the return current from the subpanel to the meter would divide between the neutral (white) conductor and the earth ground (green) conductor. Neutral return current might also be flowing through all other earth ground conductors such as the plumbing piping, etc.

The earth ground serves two purposes. The earth connection at the entry panel/meter provides a low resistance path for high voltages that might occur if a fault in the power company's system results in a high voltage on the neutral conductor. Its other purpose is to provide an electrical path that will cause the circuit breaker to trip or a fuse to blow if the line (hot) side of the wiring short circuits (faults) to something metallic that can touched by a person.

Suppose, for example, the line shorts to the case on a washing machine. The current through the 20 amp circuit breaker on this circuit will be the same with or without this fault - about 5 amps. If you touch the case of the washing machine and are standing on a wet floor, the current through your body could easily be 0.1 amperes which is potentially fatal. The current through the circuit breaker would increase to 5.1 amperes, but this is not enough to trip the 20 amp breaker. On the other hand, if a separate earth ground were connected to the case of the washing machine, and it were also connected to the neutral at the service panel, the current would be very high (at least 100 amps) and the breaker would immediately trip. These two cases are illustrated in Figure 2-4 and Figure 2-5 below.

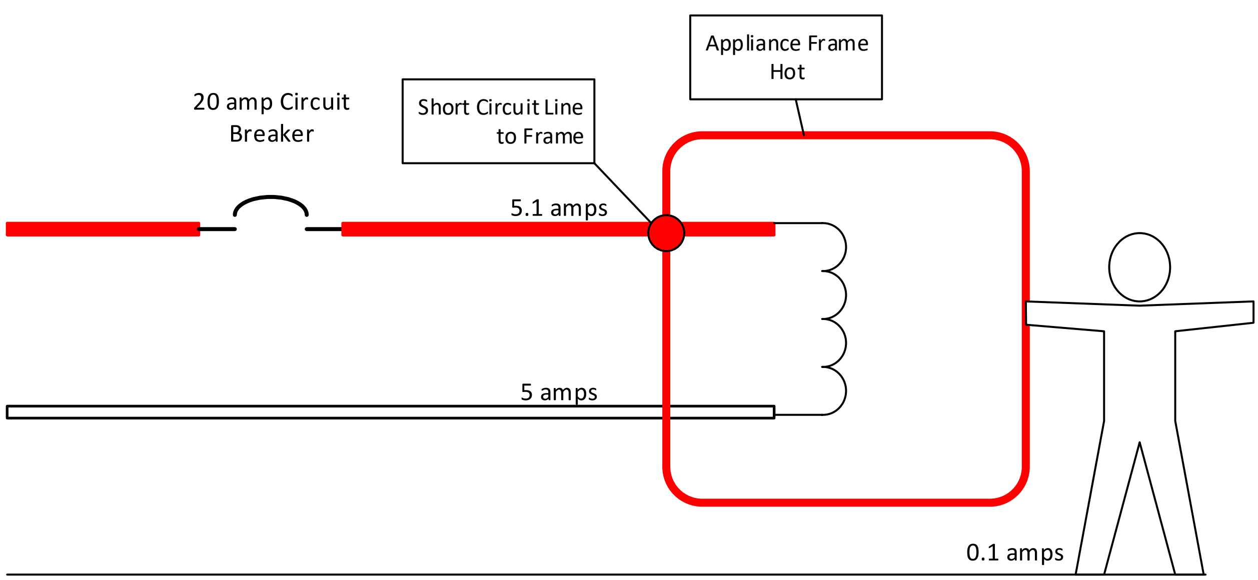


Figure 2-4 Line to Frame Short Circuit on Appliance with no Earth Ground Conductor

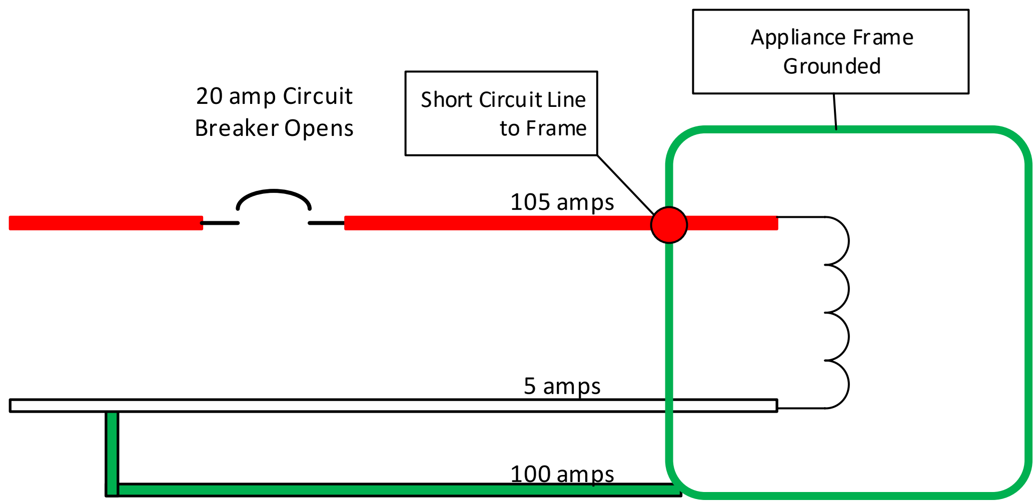


Figure 2-5 Line to Frame Short on Appliance with Earth Ground Conductor

At this point it is worthwhile to consider two questions. The first is, why not simply connect the neutral to the appliance frame and forget the earth ground wiring? This would cause the circuit breaker to trip open in the event of a line to frame fault, but it introduces another hazard as shown in Figure 2-6. If the neutral opens on this branch circuit, the entire frame then rises to line potential (through the low resistance of the load), and touching it results in a potentially lethal current through your body to the floor. So like the case shown in Figure 2-4, this is a single failure that results in a lethal hazard. In Casa Erres, the oven was actually wired this way (per the manufacturer's installation manual) in spite of the fact that an earth ground was present at the connection box behind the oven.

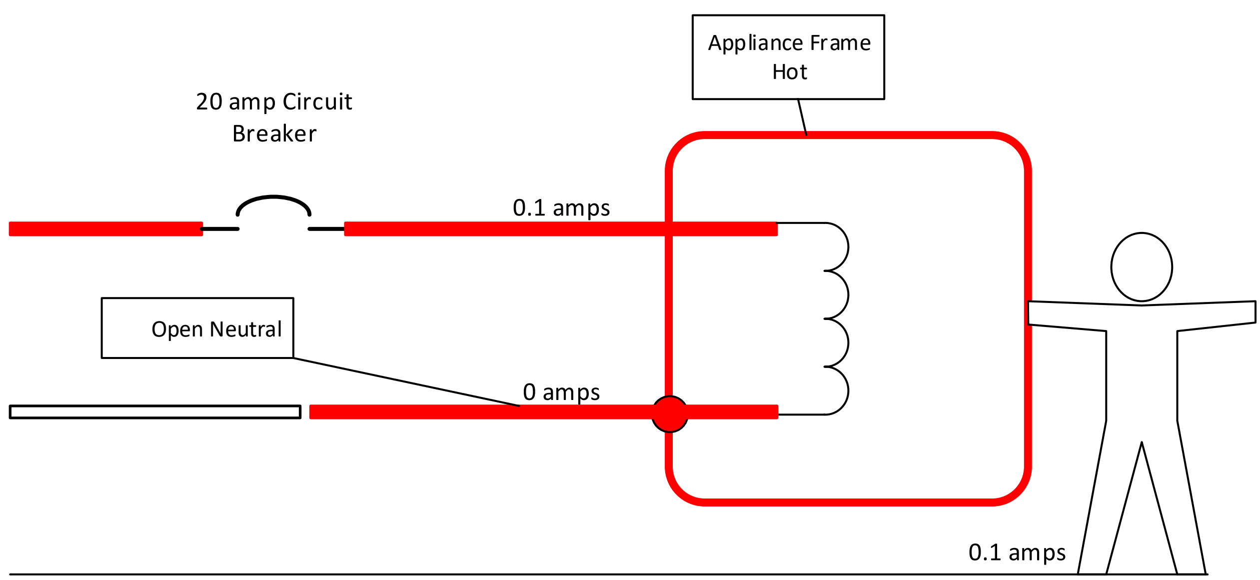


Figure 2-6 Connecting Frame to Neutral Introduces Hazard of Open Neutral

The second question is, why not connect the frame to a local earth ground such as a water pipe rather than running a separate earth ground conductor? This might work, but it might not either. It all depends on the resistance of the local ground path back to the neutral connector. In the case of Casa Erres, I found that although all the water pipes were copper, the pipes were actually insulated from each other at both the water heater and the water filtration system, and they were not connected to the neutral at the service entrance. So the connection between the washing machine frame and the water pipe served no useful protective purpose.

In addition to large fixed appliances like washers, ovens, pumps, etc. the faulty appliance might be a plug in iron, toaster, etc. that has a metal case. Actually these days there are not many such appliances. If you look around your house, you will see that almost all appliances only have a two pronged plug. What has happened is that manufacturers have double insulated their appliances so that a single fault within them will not cause the high voltage to appear on an exposed metal surface. Even most power tools are double insulated and use a two pronged plug. These are safe to use ungrounded. Major appliances with motors such as washing machines, refrigerators, etc. should always be grounded.

The other concern regarding the lack of an earth ground is the outlet box itself. Usually these are metal, and the older wall plates used in Mexico for switches, outlets, etc. are also metal and are electrically connected to the box through their mounting screws. This means that if the insulation on the hot conductor becomes exposed and touches the box, the plate will be at a lethal potential. This could occur in receptacle boxes, light switch boxes or any junction boxes used for pulling or joining wires. This fault is not as uncommon as it might seem because the common method for attaching devices (switches, outlets, etc.) to the metal boxes in Mexico is to use sheet metal screws. The sharp points on these screws can easily penetrate the insulation on the wiring and provide a short circuit to the exposed outer plate. I ran across three instances of this in the two houses I rewired.

We will discuss various ways to correct this hazard later, but in moving into a house in Mexico, I would recommend checking to be sure that such a hazard is not present. The easiest method is to use one of the simple voltage detectors available at Home Depot or hardware stores. These are probes that sense line voltage. The detectors are battery powered and indicate a high voltage by displaying a light and/or sounding a tone.

See the discussion in Section 5 regarding voltage probes and how to use them.

At this point, we are concerned with testing all wall plates for a faulty short between the plate and the line. Touch every metal plate in the house with the voltage probe and be sure none of them is “hot”. If you find one that is faulty, disconnect the circuit at the circuit breaker box immediately. Then call an electrician or repair it yourself by locating and removing the short circuit. When probing the wall plates, be sure to probe the various junction boxes also. These will have blank 4 or 5 inch square metal covers. Also check any metal surfaces on built in or plugged in appliances and the metal frames on light fixtures. It is unlikely that you will detect any such faults, but it will only take 15 minutes to test the entire house, and the consequence of failing to find such a fault is potentially serious.

If you do this, you will have identified and corrected any outlets or fixtures having hazardous exposed voltages due to internal shorts from the line side. But of course some or all of the house may still be wired without an earth ground conductor, so it is unprotected against a future short circuit between a high voltage conductor and an exposed metal surface.

There are several options for reducing this hazard.

The house could be rewired adding an earth ground wire to all outlets and switches. This would involve a lot of work, but since Mexican house wiring uses conduits, it is possible. A ground stake might need to be added near the entry box for connection of the earth itself.

Another option is to replace the standard overcurrent type circuit breakers or the receptacles in bathrooms, the kitchen and other shock prone areas with GFCI types. This is a lot simpler than adding a ground wire and less expensive.

Finally, the old metal switches and receptacles can be replaced with modern plastic ones. These will not only look better, but they are inherently safer by virtue of their insulated plastic covers.

Each of these options for upgrading the electrical system will be discussed later.

2.3 Wire Colors

In the US, electrical wires are color coded as follows:

- Green = Earth Ground
- White = Neutral
- Black or Red = Line side (any phase) or high side of switched load

In Mexico, the color coding is:

- Use whatever color wire is available.

Fortunately, this practice is changing, but on an older house the colors of the conductors will provide no clue whatsoever as to the function of the wire. For example the light switch box in the Casa Erres master bedroom contained a total of 12 wires – 3 were red and 9 were green. These were used for three different light switches. And <u>none</u> of these wires was earth ground!

There is a way to fix this that does not involve replacing the wires, but it does require considerable time tracing out the wiring in the house. This is discussed more in Section 3, but the idea is to use colored electrical tape at the ends of each conductor to identify its function once you have figured it out. This is allowable under the National Electrical Code (NEC) in the US as well. As a minimum, you should use the US standard color coding, but I would go a step further and use the following:

- Green = Earth Ground
- White = Neutral
- Black = Line phase 1 upstream of the circuit breakers (AWG 8 or larger) and any un-switched line (phases 1 or 2) downstream.
- Red = Line phase 2 upstream of the circuit breakers (AWG 8 or larger) and any "runners" in 3-way switch circuits that are wired according to US standards. (See Section 2.9).
- Blue = High side of switched load (either phase)
- Yellow = Use for marking comments with a fine tipped felt pen. This is very useful for identifying unused wires, different loads, different branch circuit neutrals, etc.

2.4 Conduits and Conductors

Mexican houses are constructed using bricks with reinforced concrete posts (*castillos*) and beams (*cadenas*). Electrical boxes are recessed into the brick and connected using an orange plastic conduit.

The conduit runs through channels chiseled into the walls. It is also embedded into the concrete ceilings and run under the concrete flooring. The walls are then covered with cement that is typically 3/4 inch thick but can be much more. See Figure 2-7 and Figure 2-8.

Figure 2-7 Wall with Castillos and Cadenas. Note Electrical Box and Conduit

Figure 2-8 Wall after Rough Coat of Plaster

The conduit is available both in flexible form (corrugated wall) or more rigid (smooth wall) and in sizes starting at ½ inch (ID).

Wiring is stranded to make it easier to pull through the conduits. Standard wire gauges are used (AWG 14, 12, 10, etc.), and the usual colors (black, white, red and green) are normally available.

2.5 Wire Size and Fusing

The most common wire gauges that you are likely to run across in a Mexican residence are AWG 6 through AWG 14 wire. AWG 6 or 8 would be used to connect the entry panel to subpanels and AWG 10 through 14 is used for branch circuits. You may, however, run across much smaller gauge wiring (AWG 16 or 18) including even zip cord that is embedded directly in the plaster ceiling or wall. This is very bad practice and should be replaced if possible.

Older entry panels used large knife switches with plug-in cartridge style fuses. More recent panels use circuit breakers for the main disconnect. The replaceable links used in the cartridge fuses are likely to be oversized for the conductors they are designed to protect.

The purpose of a fuse or circuit breaker is to protect the downstream conductors from overheating and possibly melting or burning. So the rules that apply depend on the size of conductor, the type of insulation and the number of conductors bundled together in a conduit—all of which affect the heating of the conductors. Assuming the most common 75 deg C insulation, the following guide can be used for circuit breaker sizing:

Table 2-1 Circuit Breaker Sizing

AWG 6	AWG 8	AWG 10	AWG 12	AWG 14
70 amps	50 amps	30 amps	20 amps	15 amps

It is not always obvious what the gauge of a wire is, especially in old wiring and with stranded conductors. When buying new wire, be sure to look for some where the wire gauge is clearly marked on the outer jacket. In existing wiring, compare it to the conductor size of a new piece of wire. You can also use a wire gauge. Do not use the outer insulation diameter as indicative of the conductor size as some of the older wire has much thicker insulation than comparable newer insulation.

Conductor sizes should not be mixed in the same protected circuit, but in Mexico you will find that they are. For example, a branch circuit may start out with AWG 10 wire at the subpanel, then connect to AWG 12 wire somewhere down the line to the final load. This makes sense from the standpoint of minimizing voltage drop, much like plumbing lines may start out with ¾ inch tubing near the main and reduce to ½ inch tubing near the faucets. But for purposes of fusing, the smallest gauge wire in the circuit should determine the fuse size. So in this example where AWG 10 and 12 wire are mixed, the circuit breaker should be 20 amps, not 30.

When circuits have been added, or perhaps when the house was originally wired and there was insufficient space in the subpanel box for all the branch circuits, multiple conductors may be connected to the same breaker. This is okay as long as the circuit breaker is sized for the smaller of the two conductors. Of course, it may result in nuisance tripping. For example, if two outlet circuits are wired with AWG 12 wire, connected together and protected by a single 20 amp circuit breaker, the total load must be kept below 20x120 = 2400 watts or 1200 watts in each of the two parallel circuits. That may seem like a lot, but it is only two hair dryers. A better solution would be to connect the two circuits to two separate 20 amp breakers. If no more space is available in the subpanel, you can replace the existing breaker with a tandem (two half-sized) breaker. (See Section 4.3).

2.6 Connections

As in the US, connections between conductors are made inside metal or plastic boxes. However, unlike the US, most connections in Mexico are made by tightly twisting the conductors together over a length of 1 to 2 inches then covering the connection with electrical tape. When properly made, these connections are quite secure. However, they are very inconvenient to remove for adding on an additional circuit or for temporarily disconnecting a circuit while trouble shooting. Wire nuts are now widely available in Mexico and should be used when it is necessary to open up a twisted wire connection.

When using a wire nut with AWG 14, 12 or 10 gauge stranded wire, strip each wire at least 5/8 inch from the end and twist the individual strands together. Trim the twisted strands to about 5/8 inch and place the conductors together so that all wire ends are lined up. Do not pre-twist the conductors together. Now screw on the wire nut and tighten it as tight as possible by hand. The various conductors should now begin to twist around each other and no bare copper should be visible. Give the wire nut another half turn using pliers if necessary. Hold the wire nut in one hand and pull each of the conductors with the other to be sure that all of them are firmly clamped by the wire nut. See Figure 2-9 through Figure 2-12.

If you come across a situation where a conductor is too short to reach the wire nut, you can extend it using a crimp connection. See Figure 12-6 for an example. Tape the crimp with the proper color tape or use an insulated crimp.

Figure 2-9 Taped Twisted Wire Connection

Figure 2-10 Twisted Connection without Tape

Figure 2-11 Wires Re-cut for Wirenut

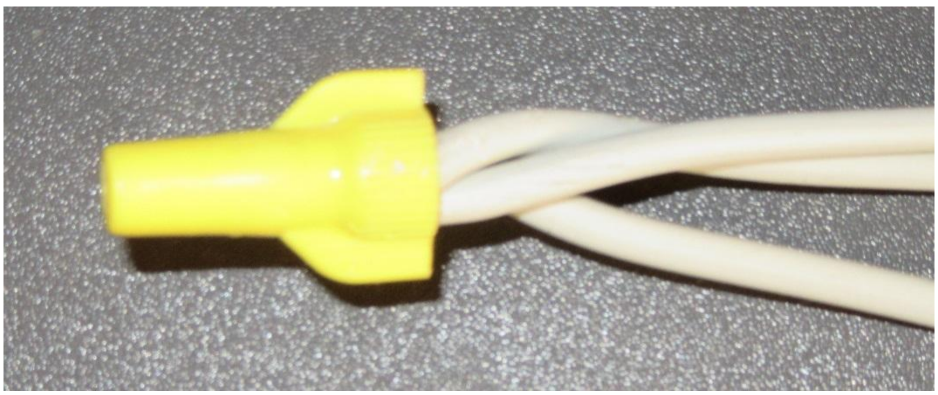


Figure 2-12 Connection with Wirenut

Square connection boxes are found in 4 inch, 4-11/16 inch and 6 inch sizes. Those used for wall outlets and switches are most commonly the 4 inch size with a single gang ring that is nearly flat.

In the US, the National Electrical Code provides rules for calculating the maximum number of wires that can enter any size box. In Mexico, the rule is to cram as many wires as possible into a box. If they do not fit, cram them tighter. There is not much that can be done about this (assuming each wire serves a purpose, which normally they do.) This is also a case where leaving a twisted wire connection alone is an advantage as they usually use up less space than a wire nut connection. When adding or changing a device (switch, outlet, etc.) to one of a larger (deeper) size, it may be easier to add a new handy box next to the square box from which the original switch was removed. For example, I added a number of Honeywell programmable timers (see Section 4.8). These are the size of a “Decora” style switch but are relatively deep. There was no possible way to fit one of these into the original switch box, so I mounted a deep handy box next to it and placed a blank cover plate over the original box. Just be sure when doing this that you mount the new box on a side of the original box where there is not a conduit!

2.7 Outlets and Switches

The usual practice in the US is to place one switch or one duplex outlet in a 2x4 inch single gang handy box. A 4x4 square box can also hold one or two switches or outlets using a single gang or 2-gang device ring.

In the Casa Erres house, 4x4 square boxes with single gang rings were used throughout. However, the single gang ring can support 1, 2 or 3 modular style switches or single outlets which are available in many combinations. Some of the many configurations are shown below.

Figure 2-13 New Style (Modular) Switches and Outlets

The ones shown in Figure 2-13 are newer models. It is much more common to find older metal plate versions of these devices as shown in Figure 2-14.

Figure 2-14 Old Style Switches and Outlets

The single gang ring will accept a Decora style device assuming there is sufficient room in the box to accept the depth of whatever you are adding. For example, I replaced a number of single switches with Lutron Maestro type dimmers. These fit well with no further change required. Figure 2-15 shows Decora style switches and outlets.

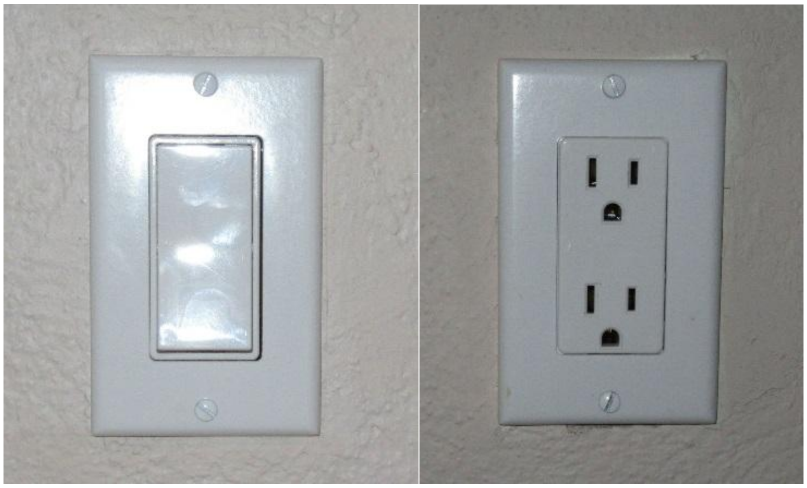


Figure 2-15 Decora Style Switch and Outlet

2.8 Box and Ring Sizes

The electrical boxes used in Mexico are the same size as those used in the US. However, in the most common square box size – 4x4 inches – there are two styles sold. The older (and more common) one has mounting tabs for the device ring located about 1 inch from the corners of the box while the newer style which has mounting tabs located about 3/8 inch from the corners. Home Depot in Mexico sells both style boxes. The newer boxes are marked “PRO,” but the two styles are frequently mixed up on the shelves. To see the difference, note the two boxes shown in Figure 2-16.

Figure 2-16 Old (Left) and New (Right) Style 4x4 Boxes

Device rings are available for the old style boxes only in the single device size shown in the center above. The new style boxes accept either single or dual device rings. Figure 2-17.

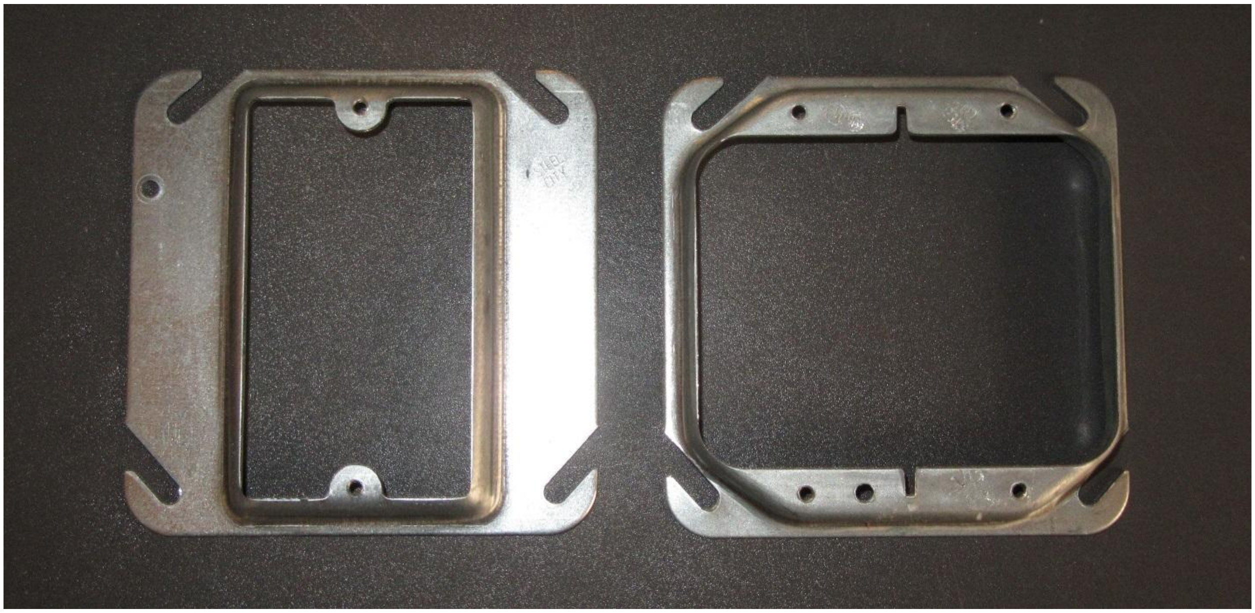


Figure 2-17 Single (Left) and Two (Right) Device Mounting Rings for New Style 4x4 Boxes

With a 4x4 box, a single device ring can be replaced by a double device ring by chiseling out the cement covering the recessed portion of the ring, replacing it, and re-cementing. If the box is the new style, that is all that is required. If it is the old style, the double ring will not fit. The solution is to use the ear tab conversion clips sold by Garvin Industries (part number EC). These allow a new style double gang ring to be mounted on an old style 4x4 box (Figure 2-18).

Figure 2-18 Old Style 4x4 Box with Ear Tab Adapters

2.9 Three-Way Switch Circuits

The US and Mexican method for wiring three-way light switches is different. In the US, both switches are wired to make or break the line side of the light circuit using two "travelers" as shown in Figure 2-19 below.

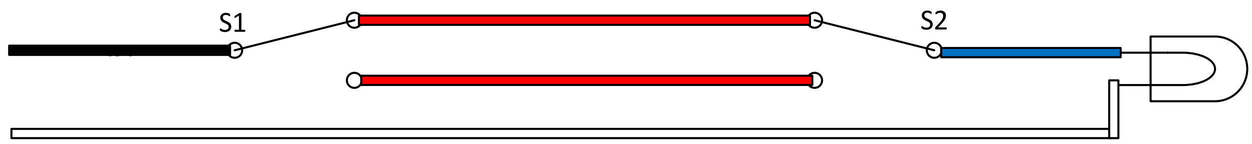


Figure 2-19 US Method for Wiring Three-Way Light Circuit

Note that the neutral is not switched and connects to the screw base of the light(s).

In Mexico, there are two other methods commonly used.

In Figure 2-20, the center contact on both switches connect to the two sides of the light bulb(s) and switch between the line and the neutral conductors. This works of course since if either switch is high and the other low the light is on.

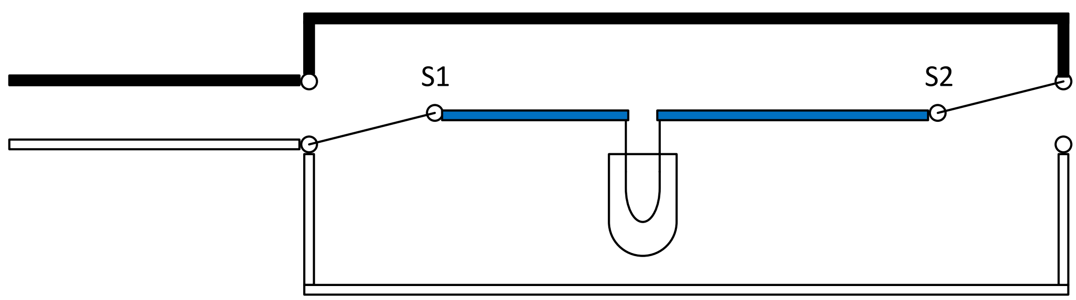


Figure 2-20 Mexican Method #1 for Wiring Three-Way Light Circuit

What this also means is that there are two different conditions that leave the light bulb off. One is that both center and screw sides of the base are low (neutral) and the other is that both sides of the bulb are high (line). It functions just fine, but it is dangerous because it provides a hot base on the outside contact of the lightbulb. You need to be aware that **there is a 50% chance that the bulb is "hot" even when it is off**. Use care not to touch the base of the bulb when changing it. Actually, you should be careful not to do this even on a simple light circuit since many light fixtures in Mexico are wired with the line side connected to the screw base.

The second common method shown in Figure 2-21 connects one side of the bulb (hopefully the screw base) to the neutral and switches the line side of the circuit (black) through a single runner (red) connected between the two switches. This is far safer than the circuit in Figure 2-20, but it is also fairly easy to convert to the NEC standard used in the US. An advantage to the US standard is that it lends itself to adding an additional (4 way) switch, while neither of the Mexican circuits does.

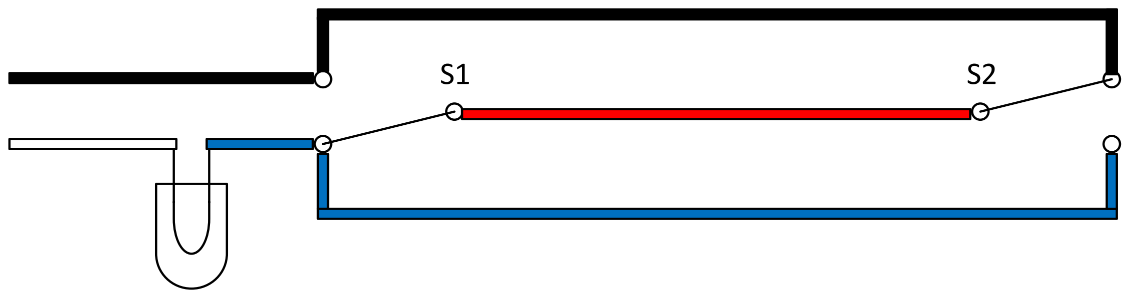


Figure 2-21 Mexican Method #2 for Wiring Three-Way Light Circuit

Rewiring these circuits is discussed in Section 4.7, but it is not always practical. For now, use caution when changing light bulbs because the base (outside contact) may be hot.

2.10 Light Fixtures

Light fixtures should be wired and connected such that the outer screw-in base is connected to the neutral and the inner contact to the switched line. This makes changing light bulbs safer since you are much less likely to touch the inner contact. The newer fixtures are wired this way, although as noted previously, one of the most common Mexican three-way wiring methods defeats this by placing the line side on the outside of the bulb in 50% of the switch combinations. However, older light fixtures, or even new ones bought at the *Mercado*, will not be wired correctly. As an example of the type of light fixtures that are wired seemingly at random, see Figure 2-22.

Figure 2-22 Classic Mexican Light Fixtures

The single lamp fixture on the upper left can easily be connected correctly to the wiring on the box, but the multiple lamp fixtures would need to be rewired completely. It would be much easier to simply replace these fixtures with ones properly wired to begin with. If you want to use these older fixtures, just be careful about touching the metal screw base on the bulbs when changing them and do not rely on the switch to de-energize the lamps if it is a 3-way circuit which may leave the base hot even when the bulb is off.

2.11 Mixing Low and High Voltage Wiring

Low voltage wiring must be physically separated from high voltage house wiring in the US. This is not always the case in Mexico. For example, in Casa Erres the security system keypad and alarm wiring were run through the same conduits as the house wiring, and an old low voltage doorbell circuit was similarly wired through the power subpanel. The telephone and TV coax wiring used separate conduits.

Fortunately, wireless alternatives exist for much of this today. In Casa Erres, I replaced the doorbell circuit with a wireless system and replaced the telephone wiring (which was very noisy) with a cordless system that works much better. There was no Ethernet wiring in the house, but we used a wireless router and extender for that anyway.

The security system had a “wall wart” transformer that was wired in a particularly horrifying manner. It was placed inside the alarm control box and low voltage bell wire was wrapped around the prongs and run directly to the unfused line inputs on a nearby subpanel. I installed a utility duplex outlet next to the subpanel and plugged the transformer into it. Using bell wire to power the transformer is apparently the standard method for connecting the security system since the one at our second house, Casa Colibrí, was similarly miswired. You should instead plug the transformer into a standard (not Decora) style outlet close to the security system and wire the low voltage between the transformer and the security system box. The reason for using a standard outlet is that the transformers are relatively heavy and tend to fall out of the outlet unless supported using a 6-32 screw that fastens them to the outlet. If you are having a new security system installed, insist that the installers wire the transformer this way. They may look at you funny, but they know how to do it correctly.

For more on what is available in the way of wireless equipment that replaces low voltage wiring, see Section 6.

3 Tracing Circuits

Depending on the age of your house and how much you want to upgrade the wiring, you will need to trace some or all of the wiring. In the case of the Casa Erres house, I traced all of it because all the wiring was done with random colors, and it was very difficult to tell how anything was connected without a proper schematic.

3.1 Subpanel Wiring

For subpanel wiring, start by disconnecting one of the main entry panel switches or breakers and note which subpanel is de-energized. Remove the cover from the main entry panel (if there is one) and trace the wiring from the switch. It should disappear into a large conduit. The wiring will pass through large conduits in the outside walls or under the floor to reach the subpanel. There will not be more than two 90 degree bends in the conduit between boxes, so look for boxes with outlets, switches or blank covers along the route between the entry panel and the subpanel.

Remove the cover plates and pull out all the loose wiring so as to expose all the conduits inside the boxes and note which wires pass through them. One trick used to minimize the amount of space consumed by wiring inside the boxes is to stuff one or more conductors back into a conduit. For example, suppose a white conductor in conduit A is connected (by twisting and taping) to a black conductor that goes through conduit B. If the twisted pair is stuffed back into conduit A, then it will appear that conduit A has 2 white conductors and 1 black conductor. Look for any conductor doubled back on itself and give it a tug to see if a taped connection emerges from the conduit.

Now mark all the conduits according to what conductors pass through them. Use masking tape on the wall directly over where the conduit runs and note the number of each color conductor. For example, if there are 2 white, 3 black, 1 red and 2 green conductors, just write 2W, 3B, 1R, 2G on the tape over this conduit. Do this for all conduits along the route. The number of wires of each color entering and exiting the same conduit should, of course, be the same. So beginning at the entry panel, you can trace the conduits and conductors running to the subpanel(s).

If, like Casa Erres, the wire colors were chosen at random, the next step is to determine the correct usage and correctly color code them with electrical tape. Choose one hot line phase and mark it BLACK and mark the other hot line phase RED. Mark the neutral WHITE and the earth ground GREEN at the entry panel. These should all be a large wire gauge like AWG 6 or 8 so they should be easily distinguishable from any branch circuits that may be running though the same conduits as these are generally AWG 10, 12 or 14. Use the voltage probe to identify the Line 1 and Line 2 conductors. If these happen to be two different colors (say black and white) then you can determine which is Line 1 and mark it with BLACK and which is line 2 and mark it with RED tape. Even if the conductor happens to be the correct color (BLACK in this example), mark it with black tape anyway so you will know that it has been identified. If the colors are the same (say both white) you will need to temporarily disconnect one of them and use the voltage probe to see which conductor is no longer “hot”. If the entry panel uses fuses, just pull one. Otherwise, you will need to disconnect a wire from the dual circuit breaker main. Of course, disconnect the power at the breaker before doing this, then reconnect it to test with the probe.

Continue in this manner until the line 1 and line 2 conductors are identified and marked all the way to the subpanel.

There should be a large gauge neutral and earth ground. These should be connected together at the entry panel, but separated at the subpanel. But they may be connected together at both ends. Also, the earth ground may be a smaller gauge under the false assumption that it does not carry any current.

It might be easiest to identify the earth ground starting from the subpanel end. (It should be connected to the ground terminal on outlets on at least a few branch circuits such as in the kitchen.) The neutral and earth ground may be mixed up or interconnected as was the case in Casa Erres, but pick one of the larger conductors and mark it WHITE for the neutral and another one and mark it GREEN for the earth ground. Do not try to disconnect one end or the other to trace it as floating the neutral can result in large over-voltages throughout the house. Instead, use the current sensor to see which one is carrying the most current and label it the WHITE neutral. The earth ground should not be carrying any current, but since it may be miswired at this point, it may be carrying some.

Don't try to make corrections to the wiring yet; just trace it all out and mark the conductors with colored tape according to their function.

You can now make a schematic of the circuits between the entry panels and the subpanels. Use those in in Sections 9-12 as a guide. These were made using a schematic design program that produced nice diagrams for this book, but a legible hand sketch is all that is required. Use labels like "BR3-NE" to indicate an outlet box on the northeast wall of bedroom 3. I like to label the conduits the same way they are labeled using the masking tapes on the wall (e.g., "2W,3B,1R,2G"), then mark the conductors according to their actual usage (and corrected colors).

Once the conductors and conduits are mapped out, it is much easier to spot miswires and figure out ways to improve the wiring, in many cases without having to pull new wires through the conduits. This is discussed in Section 4.

3.2 Branch Circuit Wiring

In a similar way, the wiring of the branch circuits can now be traced. Start by throwing a breaker at one of the subpanels and see which lights and outlets no longer work. Do this for all the breakers in one subpanel. Select one of the branch circuits and think about how the wiring might run from the subpanel to the first disabled outlet, switch or light in the branch. Remove the cover plates and pull out the loose wiring. Again, look for wires that are doubled over and stuffed back into a conduit. Now mark all the conduits using masking tape on the wall directly over the conduit. Figure 3-1 shows a typical switch box with three conduits marked on the wall and after the conductors have been identified and marked.

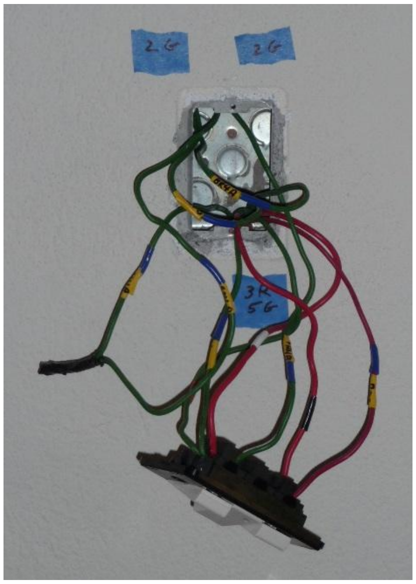


Figure 3-1 Switch Box after Marking Conduits and Conductors

Ideally, a conduit will carry only the conductors used in a single branch circuit, but sometimes it will be used for two or more. The high side of a circuit can be found by noting which conductors are connected to the high side of a receptacle (the small blade) and confirming this with the voltage probe. But there may also be other high side conductors in the same outlet box connected to a different circuit breaker. If there are two, mark both of them BLACK but then add identifying labels using YELLOW tape to distinguish the two circuits. Trace all the high side wiring throughout the branch using the voltage probe and switching the circuit breaker on and off to confirm it is the correct branch. In the subpanel, mark the BLACK conductors for the branch with a piece of YELLOW tape that identifies the branch. You could write the circuit breaker number on the tape, but it is better to note the branch by name or function; for example “BR3” for bedroom 3. This is because you may end up moving the wiring around inside the subpanel so that this branch connects to a different circuit breaker.

Now go back to the first box in the branch and look for conductors connected to the large blade on a receptacle. This is the neutral for that branch and it should be marked WHITE. Mark all the conductors connected together to this wire WHITE also. Do this for all of the outlet boxes that have been opened. There may be two neutrals in a box corresponding to two branches. These should all be marked WHITE but they should also be labeled with a YELLOW tape to identify which branch they are part of. If the neutral is connected to an outlet that is part of branch circuit BR3, then it should be marked accordingly. If it is simply passing through the box to, say BR2, then you need to confirm that using the current probe. The current through the high side of branch BR2 should be equal to the current through the neutral of branch BR2. (Be sure to turn on a lamp somewhere on branch BR2 in this case to produce a current). It is not very difficult to identify the circuits in the outlet boxes along the branch. But it can be difficult inside the subpanel since all the neutrals are connected together on a bus bar. <u>Again, do not disconnect the neutrals to identify which branch they are used in as this can result in large over voltages</u>. Instead, use the current probe to find the neutral that is carrying the same current as the high side conductor for that branch. The reason for identifying the neutrals used with each branch is that if the high and neutral conductors for a branch are (or can be) separated from other branches, then a GFCI breaker can be used for that branch.

You can now label earth grounds in the branch if there are any. These will be connected to the earth ground contact on the receptacles. Mark these conductors GREEN. It is not necessary to distinguish the earth grounds of different branch circuits since these all connect together even if GFCI circuit breakers are or will be used. In the subpanel, you can identify the earth ground for the branch by first locating the conduit used to carry the conductors to the branch circuit under investigation. The high side and neutral conductors will go through this conduit and there should be another conductor which is not yet marked. It will have no voltage (use the voltage probe) and will carry no current (check with the current probe) even with a branch lamp turned on. It should be connected to other earth ground wires, but it may be connected to the neutral bus instead. In either case, mark it GREEN.

Finally, identify the switched load (light) high side conductors in the switch boxes. Mark these BLUE and also use YELLOW tape to identify their purpose; for example, “BR3C” for Bedroom 3 ceiling.

Now you can draw up a schematic of the branch circuit.

3.3 Hidden Junction Boxes

What if in tracing a branch circuit (or the subpanel wiring), a conduit “disappears”? This happened to me several times in Casa Erres. A ceiling light box had a conduit which came from the subpanel, a conduit that led to a wall switch and a conduit that appeared to lead to another series of ceiling lights. The problem was, the wire colors did not match up. That is, there were 3 white conductors leaving one box and no such combination of conductors in any of the other conduits at the other boxes along this branch circuit. It appeared that a junction box was missing in the branch circuit.

In two cases, what had happened was that ceiling boxes had been used as junction boxes with blank cover plates, then these had been carefully plastered over. In one case, the missing box was spotted by looking carefully at the ceiling at an angle so as to see a slight depression in the plaster that took the form of the square cover. In the second case, the missing box was only found by using the circuit tracer. (See the description in Section 5).

In a final case, the missing junction box was found behind a kitchen cabinet that had been installed over the box during a remodel. Fortunately, the carpenter had cut an opening that provided access to the junction box, but it was skillfully hidden inside a decorative shelf between the top of the cabinet and the ceiling. It was accessible, but just barely. I doubt I ever would have found this box without the circuit tracer.

In the case of Casa Colibrí, someone must have instructed the workmen to be sure and hide all junction boxes. I found a total of 7 of them, but all were so skillfully covered with plaster, tile, and/or cabinetry as to make them invisible. The circuit tracer was the only way they could be located.

4 Upgrading

This is a question that depends on your skills, interest, time, and the condition of the house. You could certainly take the position that if it isn't broken, don't fix it. It would still be worth reading portions of this section so you will know what is feasible to change in case, for example, you want a dimmer, timer or brown out protector. In my own case, I made all the changes discussed in this chapter working a few hours a day, a few days a week, over a year's time. Admittedly, some of the more difficult changes, like replacing the subpanels, turned out to be a LOT of work, and the system works pretty much the same now as it did before. But it gave me a much better familiarity with what was going on with the wiring, and the system is now much easier to trouble shoot and repair than it was before. And, of course, it is safer.

One thing that I did not do, at least not much, is to pull new wires through the conduits. In several cases, I would have liked to do this, but I found that sometimes the existing conductors were pinched in the conduits and there was no possibility of adding another conductor, let alone replacing existing conductors with those of the correct color and wire gauge. But this is rarely necessary. Just tape the ends with the proper colored electrical tape. The electrons do not know what colored wire they are flowing through, but proper taping tells you—and the next person to work on the wiring—what the function of the conductors is.

The upgrades discussed below are arranged starting with the easiest to make and progressing toward the most difficult.

4.1 Replacing Switches and Outlets

This is the certainly the simplest upgrade you can make. It will improve the look of the house and add an element of safety as well if you are replacing the older style metal plates with the newer plastic ones.

You should of course disconnect the electricity at the circuit breaker box before handling the wiring.

The single pole single throw switches used in Mexico are called *sencillos* and the single pole double throw switches used in the 3-way circuits are called *escaleras*. In this section, switches are all simple (not 3-way) types. Three-way switches are discussed in Section 4.7.

There are many different modular switch styles available at Home Depot Mexico. Choose one that offers all the switch configurations that you will be using (single, double, triple, 3-way, etc.) Select switch types where the contacts contain a saddle type washer which clamps the wire when the screw is tightened. These are MUCH easier to use than forming a loop under the screw head, especially with stranded wire. Note that when received, the screws may be in the tightened position. You need to unscrew them to open up the clamp for the wire conductor.

It is important to get the polarity (hot and neutral connections) correct on all the switches and outlets.

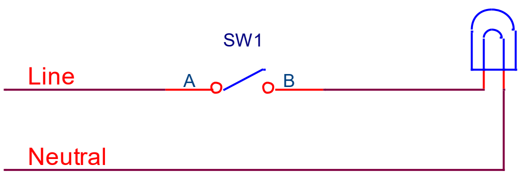
Before replacing the switches and outlets (*contactos*), use the voltage probe to identify the high and neutral conductors, and note whether the wire colors are correct. (See Section 2.3). On outlets, the high side should be the smaller blade contact and on light circuits, the high side should connect to the switch.

To test for proper polarity on the switch, measure the voltage on both terminals of the switch using the voltage probe with the light first ON then with it turned OFF. Compare the readings to the truth table shown in Table 4-1 below. Since at this point you do not know which terminal is connected to the load (light), the only way you can determine for sure which configuration applies is to look at the Light ON condition where both terminals are the same. If they are both High, the switch is correctly wired. If they are both Low, the line and neutral are reversed. See the simplified schematics below. If the switch is wired correctly, the table tells you which conductor should be marked BLUE (Load). It is the wire that measure Low when the light is OFF.

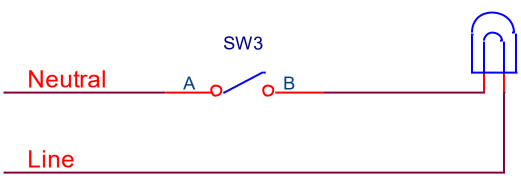
Table 4-1 Truth Table for Single Switch Light Circuit

Configuration	Switch Contact	Light ON	Light OFF
		Up	Down
SPST	SW1-A	High	High
	SW2-B	High	Low
SPST Reversed	SW1-A	Low	Low
	SW2-B	Low	High

Single Switch Light Circuit



Single Switch Light Circuit with Line and Neutral Reversed



If the switch is wired with line and neutral reversed, see if there is a consistency in the color coding or reversal of the line and neutral conductors on this branch. For example, if all the switches are connected to the neutral, you may have a situation like that shown in Figure 12-1 which I found in Casa Colibri. In that case, it is easiest to correct the polarity by swapping the neutral and hot wires for the branch circuit in the circuit breaker box. That might cause the outlets to be reversed (if they were properly wired to start with), but it very easy to reverse the neutral and hot wires at an outlet when changing it, and not so easy to do this at a switch.

After making any changes at the circuit breaker end of the branch, recheck the switches and outlet wiring with the voltage probe and mark the conductors with colored tape. Then replace the switches and outlets with the new ones.

This would be the time to decide whether to replace any twisted and taped connections with wire nuts. Look at the connection and if all the wires appear intact and the tape is in good shape (not peeling off), I would leave these alone. The main advantage of the wire nuts is that they are much easier to remove when you need to disconnect a wire from a bundle or add a new wire, but they do use up more space in the box.

If you need to disconnect or add a conductor, go ahead and open up the taped and twisted connection, then use a wire nut following the directions given in Section 2.6.

If your existing circuit used an earth ground conductor, then for sure you need to replace the outlet with one having an earth ground terminal. But if it lacks the ground wire, you have a choice between installing a new 2 terminal outlet or a new 3 terminal outlet with the earth ground terminal unconnected. There are pros and cons to either approach, but my personal preference is to use 3 terminal outlets. This is because when you do need to plug in a 3 pronged appliance, it is always a pain to find an adapter to a 2 terminal outlet. And the result is an ugly and unreliable connection since the adapter tends to fall out of the outlet easily. Again, try to find outlets that clamp the wire. For some reason, these are harder to find on outlets than on switches.

4.2 Replacing an Outlet with a GFCI Type

A single outlet such as might be in the kitchen is easily replaced with a GFCI outlet. The GFCI protection provided by these receptacles senses the small difference in current between the line and neutral wires when a potentially lethal current occurs from touching a faulted exposed surface. You might feel a small shock under these conditions, but the GFCI device will trip at a very low level very quickly so as to prevent injury or death. As such, they are a very good way to add safety to your house wiring. These outlets provide protection even when there is no earth ground.

GFCI outlets are not readily available in Mexico. Home Depot did not carry them, and the local hardware store did, but wanted nearly US$50 for one. There are a number of models available. I prefer the ones with an LED light to show when they are powered. Also be sure to get one that uses the saddle type clamps for the wiring. These are much easier to use with stranded wire. Do not use the kind with push-in openings on the back with stranded wire. The ones I got were Leviton R72-N7599-ORW. These are the white color. They cost about US$13 on Amazon.

Normally in a kitchen, a single GFCI can be used with its output connected to one or more other outlets to provide protection to the entire room. In Casa Erres, there were only two outlets, but between them was another connection for the stove and overhead fan and light. Rather than try to rewire all this, it was much simpler to simply replace both outlets with their own GFCI outlet (Figure 4-1). I did the same in the powder room which had a single outlet (without a light switch).

Figure 4-1 Kitchen GFCI

In bathroom #4, there was a switch and outlet combination similar to that shown in Figure 4-2.

Figure 4-2 Bathroom Switch and Outlet

As discussed in Section 2.8, it was necessary to replace the single gang ring with a double gang ring using ear tab adapters. The tile around the 4x4 box had to be removed using a diamond blade saw. The pictures in Figure 4-3 show the steps.

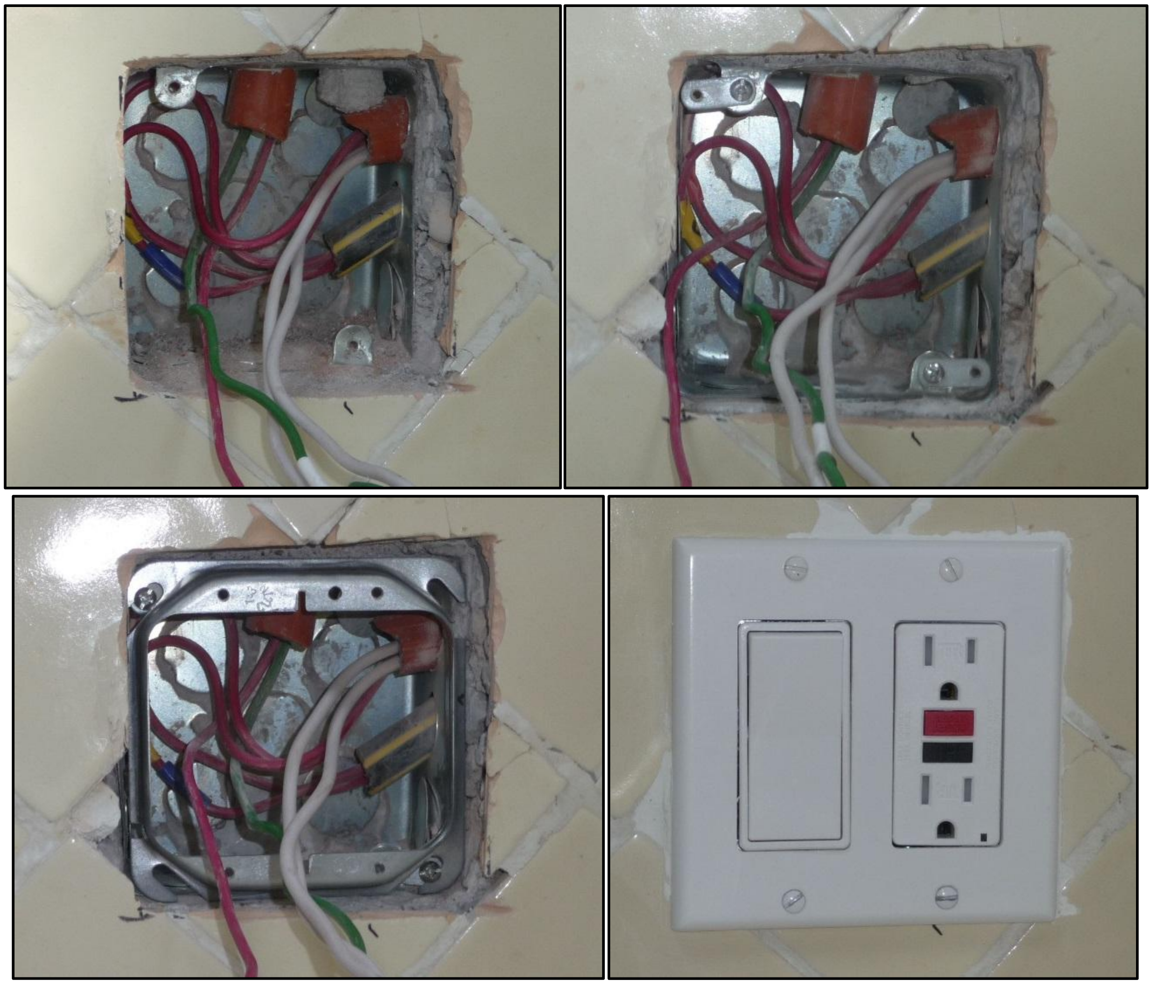


Figure 4-3 Steps for Replacing Bathroom Switch & Outlet with Decora Style GFCI

(upper left) Note old style 4x4 box tabs; (upper right) ear tab adapters installed; (lower left) dual gang ring installed; (lower right) Decora style switch on left, GFCI on right

Be prepared to do some repair on the wall, as shown above, or buy an oversize 2-gang Decora style wall plate to cover the unavoidable chips that occur when cutting the old tile.

4.3 Replacing Circuit Breakers

Circuit breakers do not normally wear out, and unless they are of the GFCI, AFI or DF style, there is no simple way to test them. Therefore, you will probably replace them only if they are of the wrong size to start with or if you are upgrading the wiring to provide, say, GFCI protection to an entire branch circuit.

In Casa Erres, I found that most of the wiring was a mix of AWG10 and AWG12 conductors. These were nearly all incorrectly fused at 30 amps. I checked the current as well with the clamp-on current probe and found that all these circuits ran about 10 amps or less. So the #10 wire was probably used to cut down on voltage drop, or maybe because it was available that day. In any event, the breakers should be sized for the smallest conductor, so I changed all of them to 20 amp sizes.

The most common series of breakers in Mexico seems to be the Square D (Schneider Electric) series QO. Hundreds of breakers are made in this series, but the most common ones used are the following:

Table 4-2 Most Common QO Series Breakers

Current	Single Pole Standard	Double Pole Standard	Tandem Standard	Single Pole Ground Fault (GFCI)	Single Pole Arc Fault (AFI)	Single Pole Dual Function (DF)
15 A	QO115CP		QO1515CP	QO115GFICP	QO115CAFIC	QO115DFC
20 A	QO120CP	QO220CP	QO2020CP	QO120GFICP	QO120CAFIC	QO120DFC
30 A	QO130CP	QO230CP				
50 A		QO250CP				
70 A		QO270CP				
100 A		QO2100CP				

The use of tandem breakers is a great way to add an additional branch circuit to an already full breaker box, and it is a better solution than simply paralleling multiple circuits to the same breaker.

GFCI breakers detect the difference between the line and neutral conductors and trip if the difference exceeds about 6 ma. They are designed to provide protection against someone coming in contact with a line side conductor. This is a good alternative to the wall surgery required in a bathroom described in the previous section to replace a modular switch + outlet combination with the decora style switch + GFCI outlet, but it does require a separated neutral.

Arc fault breakers detect the presence of an intermittent current due to arcing which might be caused by a partially broken lamp cord, etc. Dual function breakers provide both ground fault and arc fault detection.

All three breakers – GFCI, AFI and DF require connection to both the line and neutral conductors of the branch circuit. So if the neutral has been connected to another load's neutral, these must be separated before one of these breakers can be installed.

Home Depot in Mexico carries standard and GFCI breakers. If you need one of the others, it must be ordered from the US.

4.4 Fixing the Earth Ground

As discussed in Section 2.2, the earth ground should be connected

- to ground terminals on outlets when they are located in damp areas like the kitchen, bathrooms or cellars;
- to water pipes and metal housings on pumps, etc.;
- to the earth itself via a metal stake at the entry point (meter);
- and to the neutral conductor at the entry point only.

There should be no current on the earth ground between the entry point and the subpanels, but there will be some current (less than 1 amp) at the main ground connection. This is because the neutral is not exactly at ground potential because the neutral conductor between the meter and the power company's transformer has some resistance.

Isolating the earth ground from the neutral at the subpanels will involve some circuit tracing to identify the grounds and the neutrals, then removing the earth ground conductors from the subpanel neutral bus bar, if they are connected to it. The neutral bus bar should be isolated from the subpanel by insulators and there should be a separate earth ground bus bar that is not isolated from the subpanel chassis. In Casa Erres, the subpanels did not have isolated neutral bus bars, and this is one of the reasons I decided to replace them with QOX series load centers as discussed in Section 4-10.

But having done all that, I discovered that the earth ground was still not working correctly. Depending on whether or not the washing machine was plugged in, there was a current in the earth ground between the main entry and the subpanel! The reason was that the large bare stranded grounding wire that was connected to the neutral and earth ground bus bars at the entry panel and which disappeared into the cement wall near the water pipes, was not actually connected to ground. In fact there was a resistance of 500 ohms between this wire and the main copper water pipe. There was also a voltage of about 0.7 V between the neutral and the water pipe. What was happening was the neutral was being grounded through the washing machine frame which was connected to the plumbing inside the house.

The grounding solution was to connect a short length of AWG 8 wire between the entry panel neutral and ground bus bars and a brass clamp around the main copper water pipe. See Figure 4-4.

Figure 4-4 Ground Wire between Entry Panel and Main Water Pipe

The current through this ground wire was measured at about 0.5 amps.

I also measured the resistance of the copper plumbing system between this point and other locations around the house. It was less than 0.5 ohms everywhere except across the hot water heater (inlet to outlet) and across the water pump used as part of the whole house filtration system. So I added #8 jumper wires at these places to ensure ground continuity throughout the copper plumbing system. See Figure 4-5 and Figure 4-6.

Figure 4-5 Ground Wire at Water Heater

Figure 4-6 Ground Wire at Filter Pump

You should verify the integrity of the earth ground connection at every outlet where it is connected. The best way to do this is to measure the resistance between the earth ground terminal and the neutral terminal using an ohm meter. It should be less than 1 ohm. To get the best measurement and also to protect your ohm meter in the event that there is a miswire, make this measurement with the electricity to the entire house turned off at the main breaker.

4.5 Surge Protection

If lightning strikes a power line or if a storm causes a primary line (13 KV or so) to fall across the secondary lines feeding your house, great damage can result to the appliances before the circuit breakers blow. Various devices are sold as surge protectors to prevent or reduce the risk of this damage. For example, the brownout protectors described in Section 4.6 have this feature.

The best solution however is to provide whole house surge protection at the service entry panel. Assuming you have a QO series panel at the entry with two extra (adjacent) slots, you can install a QO2175SB surge protector. These install just like standard circuit breakers except they contain a pigtail white wire that needs to be connected to the neutral/earth ground bus.

Figure 4-7 QO2175SB Surge Protector

Figure 4-8 Surge Protector Installed in Entry Panel

An interesting feature to this product is that Schneider offers a two year warranty that covers up to $10,000 damage to home appliances after the surge protector is installed. Cost on Amazon is about US$60.

4.6 Adding Brownout Protection

Brownouts can cause serious damage. In our neighborhood we have experienced several sustained (hours long) brownouts that caused extensive damage to the electronics used to control refrigerators, ovens, hot water heaters, security systems, etc. On one occasion, I measured the line to neutral voltages of the three phases. One was 127 volts (exactly correct), the second was 85 volts and the third was 35 volts. These latter two voltages are well below the 5% tolerance that is expected for power lines.

There is an inexpensive solution that can be used, but it requires some caveats. A plug-in device is available from a variety of internet sites that provides brownout and overvoltage protection. Cost is around US$13 for the 120 VAC models and US$20 for the 220 VAC unit. The various models are listed in Table 4-33 below. The only 220V appliance that you are likely to want to provide brownout protection for is an electric oven.

Table 4-3 Brownout Protectors

Model	Voltage	Current/Power	Delay Time	Application
PROTECT-ELE	120V	15A/1800W	10 seconds	TV's, PC's, etc.
PROTECT-RF	120V	15A/1800W	3 minutes	Refrigerators
PROTECT-AC	120V	20A/2400W	3 minutes	Refrigerators, AC's
PROTECT-AC 220V	220V	2400W	4 minutes	AC's, Ovens

Figure 4-9 Plug-in Brownout Protector

The 120V models are specified to disconnect when the voltage input drops below 90V or gets above 130V. The 220V model disconnects below 187V or above 245V. The problem is that neither of these thresholds have tolerances specified.

I measured the actual thresholds of 8 different units (6 type AC and 2 type ELE) and found that the upper threshold specified is the minimum value and the lower threshold specified is the maximum value. In the plots below, the triangles indicate the nominal value of the line voltage and the specified value of the threshold values. The vertical bars indicate the nominal range for the power line voltage and the measured range for the upper and lower thresholds.

If you are in an area that delivers three phase power, the normal range of the line to neutral voltage is 127 +/-5%. Figure 4-10 shows that the upper end of the line input may exceed the 130 V specified upper threshold.

Figure 4-10 Three-Phase Line to Neutral Voltage Compared to Thresholds on Brownout Protector

Therefore using these devices in an area where you have 3 phase power could result in a nuisance disconnect due to a slight overvoltage. I had 8 of these installed for nearly 3 years, however, and never experienced this problem. The 220V device thresholds are shown in Figure 4-11 and these do not show any potential problem.

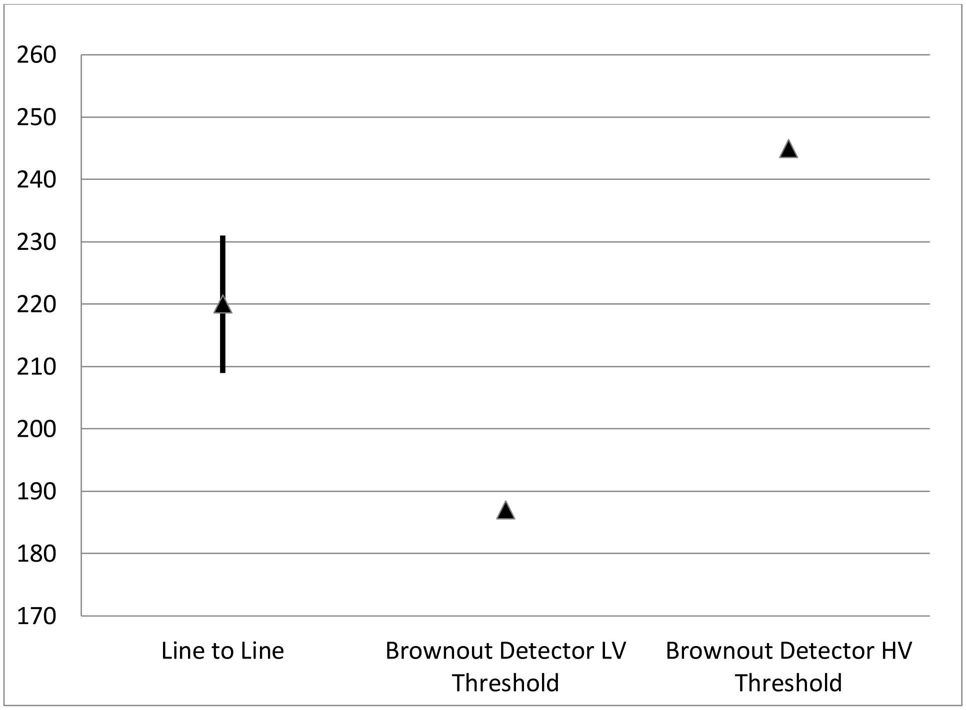


Figure 4-11 Three-Phase Line to Line Voltage Compared to Thresholds on Brownout Protector

If you live in an area where your power is two phase, the problem is reversed. That is, the 120V devices have no potential threshold problem, but the 220V unit does (at the upper threshold). See Figure 4-12 and Figure 4-13.

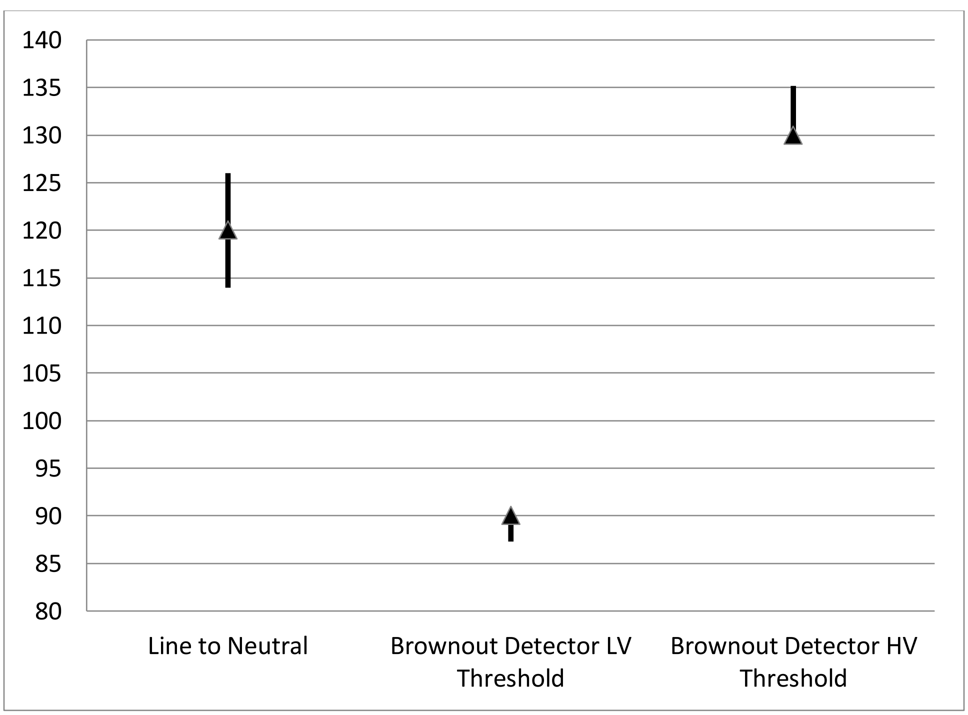


Figure 4-12 Two-Phase Line to Neutral Voltage Compared to Thresholds on Brownout Protector

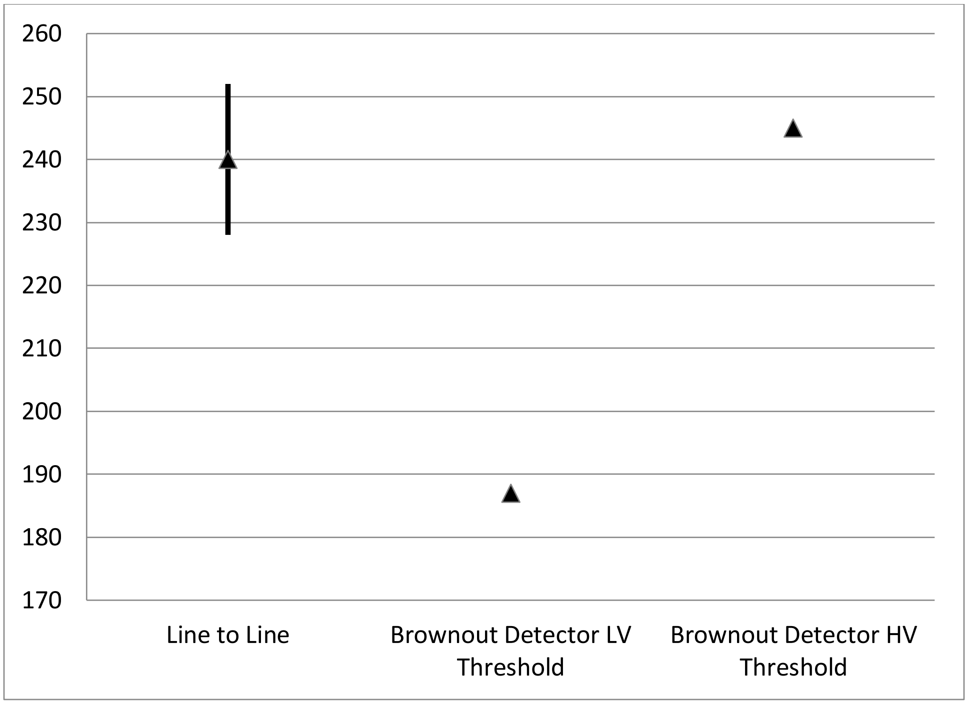


Figure 4-13 Two-Phase Line to Line Voltages Compared to Thresholds on Brownout Protector

4.7 Dealing with Three-Way Switches

As discussed in Section 2.9, the way three-way switches are wired in Mexico is often very different from that used in the US and may result in a high voltage being present on the outside base of the bulb (even when the light is off). I have found 5 different wiring configurations for three-way circuits which "work."

It is possible to identify the circuit configuration by using a voltage probe at the two 3-way switches and recording the readings (High or Low) for each of the 4 combinations of the two switches (the two ON positions and the two OFF positions).

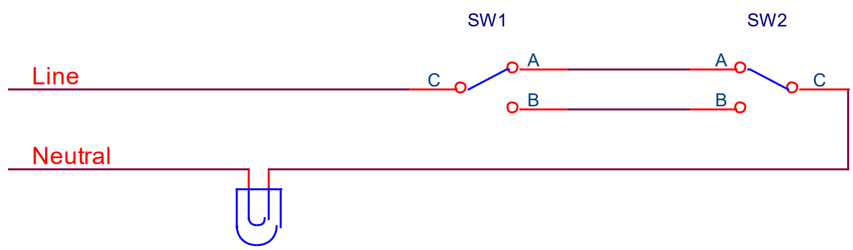
First note that the center contact (C in the following diagrams) is a different color screw on the two 3-way switches. Use the voltage probe and record whether this voltage is High or Low for each of the four combinations of the switches. Then compare the readings to those shown in Table 4-4 below.

Table 4-4 Truth Table for Determining 3-Way Switch Configuration

Configuration	Switch Contact	Light ON		Light OFF	
		Up/Up	Down/Down	Up/Down	Down/Up
US Standard	SW1-C	High	High	High	High
	SW2-C	High	High	Low	Low
US Reversed	SW1-C	Low	Low	Low	Low
	SW2-C	Low	Low	High	High
MX#1	SW1-C	High	Low	High	Low
	SW2-C	Low	High	High	Low
MX#2	SW1-C	High	High	High	Low
	SW2-C	High	High	High	Low
MX#2 Reversed	SW1-C	Low	Low	Low	High
	SW2-C	Low	Low	Low	High

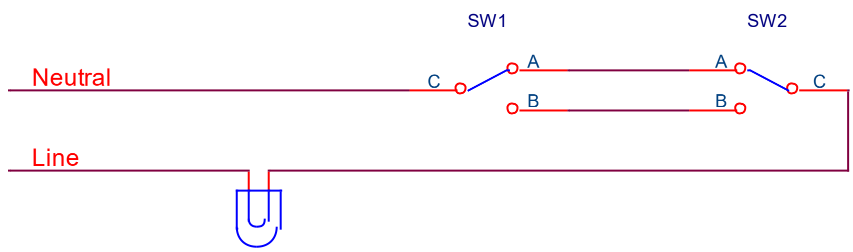
For example, consider the US standard configuration shown below. When the light is on, both switch center contacts are high, and when the light is off, one switch center contact will be high and the other switch center contact will be low.

Configuration US Standard



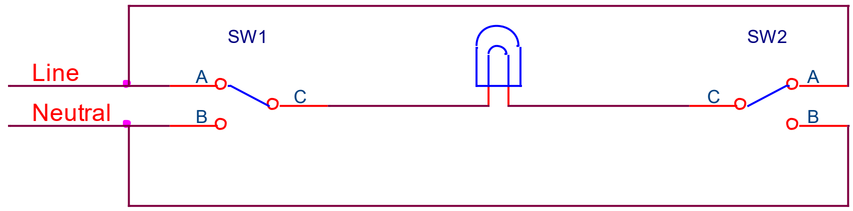
If the line and neutral are reversed in the above, we get the US Reversed configuration which is very bad because the bulb is always at line potential, even when it is off.

Configuration US with Line and Neutral Reversed



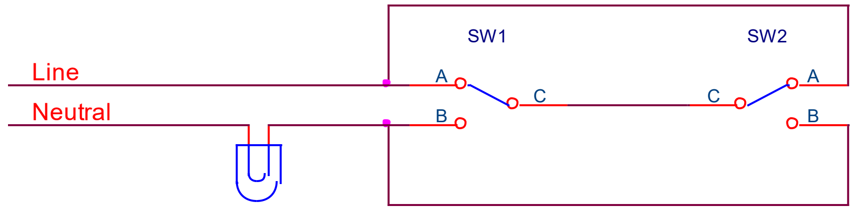
Configuration MX#1 is also a dangerous configuration as it provides a 50-50 chance that both contacts on the lightbulb will be at line potential even when it is off. The line and neutral used in SW1 and SW2 are usually connected together as shown, but I have even seen them connected to different circuit breakers!

Configuration MX#1



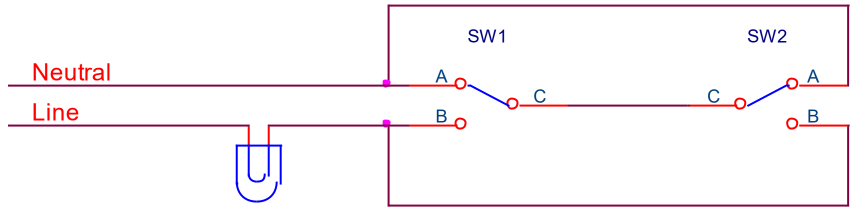
Configuration MX#2 leaves the light at neutral potential when it is off, so it is much safer than MX#1. But it is also relatively easy to rewire to the standard US configuration without adding conductors.

Configuration MX#2



If the line and neutral are reversed with MX#2 we get another hazardous condition since the light bulb will again be hot even when it is off.

Configuration MX#2 with Line and Neutral Reversed



Of the five possible ways a three-way switch circuit can be wired and function, one is standard and safe, one is non-standard and safe, and three are hazardous and should be corrected.

Rewiring to Eliminate the Three-Way Switch

One easy way to correct a dangerous three-way circuit is to simply convert it to a simple single switch circuit. You certainly would not want to do this for the switches at the top and bottom of a stairway, but many times three-way circuits are actually a nuisance. For example, many of the bedrooms in Casa Erres had a ceiling light switch near the door and a second switch mounted near the bed. The theory behind this is that one entered the room, got ready for bed, and then turned out the overhead light without leaving the bed. But that assumes one does not read in bed using a table light. And many of the overhead lights had since been replaced with ceiling fan/light combinations that use remote controls. If you wanted to turn off the light but leave the fan on without leaving the bed, you would use the hand held remote control. The second switch next to the bed could not be used because it would remove all power from the ceiling fan/light.

Eliminating a three-way switch is very simple. With MX#1, just connect the neutral to the load wire in the bedside box and eliminate the switch. The switch by the door can remain intact or replaced by a simple (not 3-way) switch. With MX#2, it is even simpler. Just remove the bedside switch and cap off the conductors with wire nuts. Switch 1 may be left as is or replaced with a simple switch.

Rewiring MX#1 and MX#2 Configurations to US Standard

The above diagrams are simplifications. Actual wiring through the conduits may assume many other forms including routing all the conductors through a junction box, through the connection box above the light or through one of the switch boxes.

If the line and neutral are reversed, this should be corrected first. Check whether the line and neutral are reversed at other lights on the same branch circuit. If that is the case, the line and neutral are reversed at the circuit breaker or in a junction box connected to the circuit breaker. If only the three-way light circuit is reversed, the error is most likely at the light itself or one of the switches connected to the light.

To convert MX#1 to the US configuration, see if the line and neutral at the tail end of the circuit (SW2) are connected to other lights or outlets. If this is the case, you will need to pull an additional black and white wire through the conduits to feed these devices since the existing line and neutral between the switches will be converted to runners (wires that go between the switches and do not connect to anything else).

When rewiring, it is generally easiest to first disconnect all the wiring at the switches. Use the voltage probe to identify the line and neutral coming from the circuit breaker and mark them black and white respectively. Use the ohmmeter to identify two conductors that can be used as the runners. Mark them red. The remaining two wires connect to the light. The one that connects to the screw-in outer contact on the bulb should be marked white and the one that goes to the inner contact should be marked blue.

The line (black) will connect to the common contact on one switch while the load (blue) will connect to the common contact on the other switch. The common contact (C in the above diagrams) is normally a different color screw on the switches. The runners (red) will connect to the other two contacts (A and B above).

As mentioned, the above diagrams are simplifications that do not show the actual routing of the conductors through the conduits. There are many possible arrangements for this, but three common ones are shown in Figure 4-14 for the US configuration. In the first, the line conduit connects to the SW1 box, and the load conduit to the SW2 box. In the second, both the line and load conduits connect to the SW2 box. In the third, the line conduit connects to the load (light) box. There are similar variations for configurations MX#1 and MX#2. However, you should end up with one of the three shown below after rewiring.

Note that there are always three conductors between the two switches, one that comes from the circuit breaker box (either black or white) and two that run between the switches (red). For simplicity, the green earth ground conductor is not shown in the diagrams or included in the count.

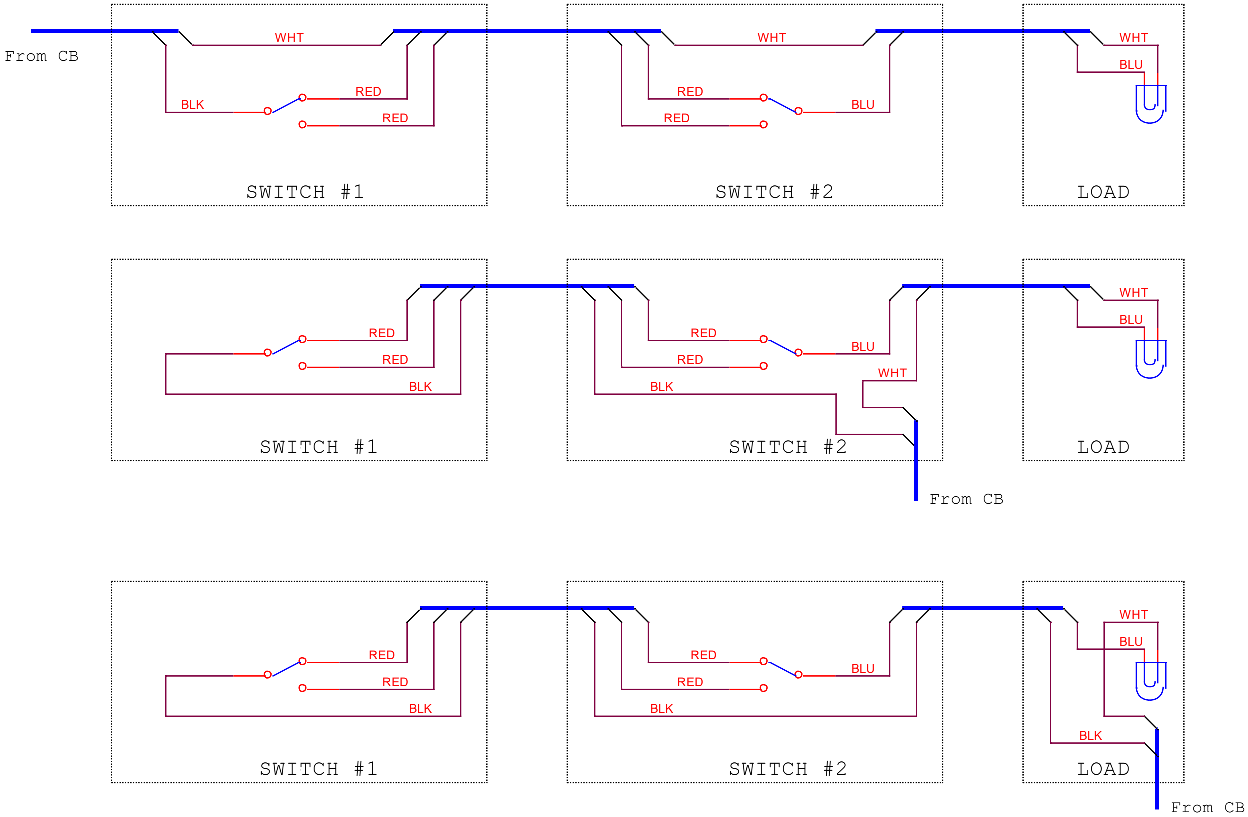


Figure 4-14 Three Equivalent Ways to Connect 3-Way Switches (US Standard Configuration)

4.8 Adding Timers and Dimmers

It's a good idea to have automatic timers that switch lights on and off both inside and outside so that your house will look occupied even when you are not home. The newest generation of timers can be programmed to switch based on times of sunrise/sunset as well as at fixed times during the day. One of the most flexible and easiest to program is the Honeywell RPLS740B (white) or RPLS741B (almond) timer. These are available on Amazon for about US$30. The Decora style wall plate is not included so be sure to order one separately. This model requires connection to the neutral wire as well as the line and load wires so you should check that a neutral exists in the switch box you plan to use. It will switch up to 1800 watts. Honeywell also makes a number of other models including ones that work in US wired three-way circuits. These will NOT work with three-way circuit such as MX#1 however. (See Section 2.9).

The timers will replace a standard wall switch, but may require a separate box adjacent to the one you want to use. This is because they occupy a good bit of depth (1-3/4 inches), and the existing box may already contain a great deal of wiring, connections, etc. It is a simple matter to install a new handy box next to the existing box for the timer. Just be sure to check that there is not already a conduit in this location before chiseling out the wall for the new box, and be sure to get a "deep" handy box to accommodate the timer. See Figure 4-15.

The programming is accomplished using three buttons and is very simple once you figure it out. Honeywell provides a pretty good user guide. The timer calculates sunset and sunrise from your latitude and longitude which you enter during the programming. (They provide a list of these for larger cities including those in Mexico).

You can tell the timer whether or not you want it to automatically adjust the time for daylight savings time. This is very handy but also a problem because in the US, daylight savings time begins on the second Sunday in March and ends the first Sunday in November. In Mexico daylight savings time starts the first Sunday in April and ends the last Sunday in October. What this means is that your timer's clock will be one hour off for one week around the end of October and/or beginning of November, and it will also be off by one hour for a period of either three or four weeks during March and early April. You can always set the clock manually in which case you should leave the daylight savings time feature disabled.

Figure 4-15 Honeywell Timer

Replacing some of your existing switches with a dimmer can really modernize the look and feel of your house. My favorite is the Lutron Maestro series. Lutron model MACL-153M-WH is the white version which works with incandescent loads up to 600 watts and with CFL or LED loads up to 150 watts. Do not get the identical looking MA-600-WH because it will not work with LED bulbs. The two small buttons on the right are used to preset the light level up or down. LEDs on the left show the setting. Once set, a simple tap on the large center button makes the light slowly turn on to the preset level or slowly turn off. Supposedly this prolongs the life of the bulbs, but the effect is what is really nice. You can buy these dimmers for about US$30 on Amazon. Be sure to get a matching Decora style wall plate since these are not included with the dimmers. The dimmer is 1-1/8 inches deep so it should fit in an existing switch box.

To install one of these, just connect the line and load wires to the black and brass colored screws. The blue screw is for connecting to a multiple-location (3-way or 4-way) circuit, and the green is for connection to an earth ground. If there is no earth ground, just cut off the green wire on the switch. There is no neutral connection on this dimmer.

When using this dimmer with LEDs, you will need to follow a simple programming step after installing it to set the minimum light setting so that it does not produce a flicker. It is also possible to program the switch for different fade times, delayed fading and other characteristics. The procedure for these additional programming options is not included with the dimmers, but if you are interested you can download the instructions from http://www.lutron.com/TechnicalDocumentLibrary/048459.pdf.

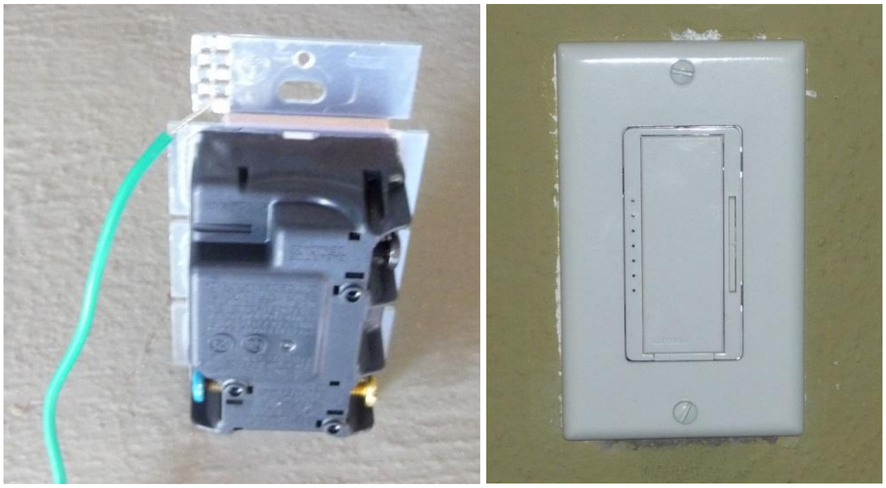


Figure 4-16 Lutron Dimmer

There is a small slide switch just below the large button that should be used to disconnect the light circuit if you need to change a bulb.

4.9 Adding to a Circuit

The easiest way to add to an existing circuit is to use wire mold, a plastic surface mount channel that is sold in a variety of sizes at Home Depot Mexico. The boxes are open on both front and back surfaces, so you can mount one directly over an existing box. Mount the channels with #6 sheet metal screws into plastic anchors about every foot apart. There are angles made that snap over the corners, but I recommend you use some white silicone to help hold them in place. This system is a bit fragile, so you should only use it where it will not be subject to rough bumping. It is also not suitable for outdoor or wet locations. See Section 11.2 for some pictures showing the use of wire mold.

Another method is to use a box extension over existing boxes with waterproof flex conduit connecting to any new boxes that can be surface mounted on the wall. This is the system I used in the pool pump area that is described in Section 9. The flex conduit is clamped to the wall every couple of feet. This is a very durable system that is suitable for outdoor and wet locations, but you would not want to use it in a living area.

The best but most difficult to install method is to add a flex conduit inside the walls. This requires cutting a slot and chiseling it out between the old and new recessed boxes. Figure 4-17 through Figure 4-20 show the steps involved.

Figure 4-17 Installing New Circuit Step 1

Mark the outline for the channel and new outlet box. Then use a hammer drill around the outlet box outline and a diamond blade saw to cut the sides of the channel

Figure 4-18 Installing New Circuit Step 2

Use a chisel to cut out the channel and the box opening

Figure 4-19 Installing New Circuit Step 3

The tubing is held in place by twisting wire ties that are wrapped around a concrete nail

Figure 4-20 Installing New Circuit Step 4

Cover tubing with cement and paint

4.10 Replacing Knife Switches and Old Circuit Breaker Panels

Load centers (circuit breaker boxes) are available in a large range of sizes with various options for covers. A typical surface mounted box with space for 8 breakers and a cover door suitable for use as the entry panel in a protected location is QO816L100DS shown in Figure 4-21 below. The outdoor version is QO816L100RBCP. Deciphering the part numbers is not simple; the best way is to look at the descriptions and pictures on Home Depot's web site to decide what you want.

Figure 4-21 QO816L100DS Indoor Load Center (Left) & QO816L100RBCP Outdoor Load Center (Right)

Load centers like the one shown above may be wired with main disconnects by connecting the input wires to a double pole breaker located in the left most pair of spaces. Normally circuit breakers unplug from the breaker box and are not “live” after they are removed. However, when wired as a main disconnect breaker, this is not the case, and the breaker and its attached wiring are “hot”. So when using a main breaker in one of these load centers, be sure to use the PK2MB retaining kit on this breaker. See Figure 4-22. This keeps the breaker from being readily removed.

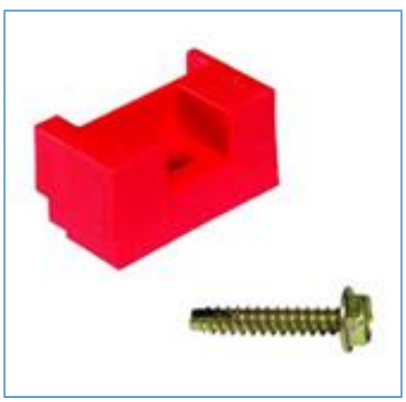


Figure 4-22 PK2MB Retaining Kit

There is a trick to installing the retaining kit. With the breaker out of the box, loosen the screws for the two conductors and note how the conductor clamps operate. You will need to reinstall these conductors after the breaker is mounted and the retaining kit is installed. Also note how the retaining kit fits against the bottom of the breaker and the location on the insulated mounting bar where the screw will install.

Install the breaker then hold the retainer in place with one hand while starting the screw by hand using a 5/16 inch socket. Tighten the screw as much as possible by turning the socket by hand, then insert a 6 mm Allen Wrench in the ¼ inch drive on the socket. This size Allen Wrench fits well and lets you tighten the screw. Nothing else I have tried seems to work including using a ratchet drive and/or a flex angle coupling because of the very limited space between the screw head and the back of the breaker box.

Finally, reinstall the two conductors and tighten the screws on the breaker. Push in on the breaker screws while fitting the conductors into the clamps. This opens the clamps which may have closed somewhat while installing the breaker and retaining kit. Tug on the conductors to be sure they are securely clamped in the breaker.

An example showing how I replaced two large knife switches with two of the above indoor load center boxes is given in Section 10. In Section 12, I replaced another large knife switch with an outdoor load center. It is necessary to pull the meter(s) to disconnect all the electricity to the entry boxes when performing this upgrade. Be sure to plan ahead and have all parts and tools on hand so that you will not be without electricity for too long while doing this work.

An interesting line of load centers that appears to be available only in Mexico is the QOX series. These are not suitable for exposed outside use but they are an excellent choice for indoor applications where a small to moderate number of circuits is required. The models available are listed below.

Table 4-5 QOX Series Load Centers

Model	Total Current	No of breaker spaces
QOX204	60 A	2+4 = 6
QOX206	100 A	2+6 = 8
QOX208	100 A	2+8 = 10

The number of spaces is shown above as 2 main spaces + 4, 6 or 8 additional spaces. The main space can be used for a main breaker by connecting it to the line input wires while the additional spaces are connected internally to the output of the main breaker. Unfortunately the QOX series panels do not permit the use of a PK2MB locking device for the main (back fed) breaker. If a main breaker is not used, as would normally be the case with a subpanel, then the input wires are connected to the lugs in the panel, and all spaces are available for branch circuits. Of course, the number of branch circuits could be increased by using tandem breakers, but at some point the wiring would get pretty tight.

These panels can be either surface mounted or recessed, and they have an attractive plastic cover/door. See Figure 4-23.

A minor disadvantage is that they only provide space for 2 double pole breakers (the main pair of spaces and one additional pair). A big advantage is that they include separate (isolated) bus bars for neutral and earth grounds.

Figure 4-23 QOX204 Load Center

In Casa Erres, I replaced the original knife switch and several individual circuit breaker boxes in the pool area with a QOX204. See Section 9. I also converted the original house and appliance circuit breaker subpanels into junction boxes and added a QOX208 and a QOX204. See Section 10. In Casa Colibrí, I replaced a number of old subpanels with these. See Section 12.

4.11 Using LED Bulbs

The variety of LED light bulbs has exploded in the past few years at the same time that their cost has dropped. It is now possible to get nearly any style lightbulb in an LED at a cost that is about 2 to 3 times that of a conventional incandescent lightbulb. BUT an LED bulb has a lifetime that is about 10 times longer than an incandescent, so switching to LEDs is cost-effective based solely on the lifetime replacement cost. In addition, an LED consumes about one tenth the electricity of a comparable incandescent light, so you may save considerable pesos on your electric bill. Note however that switching to LEDs will NOT reduce your total power consumption by a factor of 10, because the non-lighting loads in your house (kitchen appliances, etc.) are typically 60 to 75% of the total. This means that your total usage will only drop 20 to 35% if you change all the lighting from incandescent to LED.

Another reason for switching to LEDs is to give your house a new look. This is especially true in an older house where over the years a hodge-podge of light bulbs has been used. Frequently these are not the best shape, wattage or color for the fixtures in which they are used. Doing some careful planning and shopping will let you change all these out and improve the look of all lighting sources.

Selecting an LED can get confusing because of the huge variety of choices in light output, light color, bulb, base, and emitter shape. For residential use, the selection can be narrowed greatly, however.

Assuming you are replacing the bulbs in an existing fixture, first determine the type of base used. It is most likely one of 4 sizes: E26, E12, GU5.3 or GU10. The screw in bulbs are either E26 (medium base) or E12 (small base, sometimes called candelabra base). The GU5.3 and GU10 bases are used on the small conical shaped spotlights. GU5.3 has two pins that plug in directly and GU10 has two wider spaced pins that have bayonet locking stubs on them. In the US, GU5.3 bases are used for 12 V lights and GU10's are reserved for 120 V bulbs. This is NOT the case in Mexico; both bases are used for 120 V light bulbs.

The bulb shape used on the conical spotlights are always MR16's. The bulb shapes used on the screw-in Edison (E26 or E12) bases may be the classical A style, the torpedo shaped B style or the bent tipped candle CA style. There are also many other styles and sizes. Figure 4-24 shows the most common combinations.

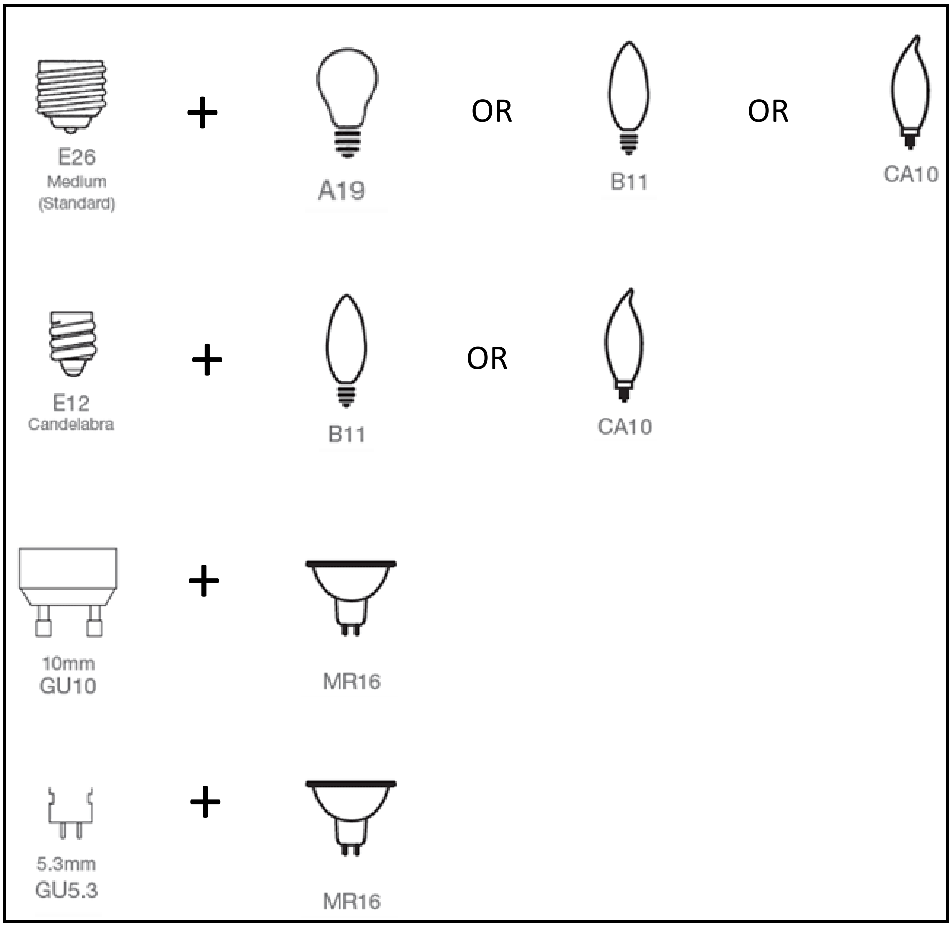


Figure 4-24 Common Residential Bulb Bases and Shapes

The number following the letter on the bulb shapes indicates the maximum diameter in eighths of an inch. For example, a B11 bulb measures 1-3/8 inches at the widest part.

The bulbs may be clear or frosted, and the diode emitter inside may be a decorative ribbon filament or a central LED with a lens that projects the light upward and radially outward.

Light output is given in lumens. Most of us are not used to this measurement (yet) so LEDs are frequently rated in terms of equivalent incandescent wattage for light output. Figure 4-25 shows the correspondence. There is a spread of lumens of about 20% due to differences in efficiency.

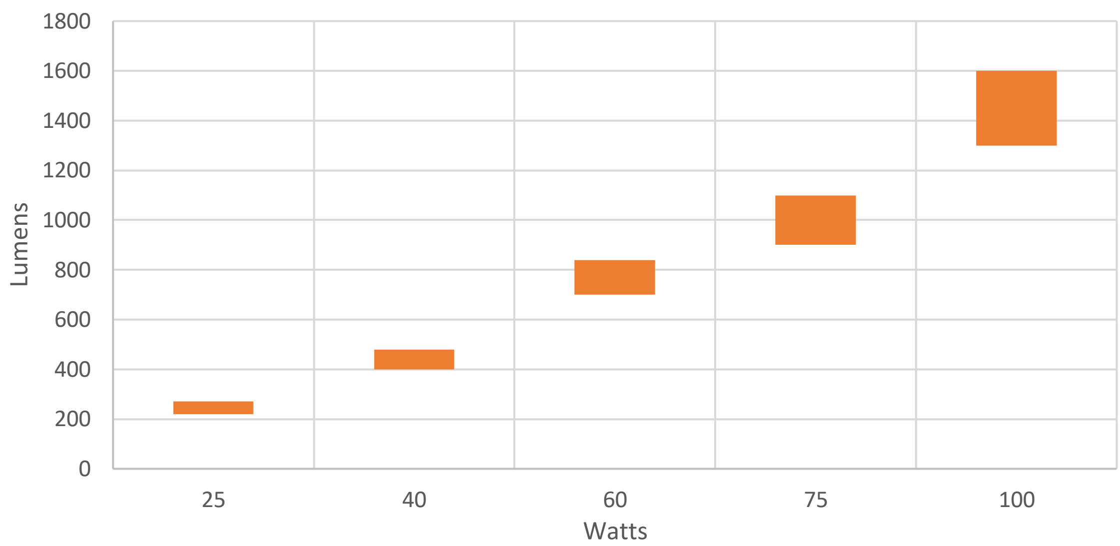


Figure 4-25 Light Output in Lumens vs Equivalent Incandescent Power in Watts for LED Lights

It is unusual to find an incandescent light bulb in a Mexican residence larger than 60 watts. That may be due to a natural aversion to paying for electricity and partly to the design of the fixtures which are mostly rated for 60 watts maximum. In addition, LED lightbulbs much larger than 60 watts (equivalent incandescent output) are still much more expensive than the smaller ratings. So for the range less than 60 watts you should remember that an LED output in lumens is roughly equivalent to an incandescent bulb of one tenth that wattage. For example, a 450 lumen LED produces about the same amount of light as a 40 watt incandescent.

LED light has a “color” which is given as a temperature. The usual warm white of an incandescent bulb is about 2700 degrees K. LEDs are available with this color as well as a slightly whiter 3000 degrees K. You can also get very warm light (2200 to 2400 degrees K) as well as daylight white (5000 to 6500 degrees K).

Finally, LED bulbs are either dimmable or non-dimmable. The bulbs that are not dimmable are less expensive, but the difference in price is getting smaller and many dealers now only offer dimmable LEDs.

With all of these choices, how does one decide which LED(s) to buy? The decision is based on aesthetics, cost, availability, and physical constraints. Here are the bulbs I selected.

For general overhead lighting in enclosed fixtures where most or all of the bulb is not visible, or for table lights with large (10 to 16 inch diameter) lamp shades, I used E26/A19/800 lumen/2700 deg K frosted non-dimmable or E26/A19/440 lumen/2700 deg K frosted dimmable bulbs.

For overhead lighting in low profile fixtures where the A19 bulb would not fit, and for wall sconces that have small (5 inch diameter) shades, I used E26/B11/330 lumen/2700 deg K clear dimmable ribbon filament bulbs. The ribbon filament provides much better radial coverage in the torpedo (B) shaped bulb.

For wall sconces that did not have shades, I used E26/CA11/300 lumen/2200 deg K clear dimmable ribbon filament bulbs. Especially when dimmed down, the 2200 deg filaments are very attractive.

For hanging chandeliers without shades that had the small base, I used E12/CA11/300 lumen/2200 deg K clear dimmable ribbon filament bulbs.

For overhead kitchen lighting, I used GU10/MR16/500 lumen/3000 deg K non-dimmable bulbs.

For overhead closet lighting, I used GU10/MR16/500 lumen/6500 deg K non-dimmable bulbs. The outdoor lighting color makes selecting clothes easier.

For accent lighting inside the kitchen cabinets, I used GU5.3/MR16/220 lumen/3000 deg K non-dimmable bulbs.

Note that this is a total of only 7 different bulb types. The best bargains are for packs of 6 or 10 bulbs. I found everything I needed at either Home Depot or Costco. Be sure to check the Costco on-line US warehouse as well as the local Mexican stores. If you need something special, check http://www.Bulbs.com.

4.12 Lowering Your Electric Bill with Multiple Meters

You have probably noticed that some neighbors have multiple electric meters. Just on our street, about half the homes have two meters and one house actually has five! The Federal Electric Commission (CFE) offers much lower rates for low usage subscribers. Therefore if you have a house that can claim to have multiple dwelling units (for example, a maid's quarters, guest house or rental area), you may qualify to have more than one electric meter. The difference can be quite substantial, so this possibility is worth looking into.

CFE residential billing uses two rate structures. *Tarifa* 2 consists of a fixed charge and a single proportional rate. The fixed charge and the rate change with time, but for simplicity I have used the November 2016 values in the following comparisons. *Tarifa* 1 is a different structure that does not have a fixed charge but uses three increasingly higher rates as the consumption increases. If the average consumption over a 12 month period exceeds 250 kWh per month under *tarifa* 1, a new rate called DAC (*De Alto Consumo*) is triggered. This rate consists of a fixed charge and a much higher proportional rate.

To make comparison of the rates easier, we can assume that all monthly consumption is the same. Then the DAC rate becomes just another segment of the *tarifa* 1 rate structure.

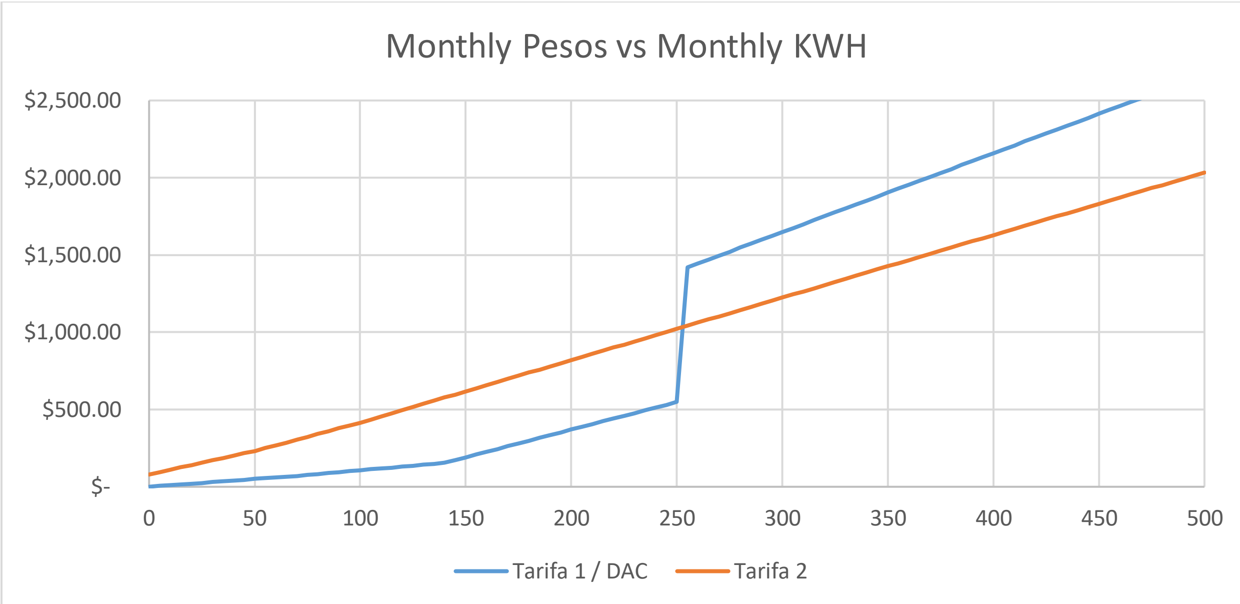


Figure 4-26 Monthly cost of electricity for low usage

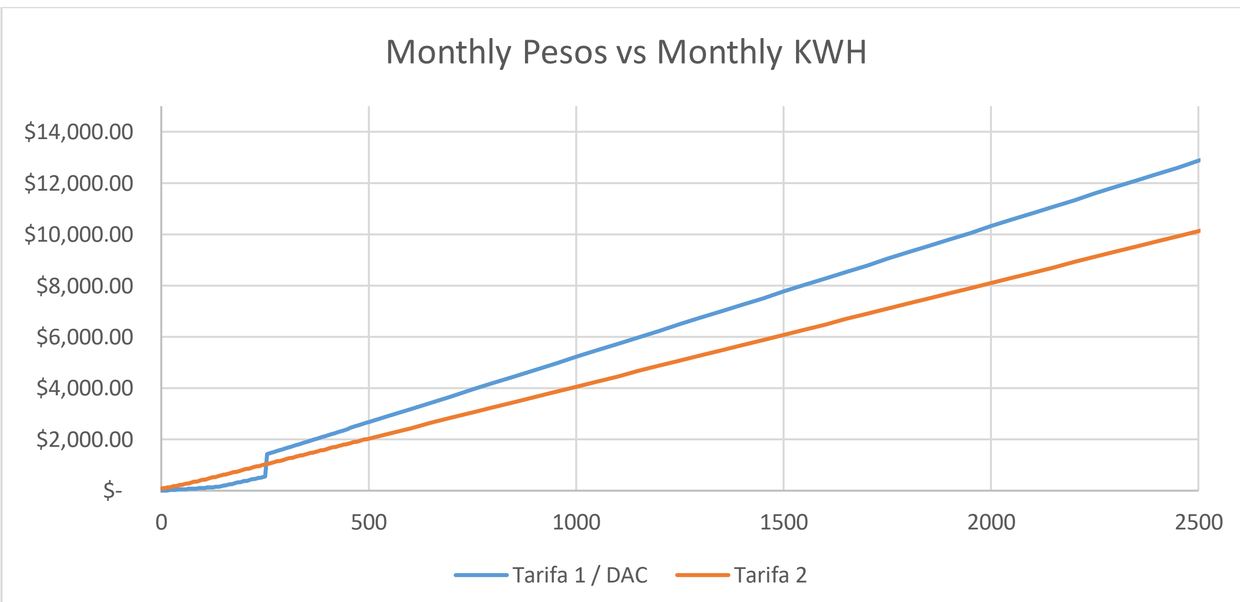


Figure 4-27 Monthly cost of electricity for higher usage

Figure 4-26 and Figure 4-27 above show the difference in cost for the two rate structures. These charts are for a single meter and include the 16% IVA and 10% DAP taxes.

Note that *tarifa* 2 provides a lower cost than *tarifa* 1 except when the consumption is less than 250 kWh per month. That is a relatively low threshold which corresponds to an average load of about 350 watts running continuously. A small San Miguel home with a refrigerator and lights that are not left on when not needed should meet this. A larger home would typically run 2 to 3 times this much. This is why many homes use multiple meters. By keeping each meter below 250 kWh per month, the DAC threshold is avoided and the much lower *tarifa* 1 rate shown in Figure 4-26 applies.

It is interesting to see how sensitive these calculations are to the balancing of the load between the two meters since the only way to guarantee an even balance would be to connect the two meters in parallel. (CFE might to object to this). The graph in Figure 4-28 shows the total bill for three levels of consumption as a function of the load balance. The dip in the center of each of the three curves corresponds to the *tarifa* 1 rate while the higher values are where the DAC applies.

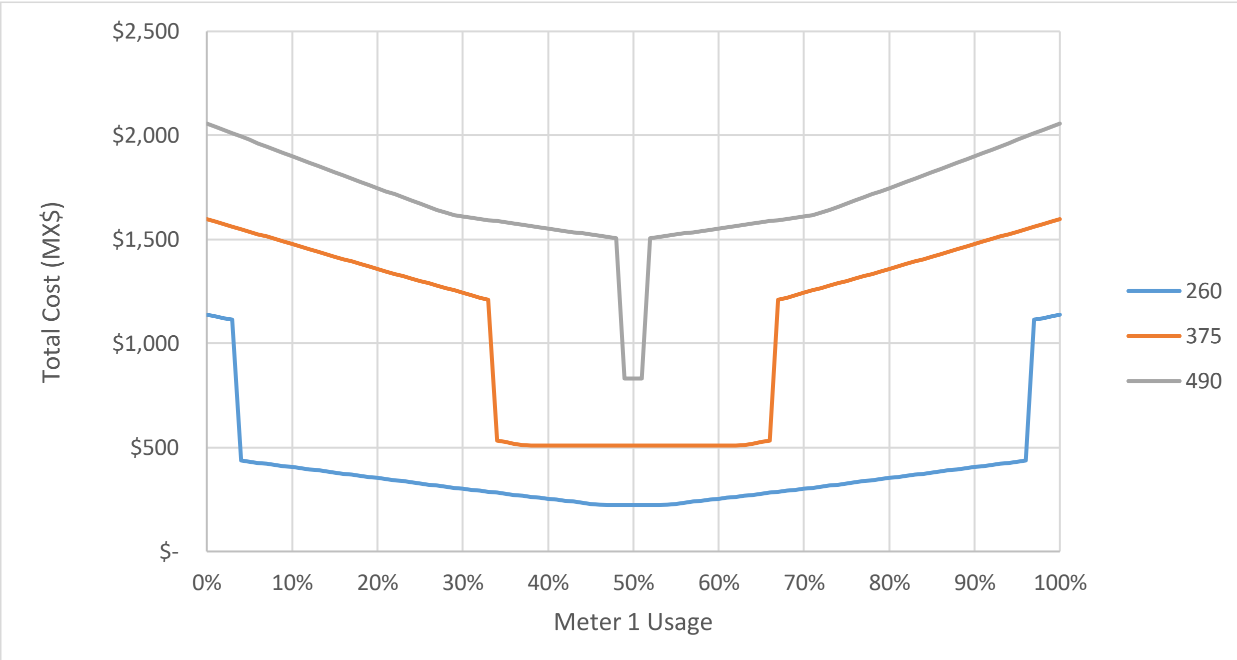


Figure 4-28 Total Cost for Two Meters vs Load Balance

The orange curve shows that for a total energy usage of 375 KWh, the balance needs to be between about 33% and 66% to avoid the DAC. For higher usage, say 490 KWH, the balance needs to be much closer to 50% while for a lower usage like 260 KWH the range is much wider.

If you are living in an area served with 3-phase power, your meter may be marked either 2F3H or 3F4H, where F means *fase* (phase) and H is *hilo* (conductors). If you are in an area served by 2-phase power, a 2F3H meter will be used. These may be either analog or digital. In any case, if you decide you want to replace your existing meter with two meters, you will want to request two of the 1F2H meters. This will involve changing meter sockets as well as requesting CFE for the new meters.

A simplified schematic of how a 2 or 3 phase meter is wired is shown in Figure 4-29. Figure 4-30 shows how a two meter system should be connected to the main entry panel. The black, red and white rectangles represent the two line side buses and the neutral bus inside the main entry panel. The conductors shown should be AWG6 if the main breaker is 70 amps, and should be AWG8 if the main breaker is 50 amps. I recommend using AWG6 and a 70 amp breaker (QO270).

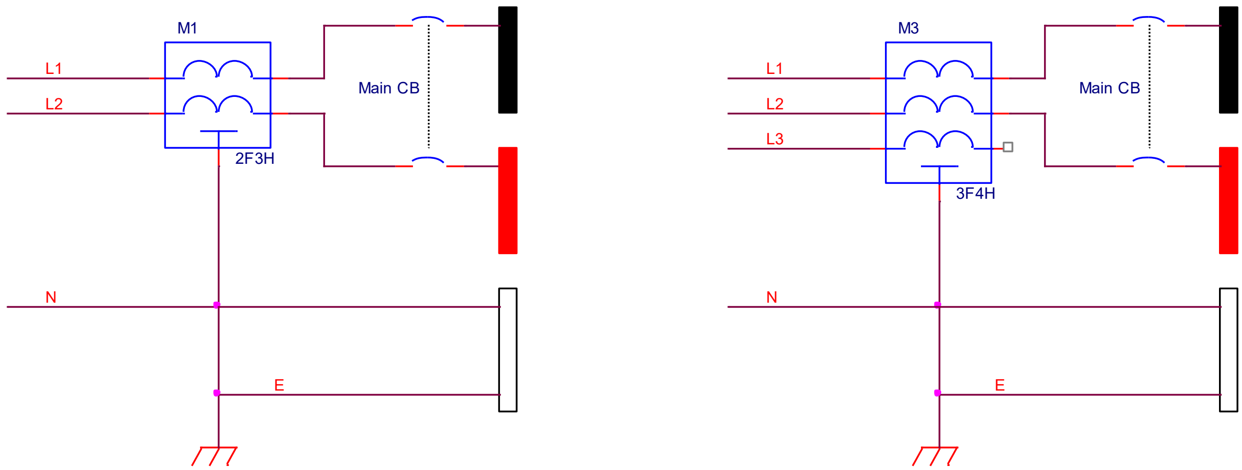


Figure 4-29 2 Phase Meter (left) and 3 Phase Meter (right) Connections to Main Circuit Breaker Panel

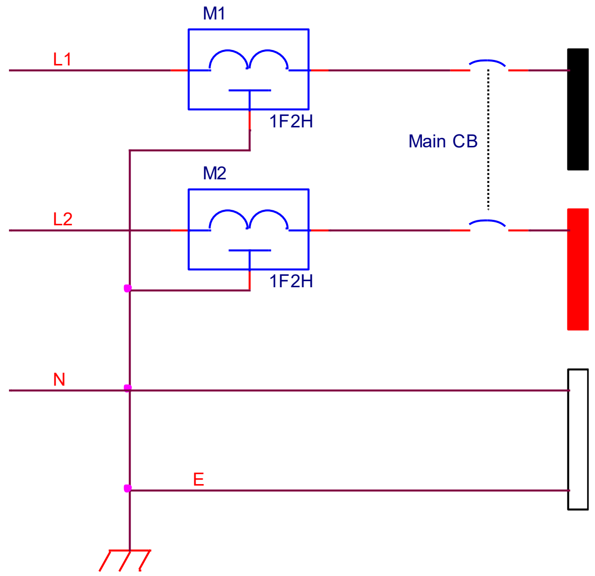


Figure 4-30 Two Single Phase Meters Connected to Main Circuit Breaker Panel

Installing a second meter is definitely a job for an experienced electrician because it involves dealing with the live wiring on the CFE side of the meter(s).

As discussed above, it only makes sense to have two meters if your total average usage is less than 500 KWh per month. But to realize the full savings, the loads on the two meters must be evenly balanced. Once the meters are installed, just write down their readings over a period of say 1 week and see if the usage is about equal. If it is not, you will need to swap one or more branch circuits between phases. This is easy to do but requires some work to figure out which ones to swap.

In my case, I had already switched over to LED bulbs, so the main loads to consider were those due to appliances, pumps, etc. I used the current meter and plug in energy meters (see Section 5) to make an inventory of all the non-lighting loads in the house. When measuring energy usage for appliances like your refrigerator, microwave, etc. be sure to do so over a period of several days minimum. Table 4-6 shows the non-lighting loads I measured.

Table 4-6 Measured Non Lighting Energy Use

Load	KWh/month
Large refrigerator	60.8
Small refrigerator	24.8
Bar refrigerator	13.6
Water pressure pump	44.7
UV water purifier	22.1
Fountain pump - Note 1	15.1
Ceiling fan - Note 2	20.7
Washing machine	3.4
Dryer	3.2
Dishwasher	10.9
Toaster	1.0
Microwave	4.5
Coffee Maker	7.2
Computer - Note 3	28.6
TV	9.2
Iron	15.3
Stereo	7.2
Total	292.2

Note 1 – Timer set for 3 hours per day.
Note 2 – Low speed 24 hours per day.
Note 3 – Power mode set for display off after 10 minutes, sleep mode after 30 minutes.

Now group and add these loads together for each of the circuit breakers and associate each of the breakers with its corresponding phase (meter) shown below in red or black.

Table 4-7 Non Lighting Loads in Casa Colibri by Circuit Breaker

Garage Subpanel QOX204		KWH/mo.
M1	AC	0
M2	AC	0
1	Garage, Utility room light, Front courtyard	15
2	Utility room pump & purifier	67
3	Kitchen	18
4	Kitchen	65
Storage Room Subpanel		
M1	Dryer outlet	0
M2	Dryer outlet	0

1	Stairs & Nicho lights, Arch lights in living room	0
2	Laundry, Lower Storage, Bedroom 2, Bath 2	6
3	Living Room N. Outlet, Upstairs Powder Room, Upstairs Office, Bedroom 1 exc N Wall, Bedroom 1 Bath & Closet	25
4	Laundry N Wall outlets, Lower Storage N Wall outlets	
5	Fountain (back yard), Lower patio outlets	30
6	TV Room, Downstairs Office outlets, Lower Patio Lights, BR3 N wall outlet	25
Wine Cellar Subpanel		
M1	Brewery	0
M2	Bar, Wine Cellar, Refrigerator	25
1	Breakfast, Pantry, Upper Patio, Dining Room, Entry, Living room S Wall	0
2	Bedroom 3, Bath 3	0
3	Downstairs Powder Room, Alcove, Downstairs Office Lights	0
4	-	
	Total RED	137
	Total BLK	139

The above table shows the loads after balancing. The initial imbalance was 50 KWh per month, and M1 and M2 in the Wine Cellar Subpanel were reversed from that shown above. So all that was required was to interchange these two breakers, and the loads were evenly balanced between the red and black phases.

5 Tools and Test Equipment

Depending what you plan to do, you may need some or all of the following.

Figure 5-1 Common Electrical Tools

Note that the wire cutters, wire strippers and pliers have insulated handles. The knife (used for cutting tape and stripping large gauge wires) does not, so don't use it on a live circuit! The small level is indispensable for getting switches and wall plates level.

Figure 5-2 Voltage Probes

The upper probe does not have a sensitivity adjustment; the lower one does. You can find the better probe on Amazon or EBay. Look for Mastech MS5902. It is much easier to use. When using these probes, be sure to test them against a known line side conductor frequently as the sensitivity can change due to the batteries losing charge. If either of them gives results that are not repeatable, change the batteries.

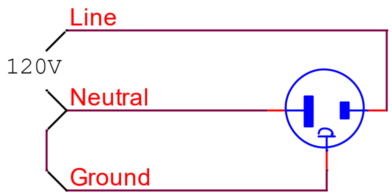
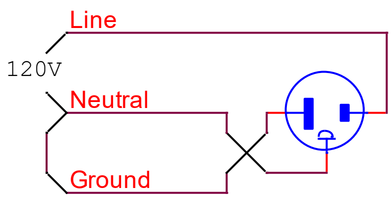
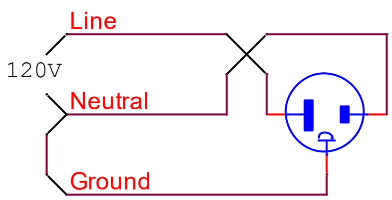
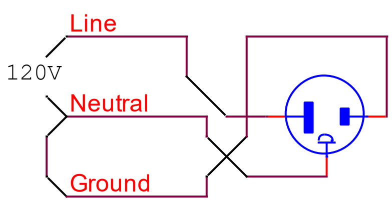
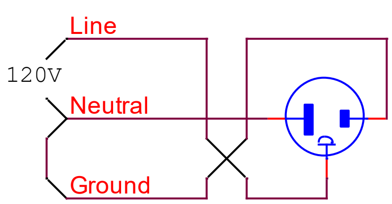
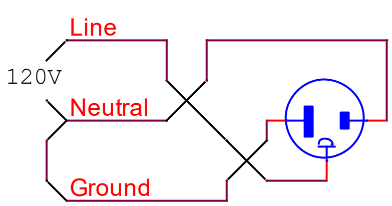
Figure 5-3 Colored Electrical Tape

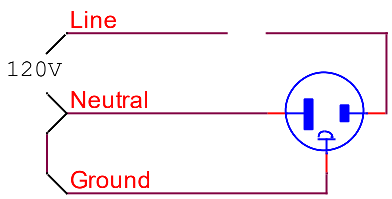
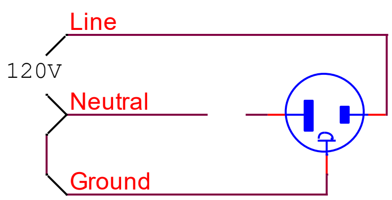
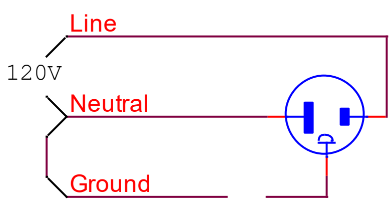
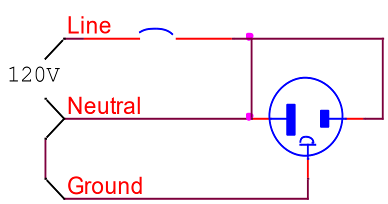
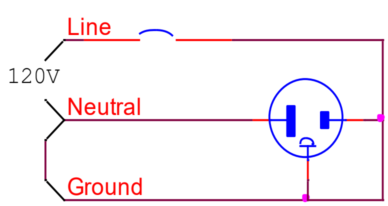
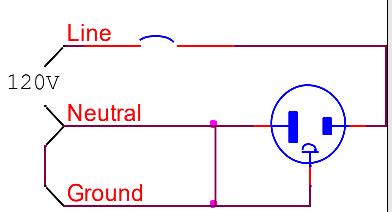
Use these to color code conductors if your house is not wired to code. The best source of these is McMaster Carr. They sell the Scotch type 33 which is recommended over the cheaper varieties. When marking names, use a fine tip felt pen on the yellow tape before removing it from the roll.

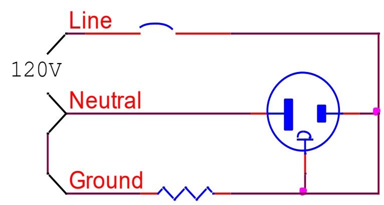
Figure 5-4 Simple Circuit Outlet Polarity Tester

This tester will work only in three prong outlets that are wired with the earth ground properly connected. The tester shows the most common faults, but be aware that the indications may be misleading. Table 5-1 below shows a more extensive list of faults and how they are displayed on this tester. Note that this type of tester does not detect any sort of neutral ground reversal. This can only be done by checking the currents through these two conductors at the breaker panels. (There should be very little current through the earth ground).

Table 5-1 Outlet Tester Indications

Wiring	Diagram	N to G	L to N	L to G	Comments
LNG					Correct wiring.
LGN					Neutral and ground reversed. Check for non-zero current through ground at panel with load connected.
NLG					Line and neutral reversed.
GLN					Line and neutral reversed, then neutral and ground reversed. Check for non-zero current through ground at panel with load connected.
GNL					Line and ground reversed.
NGL					Line and ground reversed, then neutral and ground reversed. Check for non-zero current through ground at panel with load connected.

Wiring	Diagram	N to G	L to N	L to G	Comments
OL					Open line.
ON					Open neutral.
OG					Open ground.
LN Short					CB Opens.
LG Short					CB Opens.
NG Short					Check for non-zero current through ground at panel with load connected.

Wiring	Diagram	N to G	L to N	L to G	Comments
LG Short with ground resistance					Looks like line to neutral reversal, but is not. Circuit breaker should blow but ground resistance prevents this. Measure resistance between neutral and ground at outlet to detect ground resistance. This is a very dangerous condition that propagates to all outlets in the same circuit.

The last case shown occurred when I was installing GFCI outlets in the kitchen of Colibrí. The outlet tested normal until I connected the wires to the next outlet in the circuit. Then I got the “Line Neutral Reversed” indication. How could connecting another downstream outlet cause a line to neutral reversal? The reason is the downstream outlet had a line to ground short (due to a sheet metal screw puncturing the line inside a conduit) and the upstream ground connected to the neutral through a resistance of about 10Kohms. This resistance is low enough to supply the current to illuminate the amber light but is not enough to trip the circuit breaker.

Figure 5-5 Voltage-Current-Ohm Meter

There are many models of voltage-current-ohm meters available in a range of prices. I found the Mastech units cost-effective and very easy to use with two exceptions. The model shown above is their 32-800 which features a low current range that is helpful for checking current balance in GFCI circuits. It is available on Amazon for about US$135. The two problems are that when you first turn it on to measure a voltage, it comes up in a DC mode. You need to remember to push the FUNC button to get it to measure AC. The second problem, which a number of users have complained about, and which I can confirm, is that the connectors that the test leads plug into are not very well soldered to the internal circuit board. When plugging in these leads, be careful that they engage, but don’t push them hard as it will break the solder connection. If this happens, it is not very difficult to repair, but you will have to open the unit and resolder them.

Figure 5-6 Wire puller and Lubricant

If you need to pull additional wires through a conduit, you will need these. When using the puller, push the end with the stranded steel wire through first. Strip one of the conductors you will be pulling through and loop it through the hole in the ferrule at the end of the steel wire. Tape all the conductors you will be pulling together around the stranded steel using enough tape to ensure a good bond but not so much as to increase the diameter. Then pull it through. The lubricant helps a lot. So does having an assistant to feed the wire through one end while you pull on the other.

Figure 5-7 Cutter with Diamond Blade

Not really an electrical tool, but if you need to install a new piece of flex tubing in the wall you will need to buy or rent one of these. Cut out two parallel channels then chop out the cement between them with a masonry chisel. Be prepared for a LOT of dust.

Figure 5-8 Circuit Tracer

These are expensive and probably not needed unless you are doing a lot of circuit tracing. There is an inexpensive version available called a “toner” that works with low voltage wiring, but you will need one of the above to locate a wire that is buried an inch or so inside a wall or under the floor. The one shown was bought used on EBay for about US$250. New ones cost upwards of US$1000. You can use these for low voltage wiring also.

Figure 5-9 AWG10 to 12 Crimp and Crimper

If rewiring a box results in too short a conductor to reliably use a wire nut, the crimps are a great way to extend the wire. The crimp shown is one of the uninsulated ones and must be wrapped with tape after crimping. This is the M10BCX sold by http://www.Platt.com. The crimper is part number J1005. They also sell an insulated crimp, BSV10Q. It is actually cheaper than the non-insulated crimp shown.

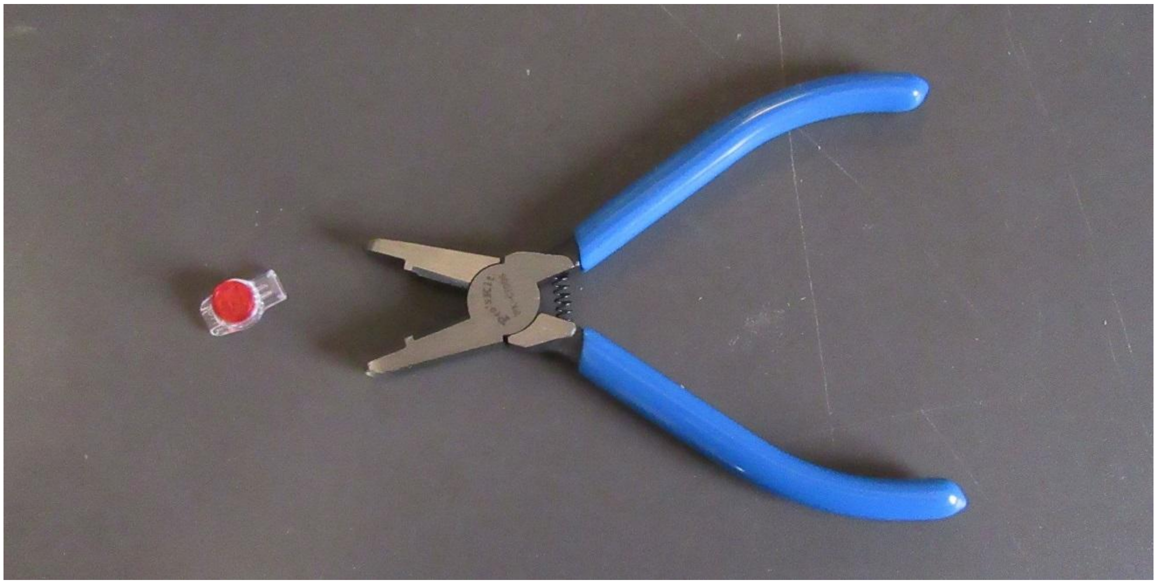


Figure 5-10 AWG 19 to 26 Splice and Crimp Tool

Use for splicing 2 or 3 low voltage conductors. Do not strip the insulation from the wires; the crimp penetrates the insulation. The splices are 3M UR and the tool is ET-100-008; both are available from http://www.Discount-low-voltage.com. Do not use these for UTP CAT5 Ethernet cables. If a splice is necessary use RJ45 Keystone jacks and a short patch cable.

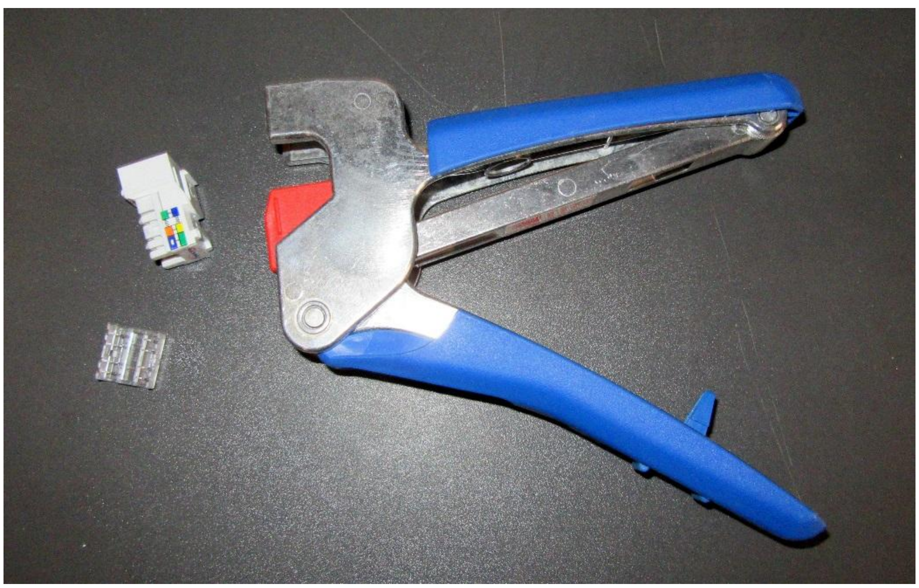


Figure 5-11 Keystone Jack and Crimp Tool

The jack shown is DY-10605K-WHT and is for a CAT5 Ethernet connection. The tool is DY-KWIKTOOL and it works with both the CAT5 (RJ45) connector shown and CAT3 used for telephone connectors (RJ11). All are available from http://www.Discount-low-voltage.com.

Figure 5-12 RG6 Coax Connector and Crimp Tool

Use these to connect TV cable to a coaxial keystone jack. The connector shown is ID-92-65 and the tool is ET-CP-313. All are available from Discount-low-voltage.

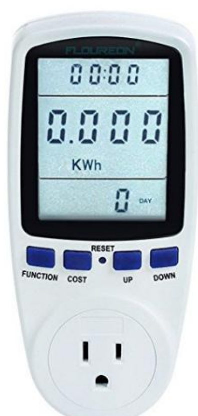


Figure 5-13 Plug In Power/Energy Meter

These are great for measuring the power consumption of intermittent devices like PCs, refrigerators, etc. To get a good averaging reading, you need to leave them connected for about one week, so it makes sense to buy more than one. Amazon and EBay carry many of these which all appear to be about the same device sold under different names. The LCD is very difficult to read, and the instructions are written in terrible English, but the price is right (about US$15), and the unit appears to be accurate.

6 Low Voltage Wiring

Not many years ago, well-designed homes in the US started to be wired using “structured wiring” where a wiring closet with patch panels was connected using category 5 cables (Ethernet), RG6 coax (TV) and category 3 (telephone) cables to ports throughout the house. In Mexico, I have not seen any structured wiring, but separate conduits are generally used to distribute these same signals. Where these exist and are in good or repairable condition, they should definitely be used. However, wireless connections for Ethernet and telephone signals can be a good alternative. There are even wireless systems available for intercom, doorbell and audio (music) distribution.

As discussed in the next section, wireless communication in Mexico is limited by the solid brick and concrete construction used. But with careful placement of wireless Access Points, even a large house can be covered.

6.1 Range of Wireless Devices

Devices are available to send voice, data and even TV via low power wireless instead of by wired connections. Most of these operate in the 433 MHz, 900 MHz, 2.4 GHz or 5 GHz unlicensed bands but they are restricted to relatively low power of 1 watt (+30 dBm). Because of the way Mexican homes are constructed using brick, cement and steel reinforcing, wireless communication is greatly reduced compared to a typical US-constructed house built using wood studs and sheetrock.

Without getting too technical, the range of a wireless device depends on frequency, transmitted power, receiver sensitivity, antenna gains, and losses due to reflections and absorptions of walls, etc. between the transmitter and receiver. What is called “path loss” is simply the reduction in signal strength due to distance and intervening blockages. It is usually measured in “dB” which is a logarithmic term that lets the overall path loss be calculated by simply adding (rather than multiplying) the individual path loss contributors.

In a typical situation such as shown in Figure 6-1, the path loss out of doors (blue line) increases 6 dB every time the distance is doubled. A loss of 6 dB simply means the signal intensity is halved but the signal power level is reduced by a factor of 4. Suppose we take a Wi-Fi router out of doors and measure the maximum range at which we get a stable, reliable signal. At 2.4 GHz, this would be somewhere around 100 feet, but you might measure more than that depending on the device you are testing. This is shown by the intersection of the blue line with the vertical line corresponding to 100 feet in the figure. The loss can be read off as 91 dB. Now suppose we add a wall between the transmitter and receiver that consists of two pieces of ½ inch thick drywall on either side of 2x4 or 2x6 wood studs. This adds about 1 dB of loss and is plotted with the red line. We can read off the range corresponding to the same path loss. It is about 90 feet, so our range has been reduced by 10 feet. If there are two intervening walls, the range is reduced to 81 feet. And if instead of a wall, we had a floor consisting of a piece of ¾ inch plywood on top plus a ½ inch drywall on the bottom of the joists, the range would be reduced to about 78 feet.

But this is typical US residential construction. In Mexico, the walls are normally 7 inch thick brick and stucco, and the floors are poured reinforced concrete that are at least 8 inches thick. A typical wall then adds about 10 dB path loss and a floor at least 40 dB path loss at 2.4 GHz. To see what this does to our range, consider Figure 6-2. The blue line marked “outdoors” is the same. A single Mexican wall will reduce the range from 100 feet to about 32 feet, and two walls will reduce it to about 10 feet. A floor reduces the range to about 1 foot meaning we have no useful range at all going through a floor. Fortunately, we can expect some help from openings like doors and windows or stairwells and open lofts. But the fact remains that the expected range of a wireless device will be severely reduced.

As an example, at Casa Erres, the Telmex router has a range of about 50 feet passing through two walls with open doors on the same floor. It has a range of about 25 feet passing through a floor with a large open loft area. This is not adequate to cover the inside of the house, let alone the back patios. The AT&T cordless telephone has a slightly better range, but again it is not adequate for the entire house. The wireless doorbell, which has a much narrower bandwidth and hence a much higher sensitivity, has a range of about 75 feet going through one outside wall, and nearly 200 feet going to the pool area behind the house. Actually the pool area is almost a line of sight to the doorbell transmitter. (RF signals do “bend” a little to go around corners).

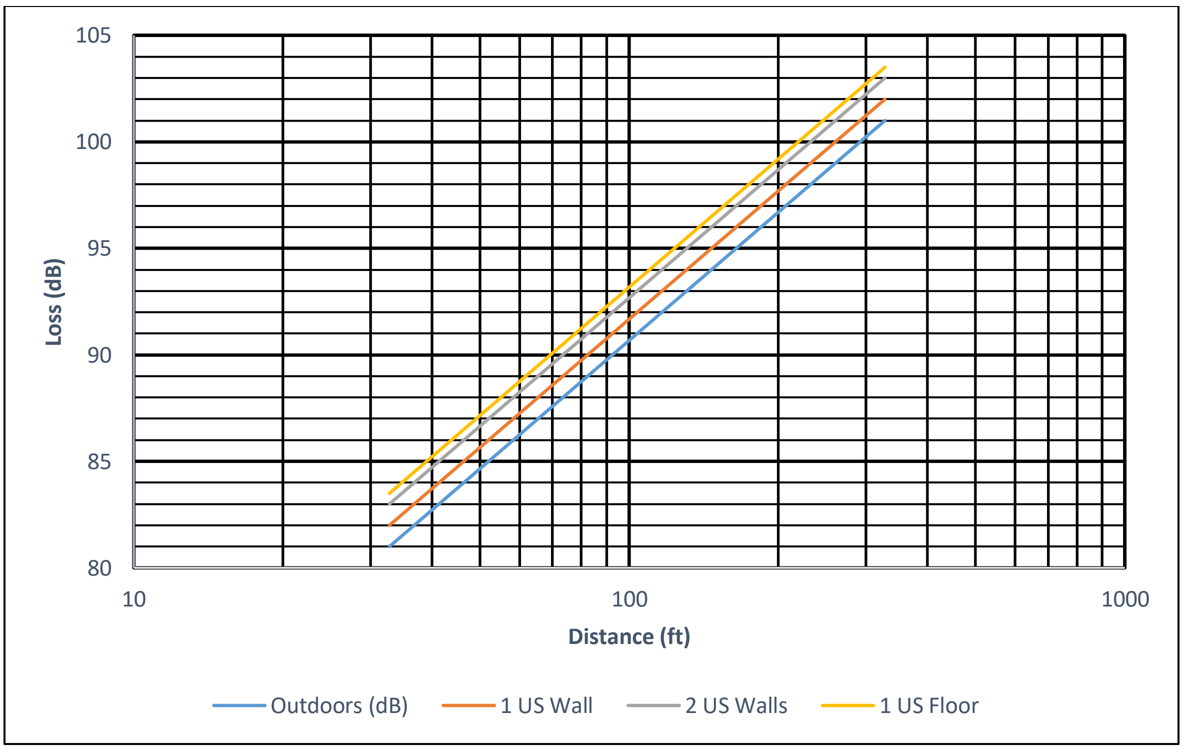


Figure 6-1 Path Loss with US Building Obstructions

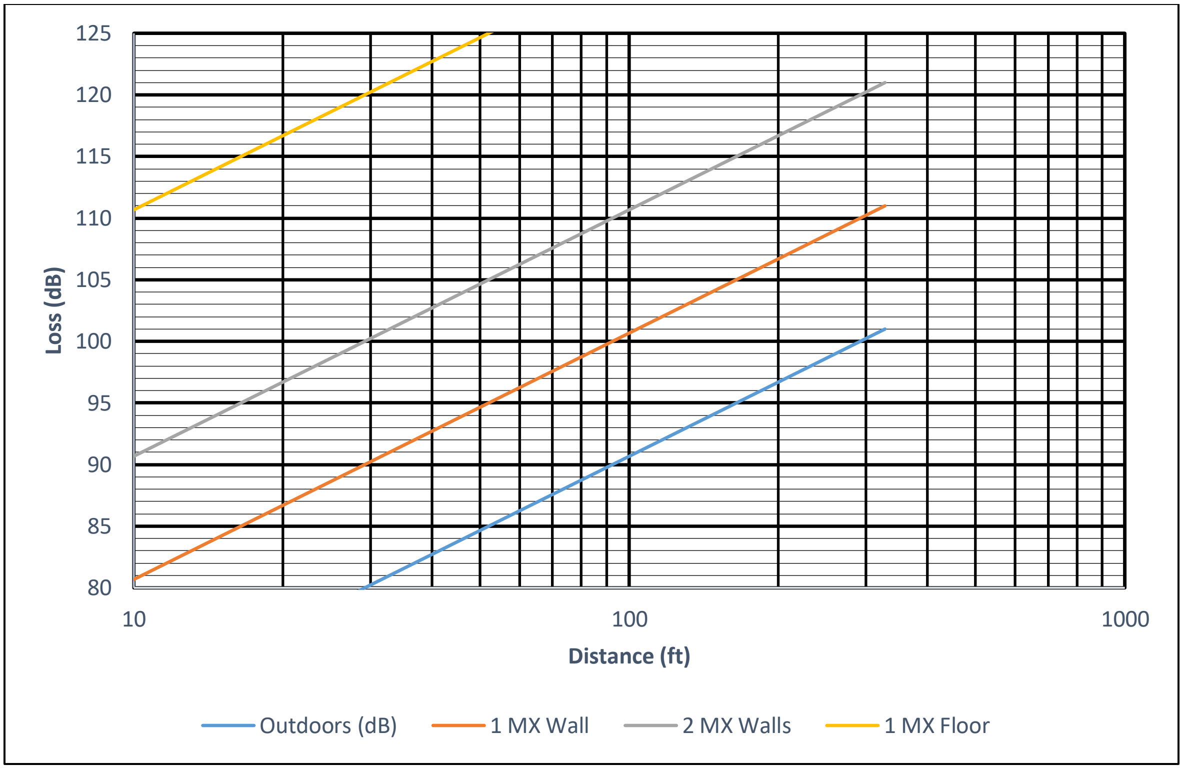


Figure 6-2 Path Loss with Mexican Building Obstructions

6.2 Internet

Your Internet Service Provider (ISP) may be Telmex, local cable TV provider, etc. The ISP will provide their modem to connect your house to the internet. You are responsible for installing and maintaining additional equipment to extend that one connection to other areas throughout your house. An understanding of some basic terms may prove helpful:

- WAN: Wide Area Network. A term generally considered to be synonymous with "The Internet."
- LAN: Local Area Network. The cables and hardware inside your house used to connect to the internet.
- Modem: MOdulator-DEModulator is the network hardware device that connects your LAN to the internet.
- Interface: The point at which your Local Area Network inside the house connects to the internet outside the house.
- Gateway: The point at which the devices on your Local Area Network inside the house connect to each other. Gateway and Interface are often used interchangeably because for most home networks they are both in the modem provided by the ISP.
- Router: The networking hardware that allows one internet connection to be shared between multiple devices (computers, phones, TVs, etc.) by routing traffic to the devices connected to your LAN.
- Switch: Also known as network switch or Ethernet switch is the hardware to which wired devices on your LAN are plugged into.

- Wireless Access Point: Also known as AP is a radio transmitter/receiver that allows wireless devices to connect to a switch. A Wireless Access Point is usually integrated with a router.
- Wireless Repeater: Also called wireless range extender, takes an existing Wi-Fi signal from another Access Point and rebroadcasts its signal to reach where the signal from the first AP is too weak.

A frequent area of confusion is that hardware components such as modem, router, gateway, switch, and Wi-Fi radio transmitters are often combined in one device. Typically the hardware provided by your ISP, the cable company or telephone company, is one unit that integrates a modem, gateway, router, switch and wireless access point all together in one compact piece of hardware. This equipment is usually the only modem, gateway, and router you have on your LAN. It is also typical that off-the-shelf hardware such as a router/switch/AP is configured in bridge mode so that its router functions are turned off. This hardware may still be referred to as a "router" even though that box has been configured to turn off its router function and use only its switch and AP.

As discussed in the preceding section, the range of the wireless signals will be severely restricted due to attenuation in the walls and floors in a typical Mexican house. In order to provide usable Wi-Fi to those areas of your home where you need it, there are three options to consider. These are, in order of preference, Cat5 Ethernet Unshielded Twisted Pair (UTP) cabling, Ethernet Power-line communication (PLC), and wireless repeaters.

In new construction or remodeling the best solution for reliable internet connectivity is to install cable raceways for Category 5 UTP cabling to all of the locations where internet connectivity is desired. These cables must be installed in a star topology. Wireless Access Points may then be installed where needed.

A second-best solution where installing new cables is impractical is to use Ethernet Power-line communication (PLC). This technology uses existing electrical wiring to transmit internet connectivity from your router to a remote location in your home. PLC is slower than Cat5 cabling but does not require installing any new wires. If your house has more than one electric meter it may be necessary to rearrange some wiring to put your PLC devices on the same meter. PLC hardware is susceptible to damage from electrical surges and is limited as to the number of units that may be installed in one house.

The simplest, slowest, and ***least reliable*** solution to extending the range of wireless internet is to use a wireless repeater. Many models are available, and under the right circumstances they can be relatively easy to set up. Wireless repeaters are not certified by the Wi-Fi Alliance and this has led to some incompatibilities between different manufacturers. It is best to purchase Access Points and repeaters of the same brand where possible to improve your chances of a successful installation. Though not recommended, multiple repeaters can be connected to the modem/router or they can be daisy-chained to provide even greater range. In Casa Erres, I used one repeater that provided coverage of the entire house as shown in Figure 6-3.

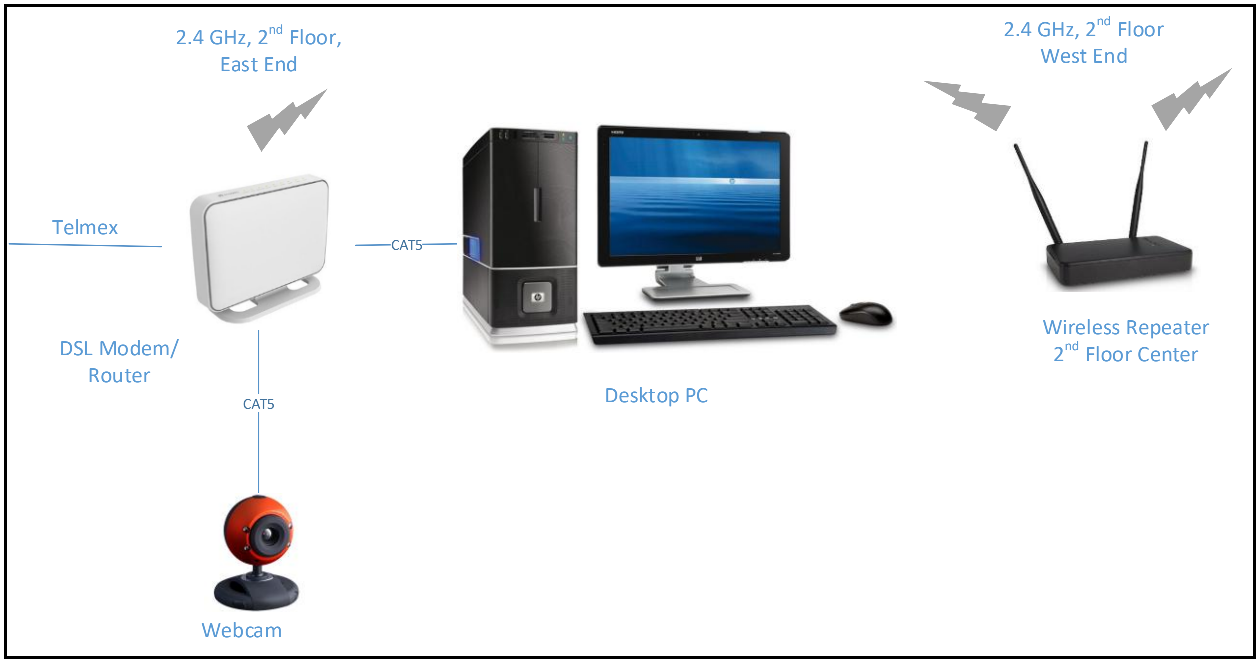


Figure 6-3 Internet Network at Casa Erres

Note that the desktop PC and web cam are wired to the Telmex hardware using CAT5 Ethernet cable. The repeater is at the opposite end of the second floor from the router and does a fair job of covering the first floor and some of the back yard. But this is only because we have a large loft opening between first and second floors.

The repeater itself (an AMP SR10000) is good but not 100% reliable. Occasionally, it loses the internet connection from the router and must be power cycled. For reliability (but not convenience) there is no substitute for a CAT5 cable. So if desktop PCs and other devices can be hardwired to the router, they should be.

In Casa Colibrí, the Telmex Infinitum modem/repeater is located in an upstairs office at the north end of the house. Downstairs there is a second desktop PC and a smart TV that are connected using CAT5 cabling. This did not exist originally, but fortunately there was a conduit that contained only a telephone line cable between upstairs and downstairs, so it was relatively easy to pull a CAT5 cable through it. The floor tile was being replaced and this allowed me to have additional conduit installed to connect to the downstairs TV and PC. The downstairs router shown in Figure 6-4 is configured as a repeater. (Almost any router can be used for this if correctly configured in “bridge mode”.) Reconfiguring the router is a fairly simple operation and there are good instructions available for doing this. See, for example, http://www.howtogeek.com/104469/how-to-extend-your-wi-fi-network-with-simple-access-points/ or http://www.labnol.org/software/add-router-to-wireless-network/19716/ for step by step directions.

The downstairs router/repeater provides a second wireless access point. Between the two, the entire house is covered fairly well.

Adding additional Access Points and/or repeaters will result in having multiple names (SSIDs) such as "Office," "Kitchen", "Bedroom," “LivingRoom” etc. Many Wi-Fi devices do not reliably switch to the strongest signal if you move to another room, instead, they tend to stay connected to the first router.

Maintaining a connection to your cell phone as you move around your house requires more advanced LAN hardware that manages handoffs between access points. A unified network experience that uses one SSID and one password for all of your APs and does not require you to manually disconnect and reconnect to different Wi-Fi names requires careful planning and hardware specifically designed for unified networks.

A final comment about Cat-5 UTP cable is that it is delicate and needs to be installed with great care. An installer who pulls too hard on the cable while installing it can damage the cable internally in such a way that its continuity will test okay while the cable has actually lost integrity and its ability to transmit data at the highest possible speeds. Equipment such as LanTEK III & FiberTEK III Cable Certifier would be needed to determine whether or not damage to the cable exists. Because the high cost of testing for defects far exceeds the cost of rewiring it is extremely important that Cat-5 cabling be installed in sufficiently large conduits and boxes so that cables that are suspected of being damaged can be easily replaced.

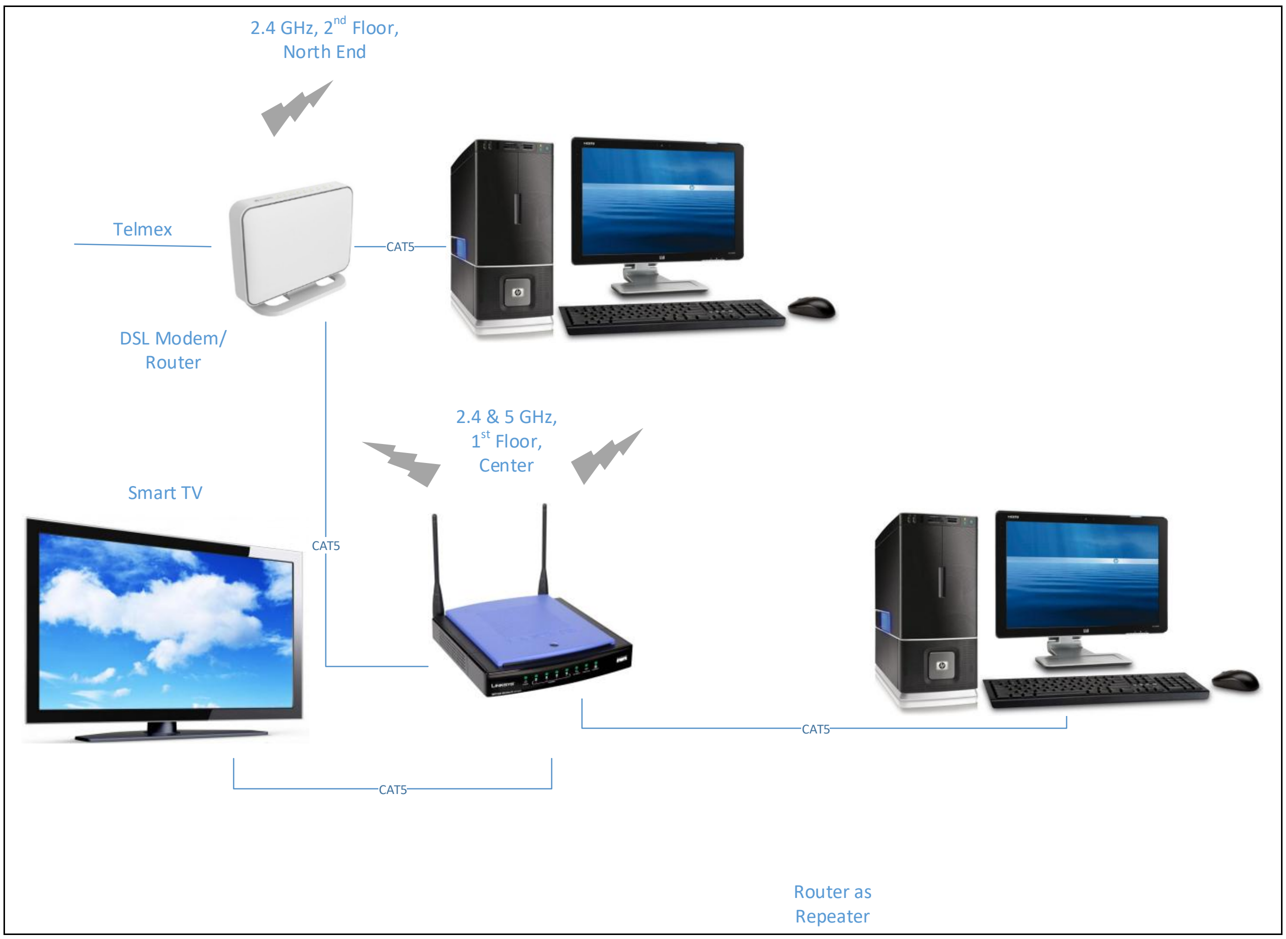


Figure 6-4 Internet Network at Casa Colibrí

6.3 Telephone

You may want to have a Telmex land line phone in Mexico as well as a cellular phone. Telmex land lines are sometimes hard to get, so if your new house has one installed, be sure to arrange to have it transferred to your name. Also, telephone (or electricity) receipts act as a kind of proof of residence in Mexico. Be sure the name on your account(s) is exactly the same as the name on your passport.

Having multiple phone outlets is nice, but these days the convenience of having a cordless phone system outweighs the bother of having to deal with tangled cords that keep you anchored to a jack. In the case of Casa Erres, the phone lines were run through conduits throughout the house, but they were in terrible condition. The line noise was so bad that conversations were unintelligible, and of course with this type of line condition, DSL for internet service was hopeless. We disconnected all the existing house phone wiring and ran a new line down the side of the house to the spare upstairs bedroom that we used as an office where we installed a cordless telephone base station (and the DSL modem). The phone system we used (an AT&T model CL83464 with 5 handsets) covered the entire house – almost. There were a few places where the remote phones rang, but you had to move toward the center of the house to conduct a conversation. It did not work outdoors on the patios. The only reason it worked as well as it did is because in addition to the stairwell there was a large loft opening in the center of the house between the first and second stories that allowed the signal (1.9 GHz) to pass between floors. See Figure 6-5.

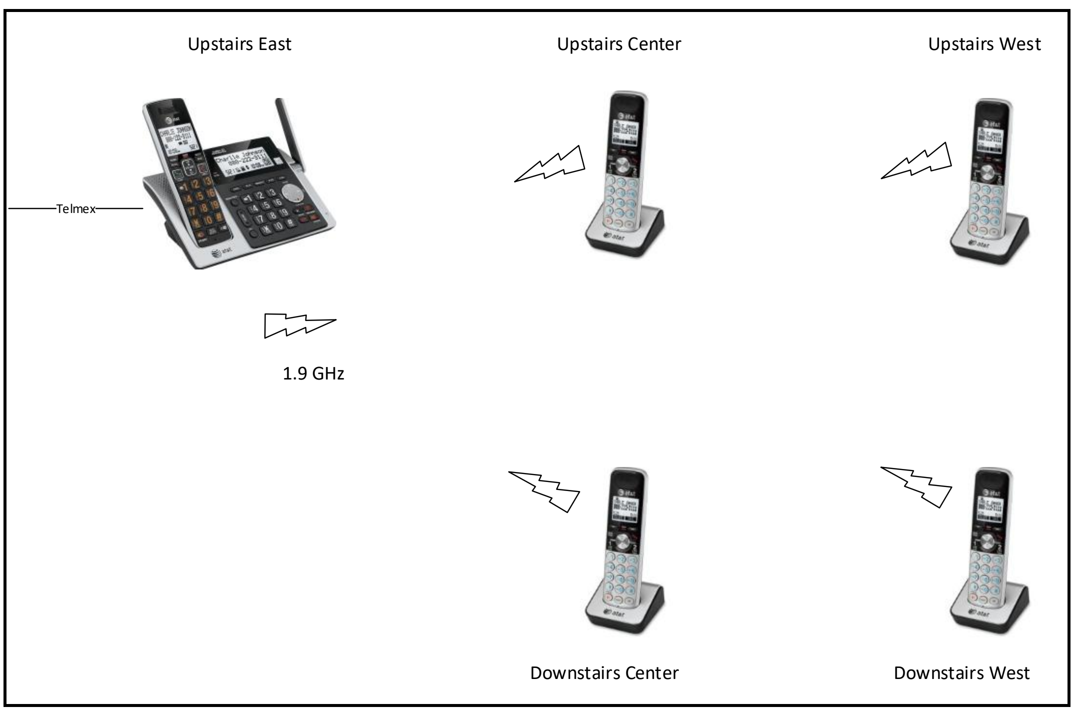


Figure 6-5 Erres Telephone System

In our second house, Casa Colibrí, the house itself was a bit larger, and there was only the stairwell between the first and second floors. So the cordless phone system was only functional on one story. Several options were considered. Since the internal house wiring for the phones was functional, we could install wired type handsets on the lower floor and use a wireless system on the upper floor. But a better solution was to install a cordless base station upstairs and a wireless repeater on the lower floor. It was important when doing this to be sure both base station and repeater were relatively close to the stairwell so they could communicate reliably.

In North America, the latest cordless phones are what are called DECT 6.0. That means they are digital, encrypted and work in the 1.9 GHz band. They all meet a common standard, but that does not mean they are compatible. In fact some handsets from the same manufacturer may not be compatible with base stations from the same company, so be careful when selecting the components you need.

Both AT&T and Panasonic make cordless phone systems that can have one or more repeaters (extenders) added to them. But the extenders only work with certain models. With AT&T, their extenders require a “small business” phone system. These are very nice, and if you need to have 4 lines into your house, that would be the way to go. But the system is expensive and more geared to a business that requires coverage over a fair sized store, for example. Panasonic makes a single line cordless system that has only 2 handsets, but can be expanded up to 6 and more importantly, it is compatible with their repeater. Up to 2 repeaters can be used to extend the range of the base station in two directions.

If you install a unified Wi-Fi network as described earlier, most of these LAN systems can also support telephones, although these phones are expensive and proprietary.

Many people today rely exclusively on cell phones to the exclusion of having a conventional landline phone. Due to the thick-concrete-wall problem described earlier, it is often necessary to rely on the “Wi-Fi Calling” feature of your phone when the cell phone signal is weak inside your house. If you use “Wi-Fi Calling” this makes it almost essential to have a unified Wi-Fi system as described earlier.

Models change all the time, but as of this writing, the system I am describing is:

Table 6-1 Panasonic Telephone Components

Model Number (Panasonic)	**Name**	**Approx. Cost (Amazon)**
KX-TG6592T	Base station with 2 handsets	$70
KX-TGA659T	Additional handset	$45
KX-TGA405B	Range Extender	$25

The Colibrí phone system is shown in Figure 6-6.

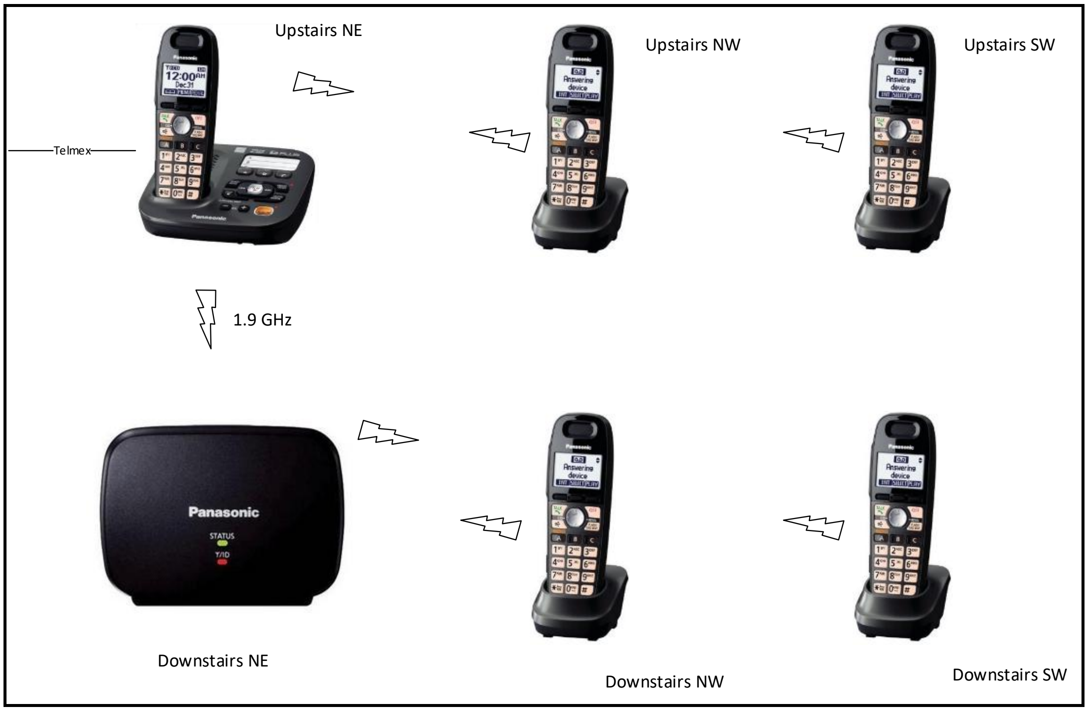


Figure 6-6 Colibrí Phone System

6.4 Doorbell/Intercom

If the doorbell system is intact and working, it should be kept or upgraded. If not, many great wireless systems now exist. In Casa Erres, the low voltage wiring was in bad shape running through the same conduits as the house primary wiring, the bells and buzzers could not be heard, and it was decided to replace it all with a simple wireless system. Initially, this was a battery-operated single transmitter/receiver pair bought from Home Depot. But the range was limited to about 30 feet because of an intervening wall, and the receiver could barely be heard from other rooms. It was replaced by a multiple receiver system made by Sadotech called Starpoint. The receivers plug into normal wall outlets and can be individually programmed for ring tones and volumes. You can even use a different ring tone that sounds from a second transmitter. The transmitter is battery-powered. Range is about 50 ft. passing through an exterior wall and floor, or about 200 ft. passing outdoors “around” the house to the back yard. See Figure 6-7 .

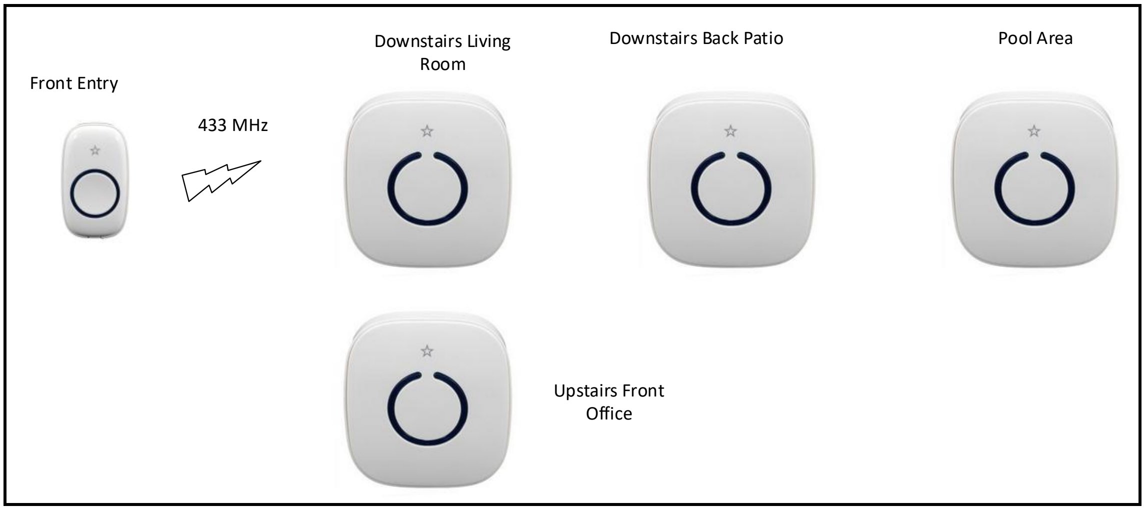


Figure 6-7 Starpoint Doorbell System at Erres

In Casa Colibrí, there was a working wired system made by Bticino. It is a two wire intercom that had an entry door unit and two remote handsets. These were not actually enough to cover the house, so a third handset was bought and added to the system. Each handset is individually powered using a "wall wart" transformer so these must be located near electrical outlets. See Figure 6-8.

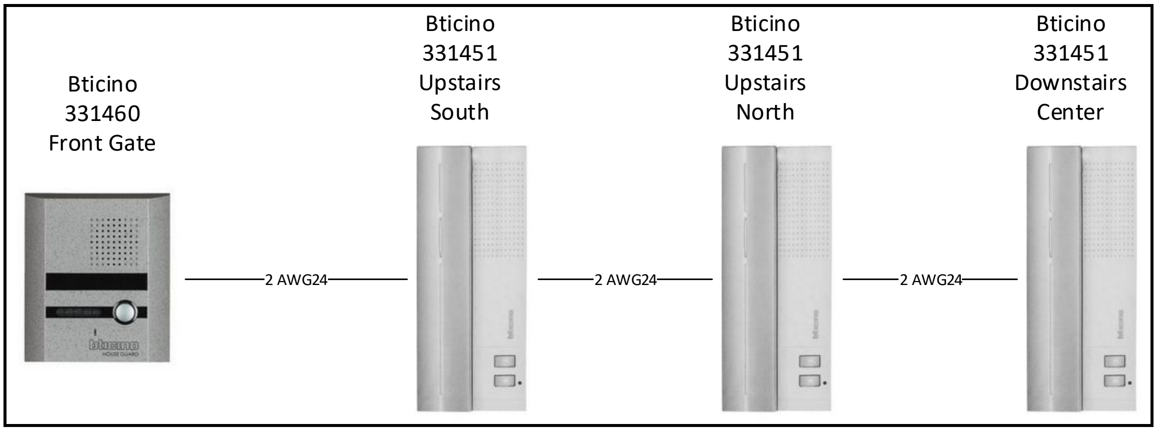


Figure 6-8 Bticino Doorbell Intercom at Colibrí

6.5 Television

In San Miguel, the best current way to get English language TV programming is via streaming. Both Megacable and Telmex offer streaming via optical fibers throughout the city. Firestick adapters seem to be the most popular and services are available which install preprogrammed Firesticks which include VPNs or other software that provide cable news channels as well as thousands of movie and series.

There is some controversy as to the legality of some of these services, but much of this may be competition rather than ethically motivated. In making a selection, I would recommend doing a search on the "Civil List" at (CivilSMA1@groups.io) to see what is available and contact information.

Amazon Firesticks are set up to connect to WiFi for internet access but adapters are available to connect via Cat5 wired Ethernet. Without exception, streaming video on a wired Ethernet connection is more reliable than Wi-Fi. Connecting a Firestick via WiFi is more susceptible to buffering problems caused by lack of signal strength and/or interference from other WiFi signals and should be considered a last resort connection method.

The same holds true for your SmartTV if you are using any of the apps installed in the TV. Streaming devices such as AppleTV, Roku, and Firestick can all connect via Wi-Fi, but all will perform more reliably when connected to Cat5 ethernet. You should plan for the possibility you might need to have not just one Cat5 Ethernet cable for your streaming devices but additional Cat5 Ethernet cables for each device.

Figure 6-9 below shows the arrangement at Casa Colibri.

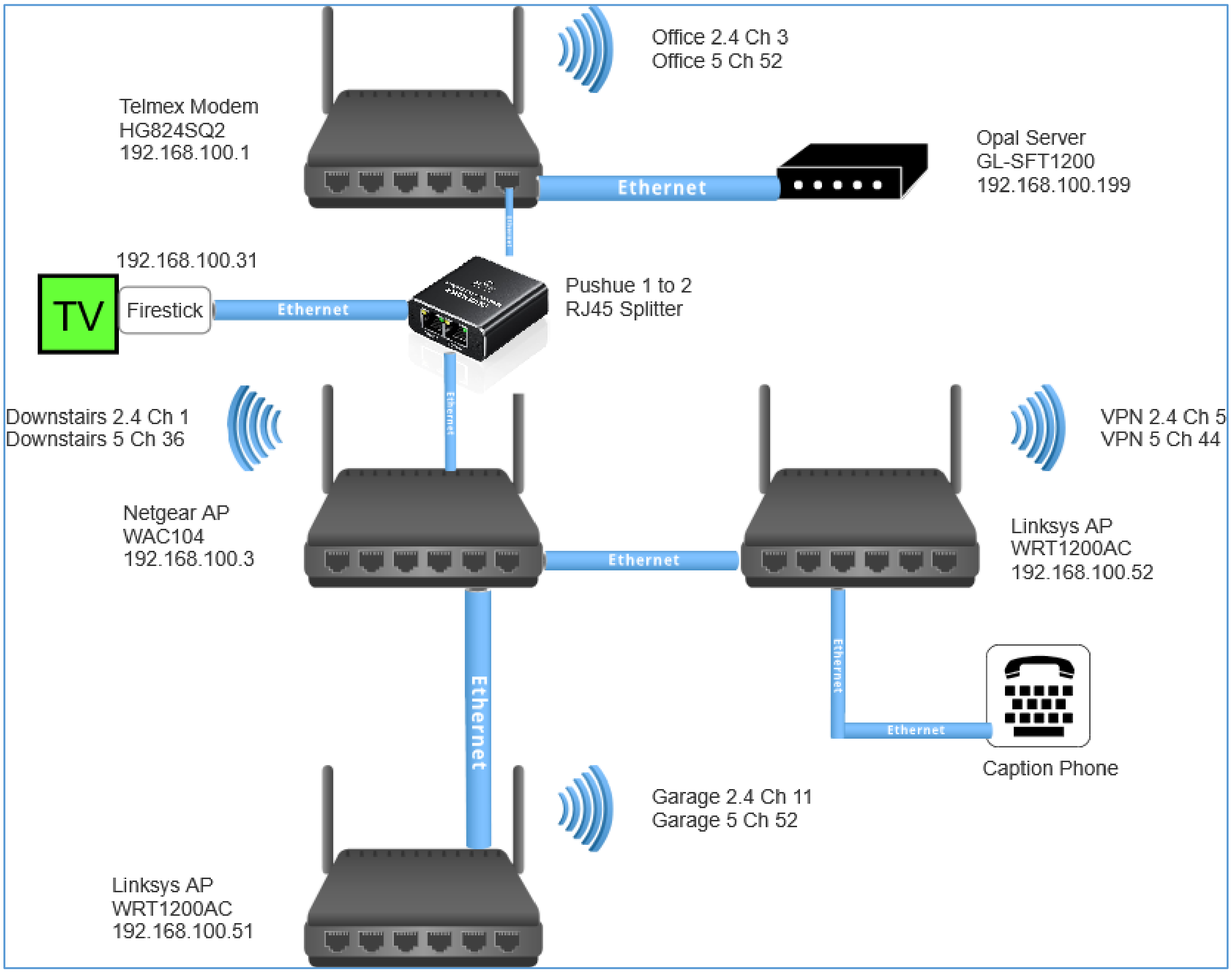


Figure 6-9 Colibrí TV Connection

7 Faults and Hazards

In this section we consider some possible fault conditions that can occur with your electrical wiring, the possible hazard and ways to deal with them. Much of this has been discussed previously, but it is useful to summarize the faults in one place. Because Mexican homes for the most part are built from non-combustible materials, the consequence of these faults may be different than in a US home.

Line to Neutral or Line to Earth Conductor Short

The hazard here is that the conductors will overheat and start a fire. Risk of a large scale fire is unlikely with no combustible materials, but the insulation on the wiring will melt or burn and the conductors fuse open resulting in a costly repair. This is the reason we use circuit breakers. Properly sized, a circuit breaker will trip before the downstream wires it is protecting become seriously overheated. In Casa Erres, I found numerous instances where this protection was defeated.

- Line and neutral or line and earth conductors were of different size (wire gauge).
- Line and/or neutral changed conductor size between the circuit breaker and load.
- Circuit breaker was of a size much too high for the wiring it was protecting.

The circuit breakers on each branch circuit should be sized for the minimum gauge wire used on that circuit, and this includes the neutral and earth ground conductors.

Intermittent Line to Neutral or Line to Earth Conductor Short

This hazard is most likely to occur in a lamp cord, extension cord or the like which is subject to bending or wear by foot traffic or furniture movement. The short will occur as an arcing that will cause the wiring insulation to melt and might result in a fire if it is close to something combustible (drapes, furniture, etc.) Since the arc is intermittent, it might not trip a standard circuit breaker even if it is properly sized. There are arc fault circuit breakers that detect intermittent currents as well as dual function breakers that combine the functions of arc fault detection and ground fault breakers. The best practice is to simply replace any lamp cord or extension cord that shows signs of wear.

Intermittent Line or Neutral Open

This hazard is also most likely to occur in a lamp cord subject to wear and flexing. The intermittent open can result in arcing that can cause a fire. Both the arc fault and dual function circuit breakers listed in Table 4-2 can detect this type of “series” arcing as well as the “parallel” (line to neutral) arcing discussed above. Replace any lamp cord that shows signs of wear or intermittent connection.

Line to Exposed Metal Short

The high side conductor can short against the metal box used to support a switch or outlet. If someone touches the box (or the cover plate if it is also metal) a shock will result. This can be potentially fatal especially in areas that are wet (bathrooms, laundry or kitchen areas, etc.) This risk is the reason why a separate earth ground is used to ground the exposed metal boxes or, in the case of an appliance, its frame. It requires the use of a three pronged outlet and plug. If the earth ground is properly connected back to the neutral at the entry panel, a line to metal frame short will cause a high current to flow through the circuit breaker and trip it. A GFCI type breaker or outlet would also protect anyone who touches the frame, because it trips at a very low current (6 ma). This is a 2-wire (line and neutral) solution so if an earth ground is not present, it would be a good alternative.

This hazard used to be much more prevalent because small appliances were frequently built using metal cases. These days, most hand held appliances and electrical tools are double insulated with plastic housings and do not have an earth ground connection.

Reversed Line and Neutral

This is unlikely to occur due to faulty house wiring especially if proper colored wires are used and connections are tested using a voltage probe. But it is very likely to occur in locally built light fixtures. The hazard is that of an electrical shock that might occur while changing the light bulb. The same hazard exists on a Mexican wired three-way circuit even when the light is turned off. (See Section 2.9). The solution is to replace or rewire the fixture(s) and to always be careful not to touch the base of the bulb when changing it. **Never rely on the switch to turn power off to a light fixture in Mexico.**

Open Line

This is not a hazard; only a fault condition that is immediately obvious because the circuit will not work.

Open Neutral

This is not a safety hazard but it can do a lot of damage. Depending on where the open neutral occurs, the voltages appearing across the branch circuits can be anywhere between 0 and 240 VAC. The voltage is typically very unstable as well since it depends on how balanced the loads are between the two phases entering the house.

The Brownout Protectors discussed in Section 4.6 can be used to protect high value appliances. This includes anything with a digital display including ovens, refrigerators, computers, TVs, washing machines, etc.

Neutral to Earth Ground Short

This is not a safety hazard and may not be detected readily since the neutral and earth ground are supposed to be connected together at the entry panel to the house. Note that if the two are connected in a branch circuit, a GFCI breaker cannot be used. In fact, if you install a GFCI breaker on a branch circuit and it immediately trips, this would most likely be the reason.

Over and Under Voltages

These might occur due to an open neutral as discussed above or they might result from some failure in the power distributed by CFE. As mentioned, a lot of expensive damage can result so the use of Brownout Protectors (Section 4.6) is a good investment.

Voltage Surges

These are momentary spikes of very high voltage that can result from lightning strikes or other failures in the CFE distribution system. They are primarily a hazard to your pocketbook because they can do a lot of expensive damage in a house full of electronically controlled appliances. The Brownout Protectors are supposed to provide some protection against surges, but the best solution is to use a whole house surge protector at the entry panel. These devices resemble circuit breakers and plug into the service panel. See Section 4.5.

The table below summarizes these faults, the associated risks and amelioration.

Table 7-1 Summary of Faults, Hazards and Ameliorations

Fault	**Hazard**	**Amelioration**
Line to Neutral or Earth Short Circuit	Damage to Wiring, Fire	Properly Sized Circuit Breaker for Each Branch Circuit
Intermittent Line to Neutral or Earth Short Circuit	Fire	Arc Fault or Dual Function Circuit Breaker. Replace suspect lamp and extension cords.
Intermittent Line or Neutral Open Circuit	Fire	Arc Fault or Dual Function Circuit Breaker. Replace suspect lamp and extension cords.
Line to Exposed Metal Short Circuit	Electrical Shock	Earth Grounding or GFI Circuit Breaker
Reversed Line and Neutral	Electrical Shock Changing Light Bulbs	Replace or rewire fixture, and avoid touching bulb even when it is off.
Open Line	None	NA
Open Neutral	Damage to Appliances, Electronics, etc.	Use Brownout Protectors on Expensive Appliances
Neutral to Earth Ground Short Circuit	GFCI breaker will trip. Not a hazard.	NA
Over & Under Voltages from CFE	Damage to Appliances, Electronics, etc.	Use Brownout Protectors on Expensive Appliances
Voltage Surge from CFE	Damage to Appliances, Electronics, etc.	Use Surge Protector at Entry Panel

8 New Construction

What can be done to avoid all the problems discussed previously when building a new home in Mexico? Well, first you will need to find an architect/builder who is willing to work with you and accept a somewhat unusual (in Mexico) arrangement for specifying the electrical system. Most likely having a cost plus type of contract will be best. Explain that you want the house wired using standards similar to those employed in the US and that certain components (boxes, rings, switches, plates, etc.) will be provided by you. The best way to get what you want is to buy it yourself or to specify it. This can be done by using the following specifications and drawings as a guide. Note that many of these reflect my taste, but also were chosen for the reasons given throughout this book. If you want a different model switch, etc. tell your architect and let him prepare new specifications. The important thing is to get this all down in writing and to have him go through it with the electrician who will be doing the actual wiring. This is not standard in Mexico. Typically the electrician will work from a plan that shows the switch, light and outlet locations, supply the materials of his choosing and install them in whatever manner he is accustomed to using. (And thus produce a house that has many of the problems discussed in Section 2).

8.1 Meter(s) and Ground Bar

If your house is small (less than 2000 square feet) you will probably need only one meter. This can be a single phase (1F2H) type if you know you will not need 240 volts such as required for say an electric oven, but it is just as easy to get a two phase (2F3H) meter that will provide both 120 and 240 volts. If you think your usage might exceed 250 KWh per month, and certainly if the house is larger than 2000 square feet, I would get two separate single phase meters (1F2H). This will provide you both 120 and 240 volts and permit you to get the lower rate by balancing the loads between the two meters.

The meters will mount on a wall at the front of the house where they can be read from the street. Use Square-D type MS1004 boxes for mounting the meters as these provide waterproof protection for the wiring and conduit type entry holes. There needs to be a ground bar driven into the earth below the meter and connected to the ground/neutral terminals on the meter. This connection should be made with AWG#6 or larger wire. Similarly the connection to the CFE mains should use AWG#6 or larger wire. AWG#6 is good for 70 amps. Often this gauge wire is only available in black, but Home Depot has it in black, red, white and green which I would specify. You might as well get the color coding started correctly right from the street. The cables should be contained in a conduit between 1 inch and 2 inches diameter. This will depend on the length of the run. The usual flex PVC electrical conduit can be used if it is buried in the wall or ground, but if it is exposed, use the flex grey vinyl waterproof tubing to and from the meter box.

8.2 Entry Panel

There should be a way to disconnect the entire house using a single circuit breaker. This should be located in an entry panel outside the house and close to the meter(s). In a small house, a single small box with a single or double pole main breaker (QO170 if you only have 120 volts or QO270 if you need both 120 and 240 volts) will work fine. If the house is larger, I would mount a panel with a capacity of 6 to 8 breakers (3 to 4 double pole breakers). The left side breaker connects to the meter using AWG#6 wire and is secured using a lock PK2MB. This screws in below the main breaker and keeps it from being removed easily in the future since the wires connected to the breaker remain live. See Section 4.10 for details on how to install this locking device.

The waterproof entry panels can be Square D models QO612L100 and QO816L100. The two are the same overall size but the 816 accommodates 8 double wide breakers and the 612 only holds 6. The additional slots can be used for 50 amp breakers for each of the subpanels. These can be connected using AWG#8 wires. Assuming you are wiring both phases, use QO250 breakers. The entry panel might also be a good location to connect the water pump for the cistern if you have one. Typically that will be a single phase 30 amp circuit wired with AWG#10 conductors. If there is still room in the entry panel, you might consider installing surge protector QO2175SB. See Section 4.5.

8.3 Subpanel(s)

If your house has two floors, I suggest putting a subpanel on each floor and feeding each separately from the entry panel using AWG#8 cable. A single panel will require running a number of branch circuits through the floor, and this is typically done using one large conduit with many conductors to a junction box. This makes it very difficult to keep each of the branch circuits separate which is necessary if you decide to use a GFCI or AFI breaker on one of them. It also makes for a very messy and overcrowded junction box which is also somewhat ugly. In my opinion, junction boxes should only be used when you have a very long or circuitous run that requires one as a pull box. (There can only be two bends in any conduit).

Be sure the subpanels are located where they are easily accessible. If you use the new QOX series, they look pretty good so they do not need to be hidden inside closets where they are hard to work on. Since the subpanels are protected by separate 50 amp breakers at the entry panel, these breakers can be used to switch off each subpanel. This means that all slots in the QOX panels are available for use as branch circuits. For example QOX204 will support 6 branch circuits. The exact model should be selected once the number of zones has been chosen. Home Depot in Mexico stocks the QOX204, 206 and 208 subpanels.

8.4 Branch Circuits & Device Boxes

Divide the house into zones which will be supplied by separate branch circuits. These will be indicated on the electrical plan discussed in Section 8.7. There are lots of ways to do this, but the idea is to keep the peak load in each branch below the circuit breaker rating for that branch. Each branch circuit should be wired with AWG#12 wire fed from a 20 amp breaker QO120. It is helps with labeling the breaker panel to have one or perhaps two rooms at most in a branch circuit. For the kitchen, you should have at least three branch circuits. This is because appliances like the microwave, toaster and coffee pot all run about 15 amps and are often used at the same time.

It is standard practice to save material and labor by combining the “home runs” (cables between the breaker box and the first outlet box on a branch circuit), then separate out the branches in the outlet or junction box. I recommend against this for the reasons given in Section 8.3 and especially because putting multiple branch circuits in the same box makes it very crowded. As long as some care is made in laying out the branches, you can use 4x4 boxes for all the outlets, switches and even wall lights in the house. Be sure to specify that these are the new style that has the screws for the mounting rings in the corners. (See Section 8.4). The boxes should be 1-1/2 inch deep with ½” and ¾” knockouts and contain a threaded hole on the back surface for a grounding screw. These boxes are available in Mexico but the old style is also, so you need to be very careful which ones are bought. A wide range of single, double and circular mounting rings are available. Most of the boxes should use ½” or 5/8” deep rings mounted so that the front surface of the ring is even with the finished plaster coat on the walls. If a deeper ring is required (for example when mounted on a stone surface), you can order it from Garvin (http://www.garvinindustries.com), but since the boxes and rings are relatively heavy you should try to find them locally. The circular rings need to be ordered from Garvin. You may also need some deeper (2-1/8 inch) boxes as discussed below. These might have to be ordered from Garvin.

An advantage in using these boxes throughout the house is that a single ring can be replaced by a double ring with a minimum of work. So for example, if someone wants to plug in four devices at a nightstand, the single device ring can be replaced with a two device ring, and a second duplex outlet added at the same box instead of adding a power strip or multiple outlet adapter.

Specify that 6-32 machine screws (which come with the switches and outlets) are to be used. It would be a good idea to buy a T handle and some 6-32 taps since the holes on the boxes are likely to get filled with cement and must be cleaned out before using the machine screws to mount the devices. Your electrician is unlikely to have these tools as he is used to using sheet metal screws for everything. It is worthwhile having some 8-32 and 10-32 taps also as these are also used on electrical boxes and panels. I could not find the taps locally so I ordered them from McMaster-Carr. (http://www.mcmaster.com)

Deciding how to run the flex conduit between boxes is normally done in the field by the electrician. But you should encourage him to limit the number of conduits connected to each box and the number of conductors that are present inside each box to prevent overcrowding the boxes. You can do this indirectly by specifying on the plans which boxes and switches are assigned to each branch circuit and how the switches are grouped.

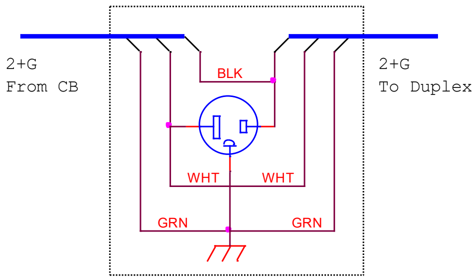
There are rules specified for this under the NEC, but following is a simplification that will work as long as all the branch wiring is AWG#12. Table 8-1 lists the calculated minimum volume required for different configurations of outlets and switches mounted in the same box. For example the second configuration listed is for an outlet that is connected to feed two additional outlets. See A-2 in Figure 8-1. There is one input conduit and two output conduits. The table shows a total of 3 conduits with a maximum of 3 conductors in any of them. The required volume for an AWG#12 conductor is 2.5 cu inches. The number of conductors entering or leaving the box is 6 not counting the ground or the wires connected to the device (duplex outlet in this case). All the grounds together count as one volume and the device itself counts as 2. So the total volume required is (6+1+2) x 2.5 or 20.25 cu inches. The last two columns list the available volume for both a standard depth and a deep 4x4 box with single or dual device mounting rings. The required box is shown in bold; in this case, it is a standard depth single ring unit.

Table 8-1 Box Size Requirements

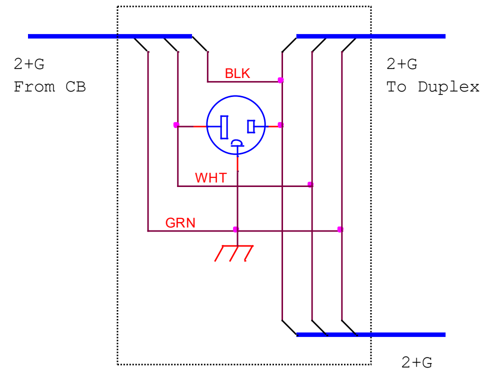
Box Configuration	Figure 8-1	No of Conduits	Max No of Wires/Conduit	Rqd Min Volume	Available Volume 4x4x1.5 box & 0.5 ring	4x4x2.125 box & 0.5 ring
Single Device Rings						
Duplex	A1	2	3	15.75	**24.50**	33.80
Duplex	A2	3	3	20.25	**24.50**	33.80
SPST	B	2	3	15.75	**24.50**	33.80
3-Way	C1	2	4	18.00	**24.50**	33.80
3-Way	C2	2	4	18.00	**24.50**	33.80
4-Way	D	2	4	20.25	**24.50**	33.80
Two Device Rings						
Duplex & Duplex	E	2	3	20.25	**26.50**	35.80
SPST & SPST	F	3	3	24.75	**26.50**	35.80
Duplex & SPST	G	3	3	24.75	**26.50**	35.80
SPST & 3-Way	H1	3	4	27.00	26.50	**35.80**
SPST & 3-Way	H2	4	4	31.50	26.50	**35.80**
3-Way & 3-Way	I1	3	4	29.25	26.50	**35.80**
3-Way & 3-Way	I2	4	4	33.75	26.50	**35.80**
SPST & 4-Way	J	4	4	33.75	26.50	**35.80**
3-Way & 4-Way	K1	4	4	36.00	26.50	**35.80**
3-Way & 4-Way	K2	4	4	36.00	26.50	**35.80**

The table shows that standard depth boxes can be used everywhere except where a 3 or 4 way switch is paired with another device. In those cases you should specify a deep box. This will be done on the electrical plans discussed in Section 8.7 below.

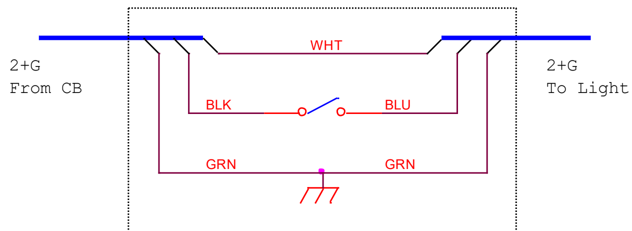
The simplified schematics shown in Figure 8-1 below show that the neutral (and earth ground) are present in every box. This is not standard practice in Mexico, but you should see that it is done. The earth grounds can all connect directly to the back of the boxes using a ground screw that is part of a green ground pigtail. It is easiest to install the pigtail before the box is even mounted on the wall. Order PTS012GN from Garvin Industries. The reason for having the neutral pass through all the switch boxes is in case someday someone wants to change a switch to a different control device. Most timers and some dimmers require a neutral connection.


2+G
From CB
BLK
WHT
WHT
GRN
GRN
2+G
To Duplex

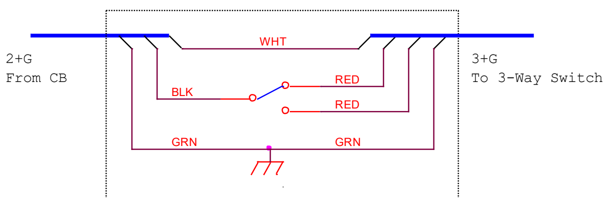
A1


2+G
From CB
BLK
WHT
GRN
2+G
To Duplex
2+G
To Duplex

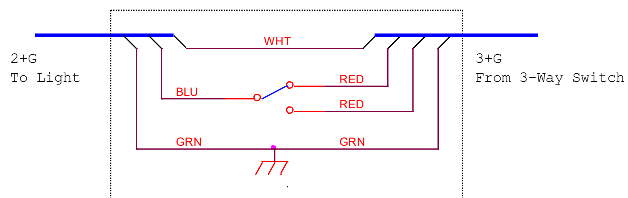
A2


2+G
From CB
WHT
BLK
BLU
GRN
GRN
2+G
To Light

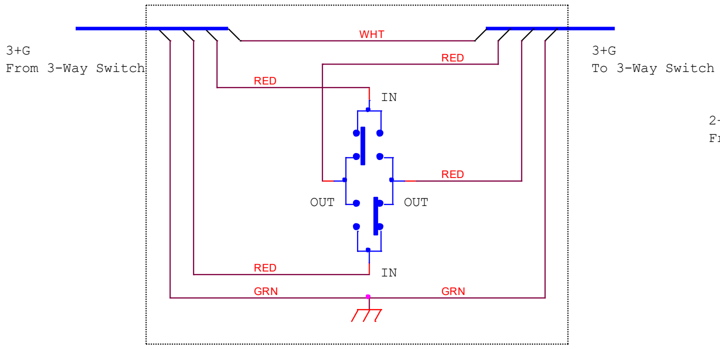
B


2+G
From CB
WHT
BLK
RED
RED
GRN
GRN
3+G
To 3-Way Switch

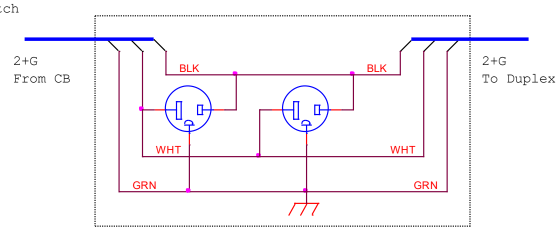
C1


2+G
To Light
WHT
BLU
RED
RED
GRN
GRN
3+G
From 3-Way Switch

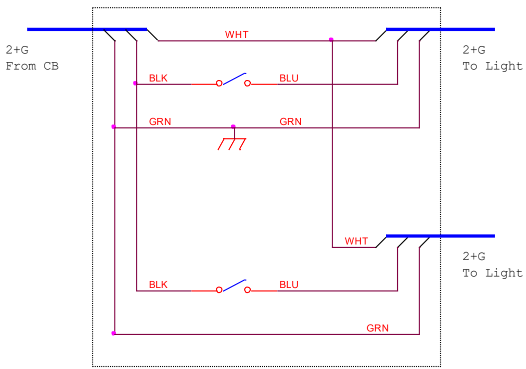
C2


3+G
From 3-Way Switch
WHT
RED
RED
IN
RED
OUT
OUT
RED
IN
GRN
GRN
3+G
To 3-Way Switch

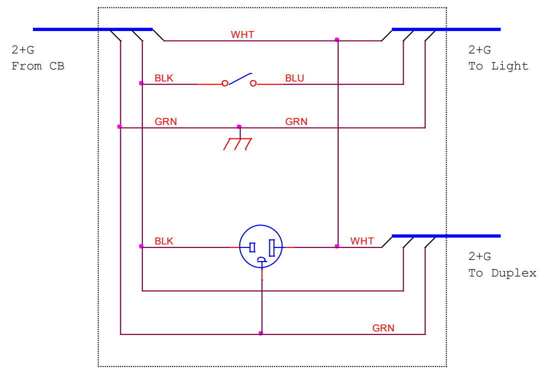
D


2+G
From CB
BLK
BLK
WHT
WHT
GRN
GRN
2+G
To Duplex

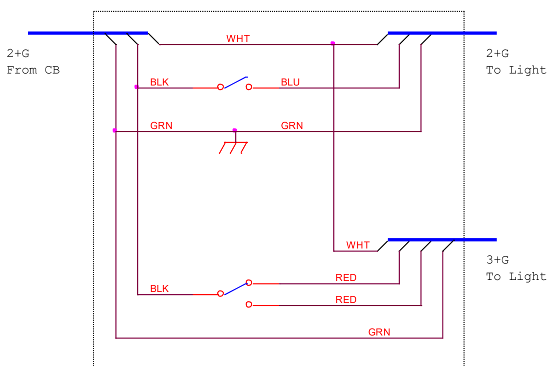
E


2+G
From CB
WHT
BLK
BLU
GRN
GRN
2+G
To Light
WHT
BLK
BLU
GRN
2+G
To Light

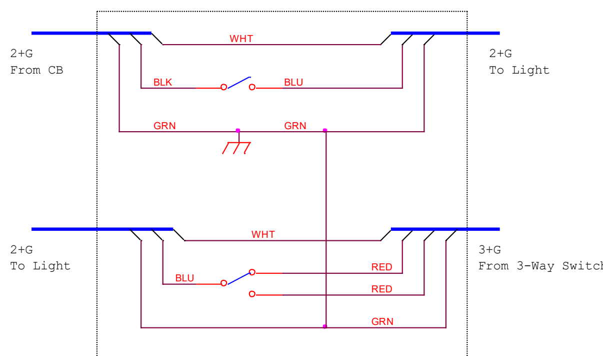
F


2+G
From CB
WHT
BLK
BLU
GRN
GRN
2+G
To Light
BLK
WHT
GRN
2+G
To Duplex

G


2+G
From CB
WHT
BLK
BLU
GRN
GRN
2+G
To Light
WHT
BLK
RED
RED
GRN
3+G
To Light

H1


2+G
From CB
WHT
BLK
BLU
GRN
GRN
2+G
To Light
2+G
To Light
WHT
BLU
RED
RED
GRN
3+G
From 3-Way Switch

H2

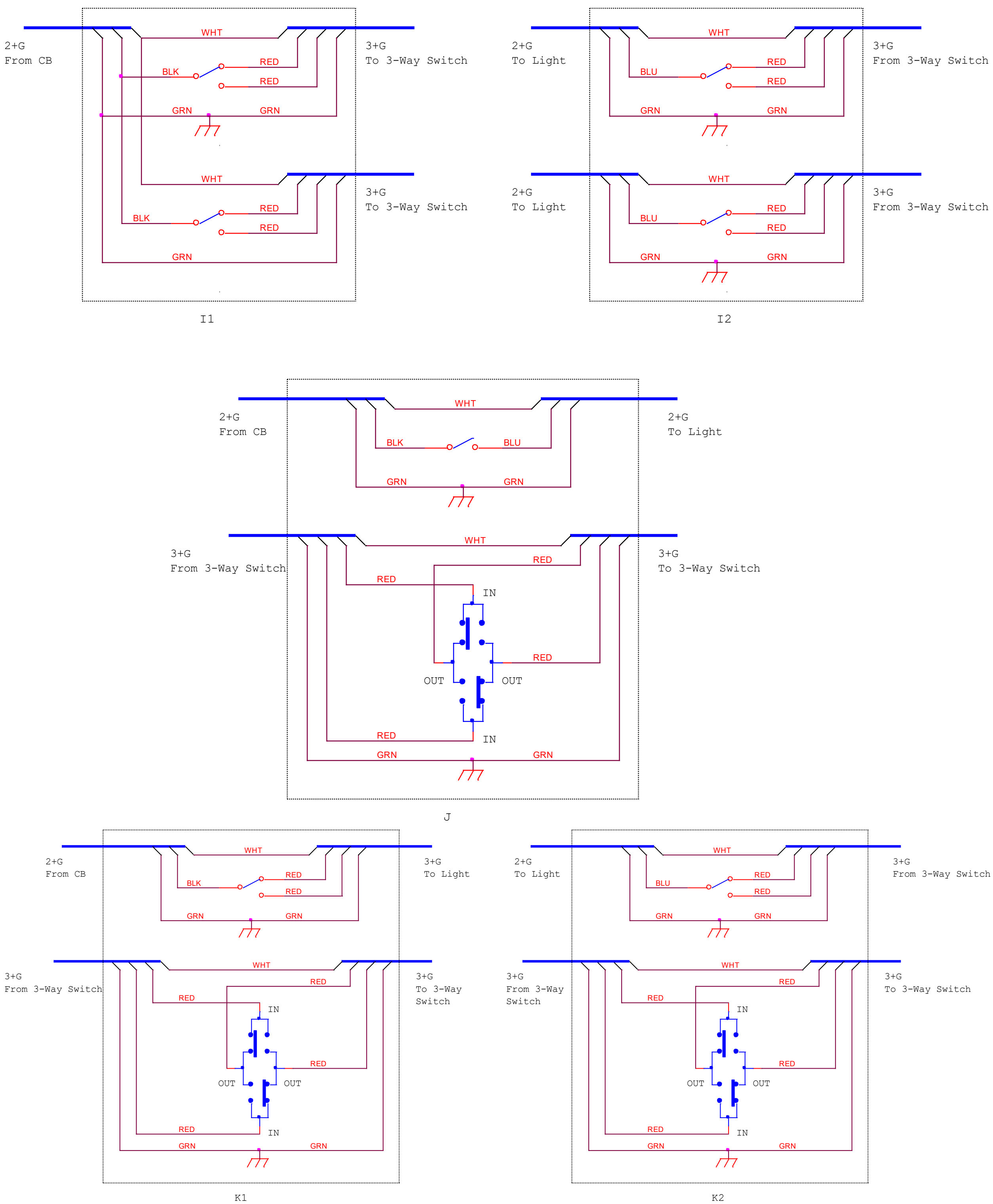


Figure 8-1 Typical Box Wiring Configurations

8.5 Device Selection

My personal preference is the Decora style switches and outlets, but I did not find these in Mexico. However, there are some excellent savings available on line, and this will pay for the shipping cost.

If you prefer another style, look for wire contacts where the conductor fits into a brass saddle that clamps when you tighten the screw. These are called "back entry" and are not the same as the rear entry push in clamps which should not be used with stranded wire. The back entry connections are MUCH easier to work with and more reliable.

Many of the switches and outlets sold in Mexico are modular types that let you stack any combination of SPST or 3-way switches and/or outlets on the same mounting frame. You could theoretically put 6 switches in a single 4x4 box this way using a double wide ring, but the cables would not fit. Try to stick with the configurations shown in Figure 8-1 and limit the number of devices per box to 2.

Even the Decora style devices come with push in and screw type wire fasteners in addition to the back entry compression fittings. The ones I recommend are listed in Table 8-2. These all have back entry. All are made by Leviton. The ones listed have a spring type fitting behind the lower mounting screw. This provides an earth ground connection to the box thereby eliminating the need to connect the green grounding screw on the device itself. But getting a good contact depends on having the device mount directly to the front of the box mounting ring. For this reason it is important to install the box such that the front surface of the device ring is even with the finished wall.

The standard duplex outlets listed allow up to 4 wires to be connected to each side (line and neutral). This cuts down on the number of wire nuts required.

Table 8-2 Leviton Device Part Numbers

Device	PN White	PN Ivory
SPST Switch	5621-2W	5621-2I
SPDT Switch (3-way)	5623-2W	5623-2I
DPDT Switch (4-way)	5624-2W	5624-2I
Duplex Outlet	16252-W	16252-I
GFCI Outlet	N7599-W	N7599-I
Single Device Wall Plate	80401-W	80401-I
Two Device Wall Plate	80409-W	80409-I

8.6 Low Voltage Wiring and Components

Many of the low voltage signals (security system sensors, telephone, doorbell and Wi-Fi) use wireless connections, but some wired infrastructure is needed to connect the base stations to the service providers. The problem is that the homeowner may want to move the telephone base station or DSL modem's location, so a flexible wiring arrangement is needed. What I chose to do amounts to a poor man's structured wiring scheme. It consists of home run cables from each room to a central junction box on each floor. These are all terminated in Keystone jacks (RJ11 for telephone, RJ45 for Ethernet and F for television) on a Decora style plate in each room. At the junction boxes, only those cables that will be used are connected.

This arrangement allows a single DSL modem, for example, to be located anywhere in the house. The input to the modem is the telephone line RJ11 connector and its output goes to the RJ45 on the same plate. By connecting the appropriate Ethernet cables at the junction boxes, a single hardwired Ethernet signal can then be run to any other outlet in the house. Or if a router is installed adjacent to a junction box, multiple Ethernet connections can be provided. The DSL modem also provides wireless coverage and supports a local Ethernet connection to a PC or TV, for example.

Similarly a cordless phone base station can be connected at any of the room outlets. A location should be chosen that provides good wireless coverage to the other rooms, or a repeater can be installed if necessary to extend its range.

Television signals are sent through RG6 cables from the rooftop antenna or cable TV provider through the junction boxes to the TV receiver. If cable TV or over-the-air reception is used, standard 2-way splitters can be used in the junction boxes to supply multiple TV sets. If a satellite service is used, the service provider can connect the cables from his set top decoder to his roof top antenna. If multiple satellite receivers are desired, it might be necessary to add additional cables between the junction boxes, but if the conduits are large enough this should not be a problem.

The boxes specified for the low voltage signals are 4x4x2-1/8" for the rooms and 6x6x2-1/2" for the junctions. These allow conduits of 1" diameter which is large enough for two CAT5 cables (one for Ethernet and the other for the telephone) and an RG6 TV cable. These boxes should be ordered from Garvin since they will be difficult to locate in Mexico.

Keystone jacks, plates and crimping tools are all available from http://www.discount-low-voltage.com. Check to see if your electrician has the tools. They are not expensive, and if you need to make future changes they will come in handy.

Table 8-3 Low Voltage Tools and Crimp Splices

Used for	Part Number
Crimping RJ11 and RJ45 Keystone Jacks	DY-KWIKTOOL
Crimping F connectors on RG6 cable	ET-CP-313
Crimping 3M low voltage splices	ET-100-008
3M low voltage splices (CAT5, etc.)	3M-UR

8.7 Electrical Plan

The architect should prepare a plan showing the location of the light fixtures, switches, outlets, breaker panel(s) and meter(s). Be sure he marks this preliminary because it is the starting point for you to review and add additional details. Now is the time to think about where you might prefer 3-way switches, more outlets, etc.

The plans should show the meter, ground bar, main entry panel and subpanels as discussed in Sections 8.1 through 8.3.

Review the plans and determine zones for the branch circuits. The plans can indicate these zones in several ways. I prefer to use a different letter for each zone (A, B, C, etc.) Mark the outlets with these letters. Lighting circuits for zone A can then be identified A1, A2, etc. Mark each lighting fixture and its switches accordingly. For example, if there are 4 overhead lights controlled by two switches in zone A, mark the 4 lights and 2 switches as A1. If there is another set of lights and switches in zone A, mark them all A2.

Figure 8-2 shows a portion of the second floor electrical plan for Casa Soledad. A complete electrical plan for this house is provided as an attachment to this book and may be printed on D sized (24x36 inch) paper.

The symbols used should clearly indicate the type of switches (SPST, SPDT for a 3-way switch, DPDT for a 4-way switch). Your architect may use different symbols but there should be a key that defines all of them. The symbols used in Figure 8-2 are defined in Figure 8-3.

The subpanel is marked "*Centro de Carga*" and is in the lower center of the drawing. *Recamara* 2 and its *Baño* are zone J while the *Sala* TV and *Pasillo* are zone K. Indicate the home run location for each zone with an asterisk. For example, the outlet K* is the home run location for zone K.

Where two switches are mounted together in the same 4x4 box, this can be shown by placing a rectangle around the two adjacent switches on the drawing.

Now refer to the box requirements in Table 8-1. If the two devices that are in the same box require a deep box, then indicate this on the drawing by placing a second concentric rectangle around the original rectangle.

The drawing should show the height of each device (outlet, switch, etc.) above the finished floor. By default, switches in Mexico are mounted 100 cm (40 inches) above the finished floor. In the US, 120 cm (48 inches) to 130 cm (52 inches) is the standard. This dimension is to the center of each mounting box. Whatever you decide, place this on the drawing. Outlets are mounted 35 cm (14 inches) above the finished floor. This is about the same as in the US.

The low voltage outlets are indicated by the symbol SS and the junction boxes for these is RS. Try to locate the junction boxes for the two floors and the roof more or less above each other so they can be connected using vertical conduits.

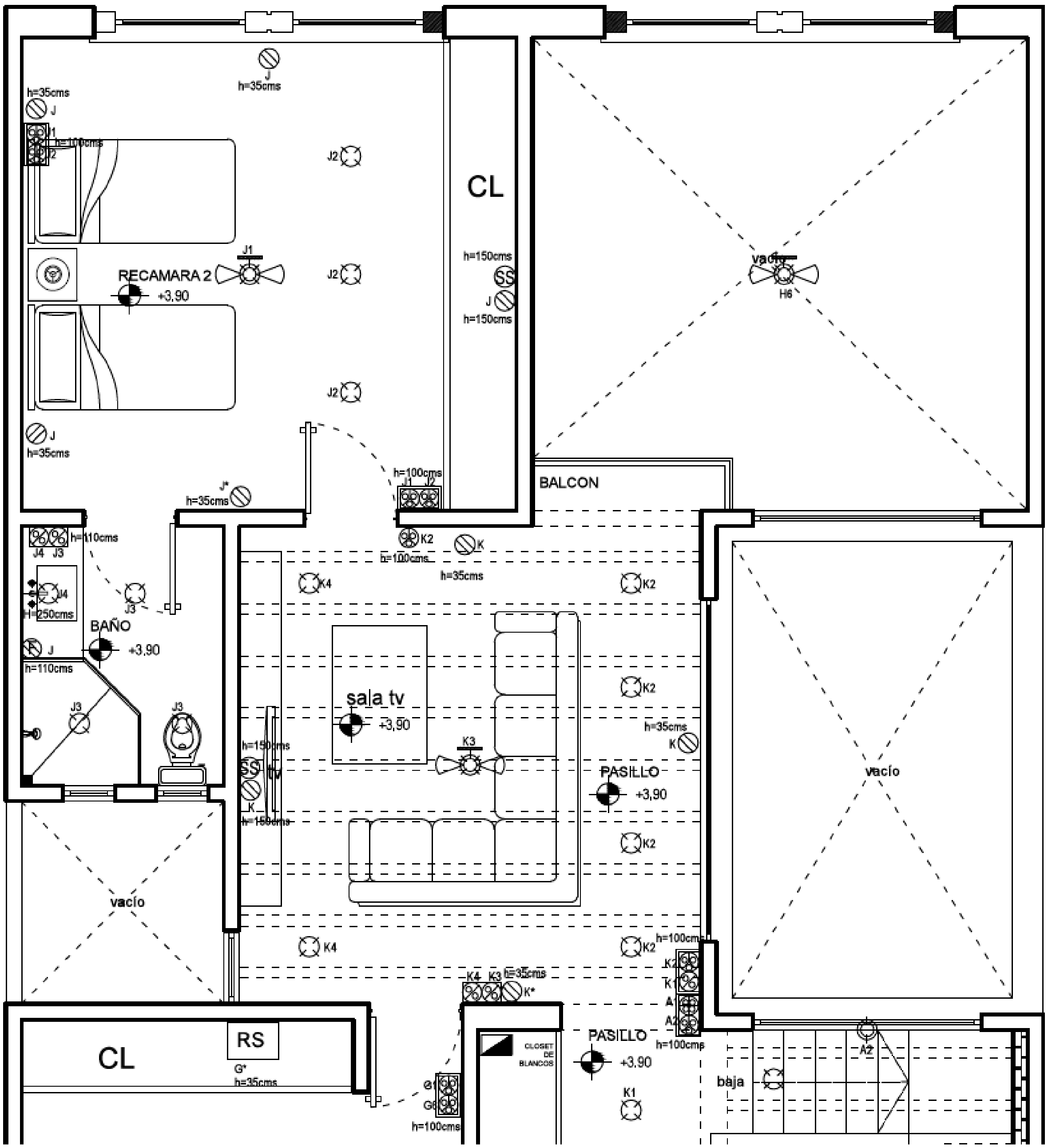


Figure 8-2 Sample Electrical Plan

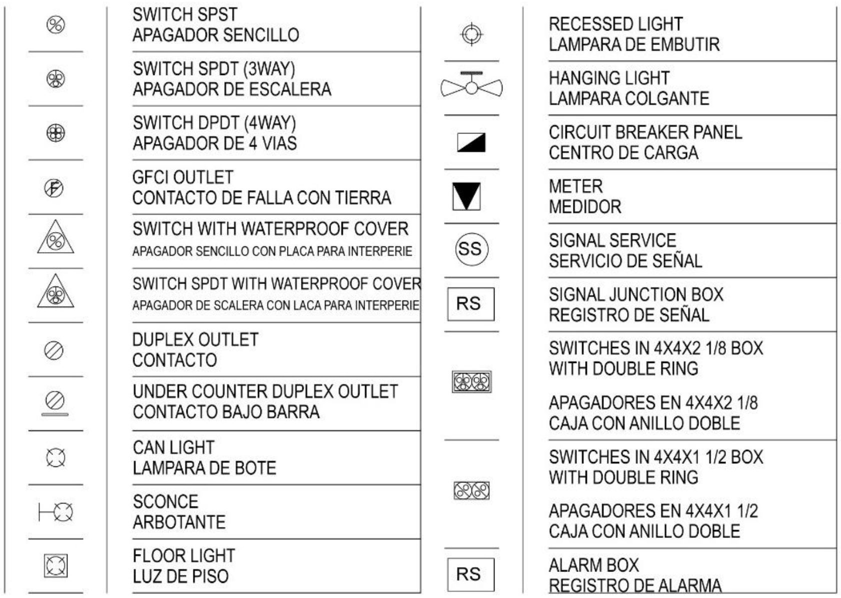


Figure 8-3 Electrical Symbols Used on Plan

8.8 Specifications and Parts

The specifications should be made part of the house plans and should identify the electrical parts and method of installation. For example, the model numbers for the switches and outlets, the mounting of the boxes and device rings (flush to the finish surface), method of wiring 3-way circuits, etc. should all be specified. They should be in Spanish so the electricians can readily understand it. Using the electrical plan and the specifications, a bill of materials (BOM) can be prepared for ordering the parts. Together with the architect, you need to make clear who will be responsible for providing the various parts. Anything unusual should be provided by you, the home owner. Common items like conductors and conduit should be provided by the electrician and light fixtures by the architect. In my opinion, providing the specified items is the best way to insure that they are actually used and that the best prices are paid whether they are locally purchased or imported from the US. If a substituted part is used because of price or availability, you should make that determination yourself.

The best way to keep track of the parts that you as the owner will supply is to prepare a spreadsheet BOM. Everything else not listed is then provided by the electrician and/or architect. At this writing, cost to ship to San Miguel using a package forwarding service from Texas runs about $3.75 per pound. Most of the items on the BOM (switches, etc.) are not heavy. The heavy items are the metal boxes and rings, but most of these are available in Mexico. When ordering, be sure to order some extras for spares. It is likely that once construction of the house begins, you will want to add a few extra outlets, etc.

An example specification written in both English and Spanish and a BOM are provided as attachments to this document. These were prepared for Casa Soledad (Section 13), but you can easily modify them for the devices and quantities for your own home.

8.9 Personal Supervision

This needs to be done because communication between you, the architect, the maestro, and the electricians will not always be perfect. And there will be mistakes including some on the plans and in the specifications. If you really care about the electrical work being done the way you intend, you need to be on hand each time something new and different is done. In my experience, no one will be offended by this. And if something is done wrong, the electricians are happy to redo it. Of course, they work on a time and materials basis, so rework is simply more work and more pay. However, remember that ultimately you are the payer, so it is to your benefit to minimize the rework.

9 Rewiring the Pool Area at Casa Erres

9.1 Introduction

Our first home in San Miguel was Casa Erres. This house was constructed around 1987 and included a separate pool area in the back that had a covered outdoor kitchen/BBQ behind the pool and a pool equipment room in a basement below the kitchen area.

The wiring in this area was so visibly bad that it got me wondering, is this as dangerous as it looks, can it be fixed, and would anyone else want to know how to go about fixing a similar problem? The answer to the first two questions was yes. As to the third, that is the reason for this book.

The pool area was wired independently from the house proper. The subpanel for the pool area was located in the basement pool equipment room, and it could be disconnected using a large knife switch located at the service entry panel at the front of the house. Rewiring of the entry panel and the other two subpanels used in the house itself will be covered in Section 10.

9.2 Mapping the Original Wiring

The appearance of the electrical switches and outlets in the upper area looked fine, but the wiring in the basement area was terrible. Many of the individual conductors were simply strung between boxes outside the wall. Others used an assortment of orange flex conduit, some inside the walls, others outside; steel conduits and even extension cords. I knew right away that I was going to replace the knife switches, fuses, individual circuit breakers and exterior cabling with a new circuit breaker box. But first, the existing wiring needed to be mapped out using the method described in Section 3.

The original wiring diagram is shown in Figure 9-1 and Figure 9-2 with the lower basement area on one page and the upper patio area on a second page.

Each block shown in dashed lines represents a physically separate wiring area. Most of these are simply electrical boxes, usually 4-11/16x4-11/16 inches located behind switches, receptacles or blank panels. The Control Panel was a large wooden board with individual circuit breakers, a mechanical timer for the filter pump, and a main disconnect knife switch mounted on it.

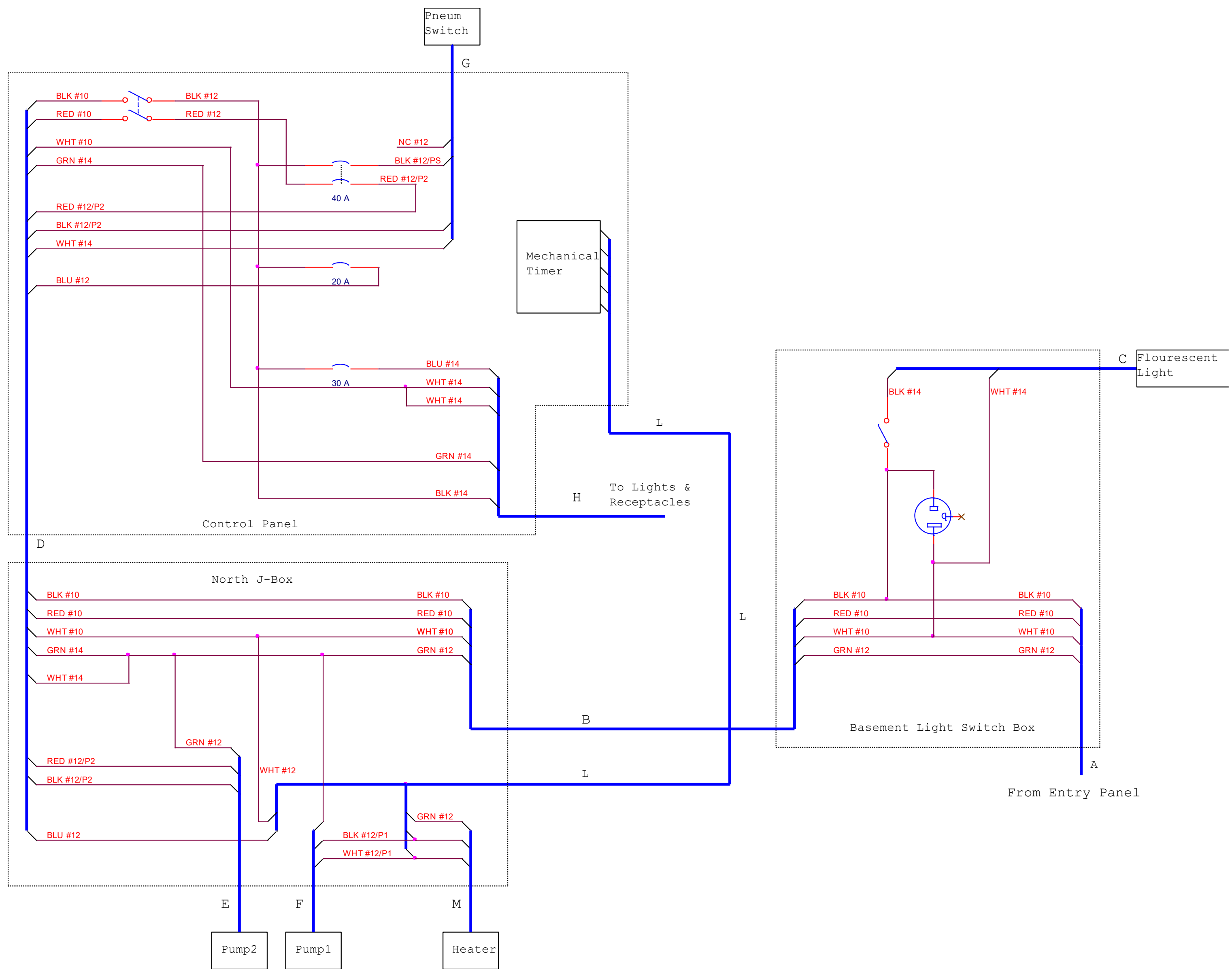


Figure 9-1 Pool Lower Level Original Wiring

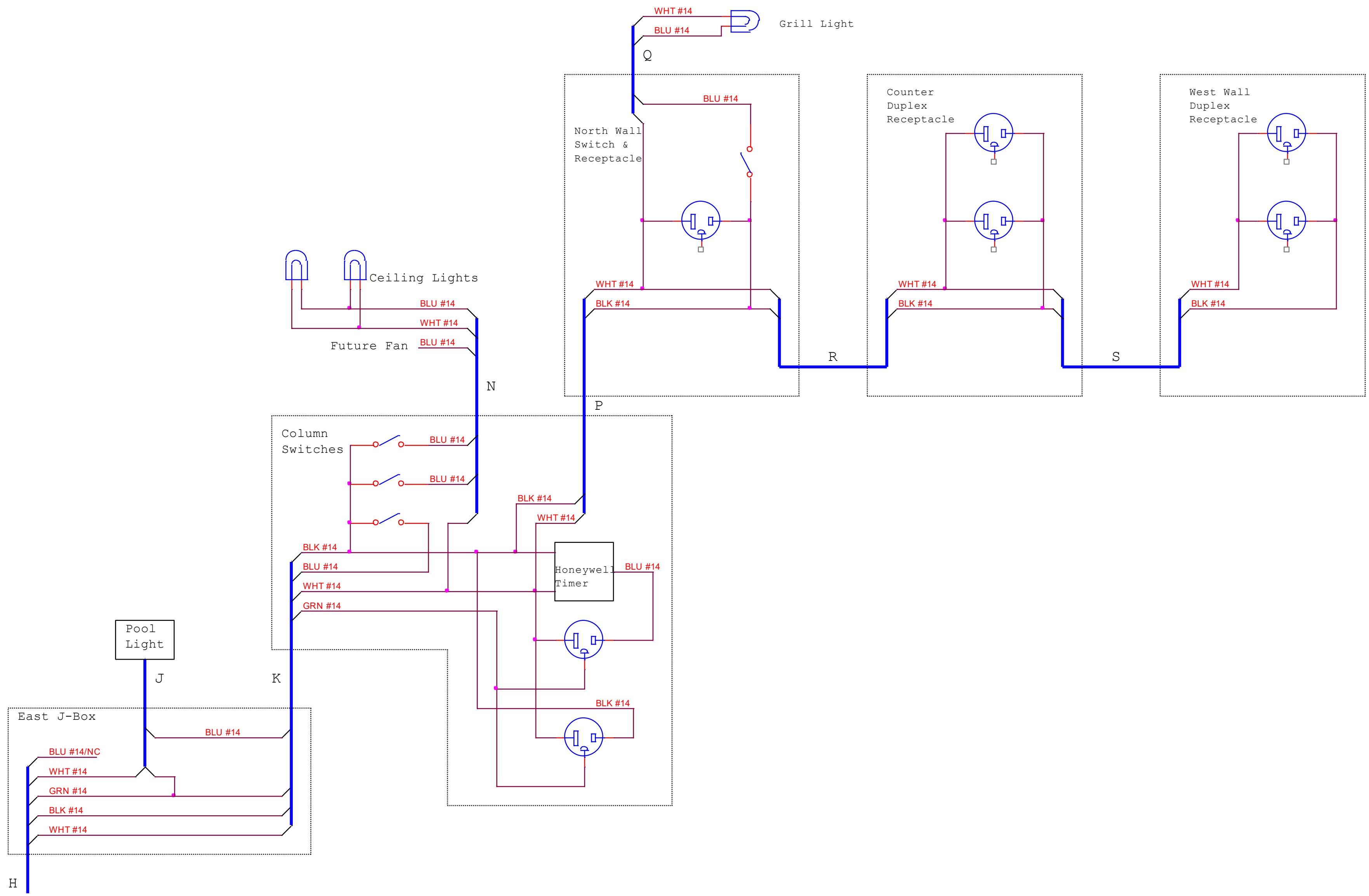


Figure 9-2 Pool Upper Level Original Wiring

Each electrical block is connected to one or more others through conduits shown in the diagrams by the heavy blue lines and marked A, B, C, etc. The individual conductors feed through these conduits. These are the black lines. The short, slanted lines indicate where the individual conductors enter the conduits. For example, in Figure 9-1, the box behind the basement light switch is in the lower right hand corner and is shown to have four conductors entering through conduit A which comes from the main service entry panel at the front of the house.

Note that heavy dots are used to indicate connections between conductors. Where two wires cross on the diagrams without being connected, there is no dot.

The conductors are marked as having a color and wire size. The actual wire color was almost always different from that shown in the diagram, but after determining its function, it was marked with colored electrical tape using the convention that I find most convenient.

BLACK	RED	WHITE	GREEN	BLUE	YELLOW
Line 1 (hot)	Line 2 (hot)	Neutral	Earth ground	Switched load (hot)	Added for comment

Particularly during tracing of the wires, it was helpful to write something on each end of some of the wires to indicate their function. I used yellow tape for this purpose, along with the appropriate other colored tape (black, red, etc.). I also made it a point to color code all wires as they were identified – even putting, for example, white tape around white wires in the rare cases where they were actually used as neutrals.

9.3 Analysis of Existing Wiring

Conduit A was a long run to the pool area. It terminated behind the switch used to control the overhead fluorescent lights in the basement. See the block Basement Light Switch Box in Figure 9-1. The #10 main feed conductors then passed through conduit B to a second junction box on the North wall of the basement (North J-Box), and from there though an exposed metal conduit D to the Control Panel. However, note that a receptacle and switch for the overhead fluorescent lights was connected directly to line 1 and the neutral in the switch box. This was bad because disconnecting the main knife switch on the Control Panel left this wiring live. It was also bad because this wiring was AWG 14 which is only rated at 15 amps. If these wires were to short together, the only protection would be the 60 amp fuse in the Service Panel at the front of the house. One of the things that I wanted to accomplish during the update was to connect all AWG 14 wiring used for relatively low current lighting and receptacles to a 15 amp GFCI circuit breaker on the new Control Panel. Another problem shown was that the receptacle on the light switch did not have an earth ground connection even though it was available in the same switch box. Adding the missing earth ground was very simple, but rewiring the outlet and light switch to a 15 amp circuit coming from the new breaker panel would require pulling a #14 black and #14 white wire through conduit B.

The North J-Box shown in Figure 9-3 was a very messy interconnection, and I wanted to simplify it somewhat. Basically, it passed the main entry lines from conduit B through to the circuit breaker panel via conduit D. In addition, the two pumps P1 (which runs on 127 VAC) and P2 (which requires 220 VAC) connected via floor conduits F and E to this junction box. During a recent renovation of the pool equipment, a mechanical timer had been added to control the filter pump, P1. This timer was conveniently mounted on the Control Panel board, but it was wired through exposed cables L down the outside of the wall and into the junction box under its cover plate. I wanted to move this wiring to the Control Panel board itself. Conduit M was used to supply power to the gas pool heater. This power was switched so that the heater could be on only when the filter pump was on. Conduit M was also wired to the North J-Box by routing it under the cover. This was an exposed slit plastic tube.

Since the entire basement area was below ground, all its walls were built using concrete. This meant that adding new conduit inside the walls would be extremely difficult to do. (Concrete is MUCH harder to chisel out than cement plaster and brick). An alternative way to improve the appearance and safety of the exposed conduits such as M would be to replace them with water tight flexible conduit and install fittings where they enter junction boxes such as the North J-Box. An easy way to do this would be to add an extension ring to the existing junction box. This would provide entry holes for the flexible conduit, and in addition would provide more volume for the large number of conductors inside this box.

Figure 9-3 North J-Box Original Wiring

There were two other problems with the wiring in the North junction box. The WHT #14 wire from the Control Panel was used as the neutral on the pneumatic switch relay. But it was connected to the earth ground (GRN) instead of the neutral (WHT). This worked, but it was a very bad arrangement since earth ground wires should never carry current except under fault conditions. Also, there was a GRN #12 wire that went between the mechanical timer and the heater through conduits L and M, but it was not connected to the earth ground.

The Control Panel contained a number of circuit breakers and a knife switch. There was a dual 40 A breaker for pump 2 (the Jacuzzi jet pump). This breaker was oversized for the wiring and the pump which was rated at 10 amps. Given the AWG #12 wiring for the pump, this breaker should have been 20 amps. Pump 2 was controlled by the pneumatic switch connected via the exposed metal conduit G. There was a single 20 A breaker used for pump 1 (the filter pump). This pump was controlled by a mechanical timer via conduit L. Pump 1 was rated at 6.5 amps and wired using AWG 12 wiring, so the size of this breaker was correct. There was also a single 30 Amp breaker that was not connected to anything. It might have been used for the lighting and outlets at one point, but these were not fused at all! Since the pool light and all the other lighting and receptacles used in the pool area were wired with AWG #14 wire and in total consumed about 7 amps, this breaker could be changed to a 15 Amp size and used for all these loads. The breaker also needed to be a GFCI type because of the proximity of the outlets to water. As shown in the photo Figure 9-4, the Control Panel contained separate electrical boxes for the knife switch and each of the three circuit breakers. These were interconnected with individual conductors taped together. All of this could be replaced with an inexpensive breaker panel, the Square D model QOX204. There was no need to provide a local main disconnect on this subpanel since this was provided at the main entry. The new subpanel would contain a dual 20 A breaker for pump 2, a single 20 A breaker for pump 1 and a single 15 A GFCI breaker for all the lighting and receptacles.

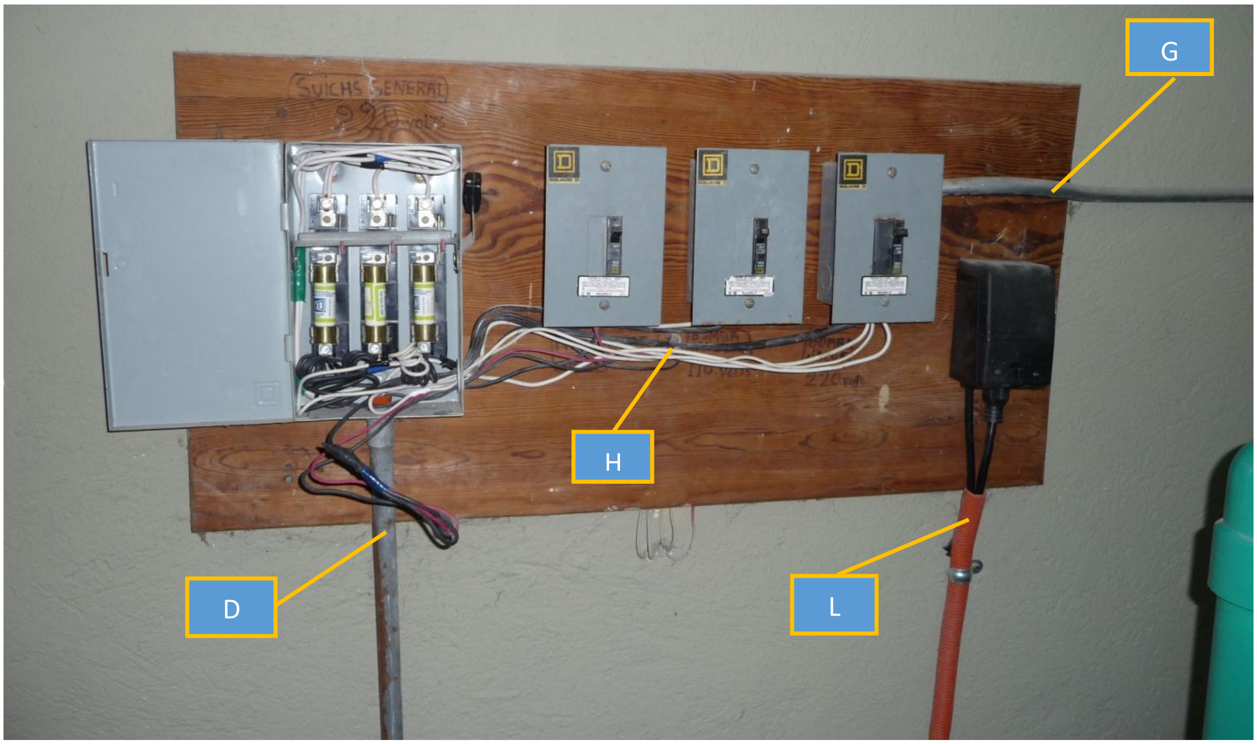


Figure 9-4 Pool Control Panel Original Wiring

The East J-Box is shown in Figure 9-5 below. Note the rusting in this box. What was happening was that the junction box for the pool light, which by US code should be 18 inches above the pool, was in fact mounted slightly below the pool deck. When the pool overfilled, for example due to a very heavy rain, the pool light junction box filled with water thereby submerging the wiring. Even worse, the flex tubing that ran from this box to the East J-box filled with water. So the water level of the pool was lowered by draining it down conduit J, through the East J-box, down the wall and across the floor to a floor drain. Fixing this disaster will be discussed separately.

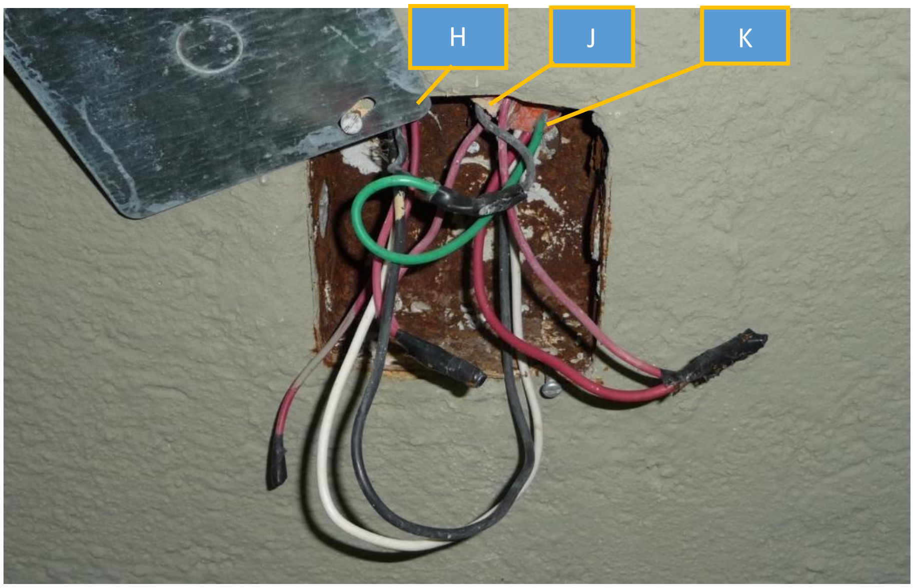


Figure 9-5 East J-Box Original Wiring

The Column Switches are shown in Figure 9-6. One switch controlled the two overhead lights, a second switch was for a future overhead fan, and the third switch controlled the pool light. The Honeywell timer had been added to control a decorative light string that plugged into the receptacle. Conduit P supplied power to the receptacles along the counter top. Note there was no green earth ground wire to these receptacles. This could be added without too much difficulty since the earth ground was available in the Column Switch box, and the receptacles were all of the 3-prong variety.

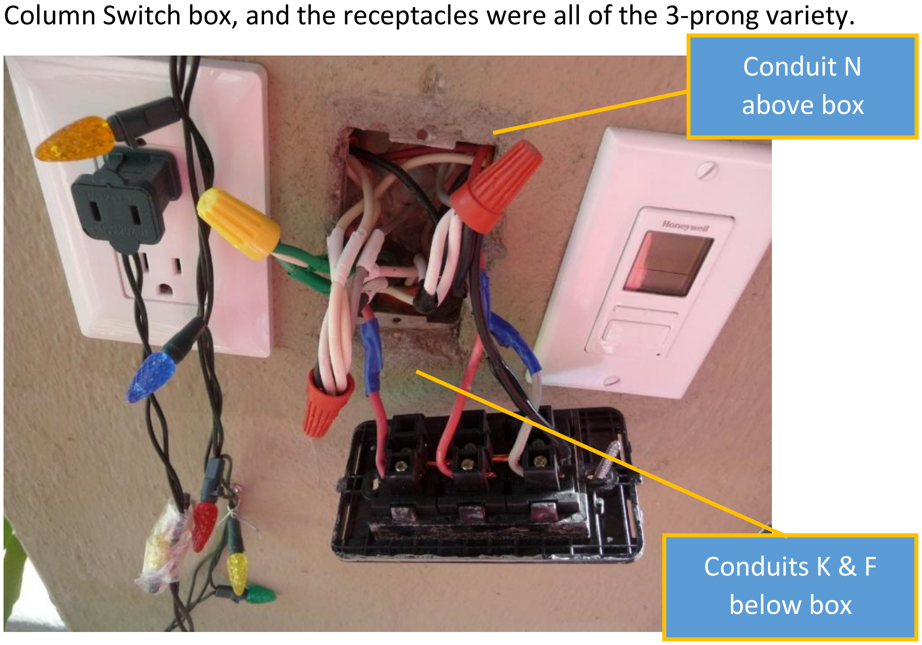


Figure 9-6 Column Switches Original Wiring

9.4 Upgrading

Summarizing the changes to be made to the pool area:

1. Replace knife switch and three breaker boxes on the Control Panel with a Square D model QOX204 circuit breaker box. Eliminate the wood panel.
2. Replace circuit breakers and fuses with a 2-pole 20 A for pump 2, 1-pole 20 amp for pump 1 and 1-pole 15 amp GFCI for lighting/receptacle circuits.
3. Add a 4-11/16 inch extension ring to the North J-box and replace existing external steel conduit D and plastic flex conduit M with new waterproof ¾ inch flex conduits.
4. Replace surface mounted receptacle at heater end of M with a handy-box mounted receptacle that accepts a ¾ inch waterproof flex fitting.
5. Replace external steel conduit G with waterproof ½ inch flex conduit.
6. Add a handy-box over the end of conduit B and reroute the individual conductors running behind the wood panel through a short length of waterproof ¾” flex conduit.
7. Mount a 120 VAC receptacle in this handy box and wire it for the input plug to the mechanical timer.
8. Add a BLK #14 conductor and a WHT #12 conductor to conduit D.
9. Add a BLK #14 conductor and a WHT #14 conductor to conduit B.
10. Add a GRN #14 conductor to conduits P, R and S.
11. Rewire according to the diagrams shown in Figure 9-7 and Figure 9-8.

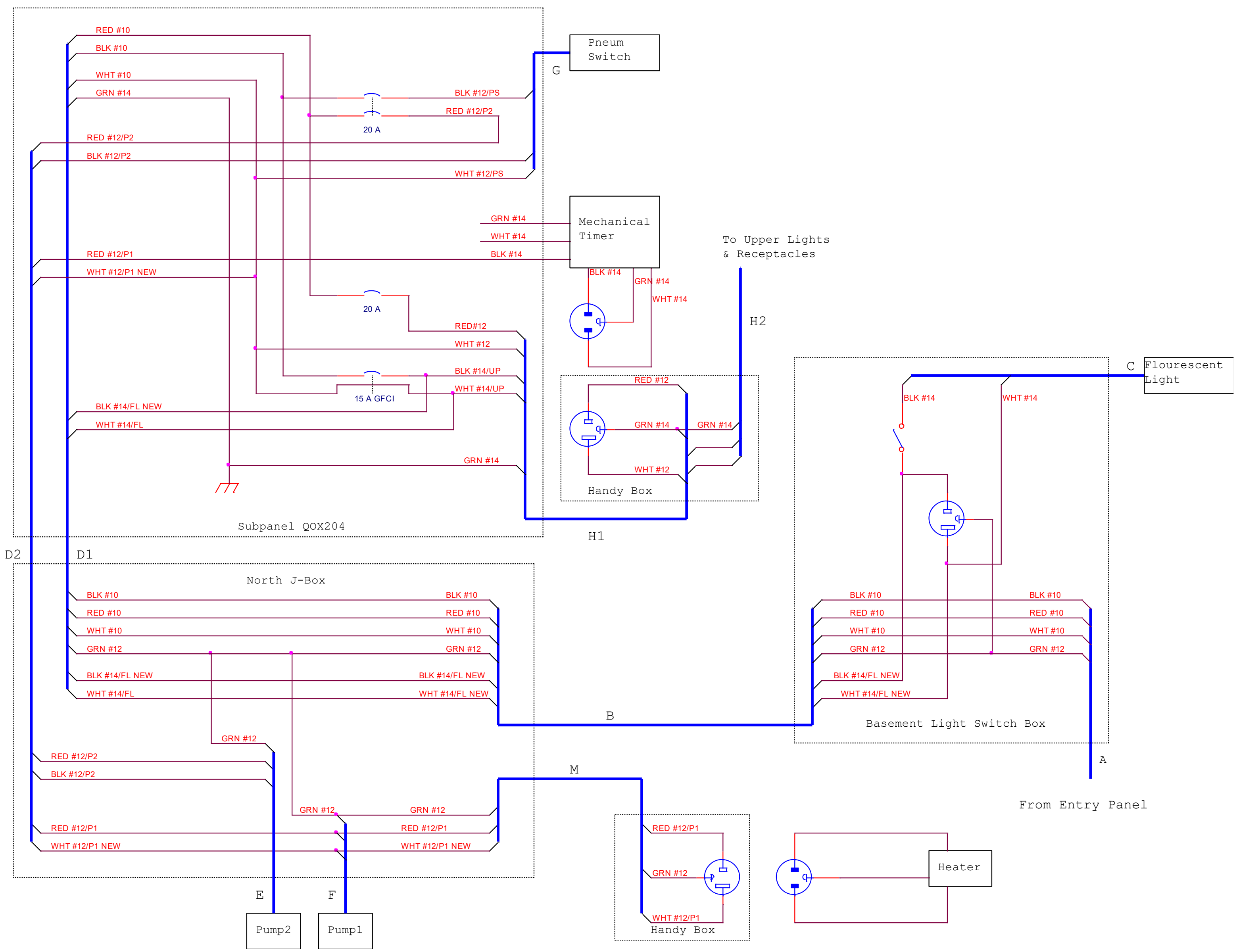


Figure 9-7 Pool Lower Level New Wiring

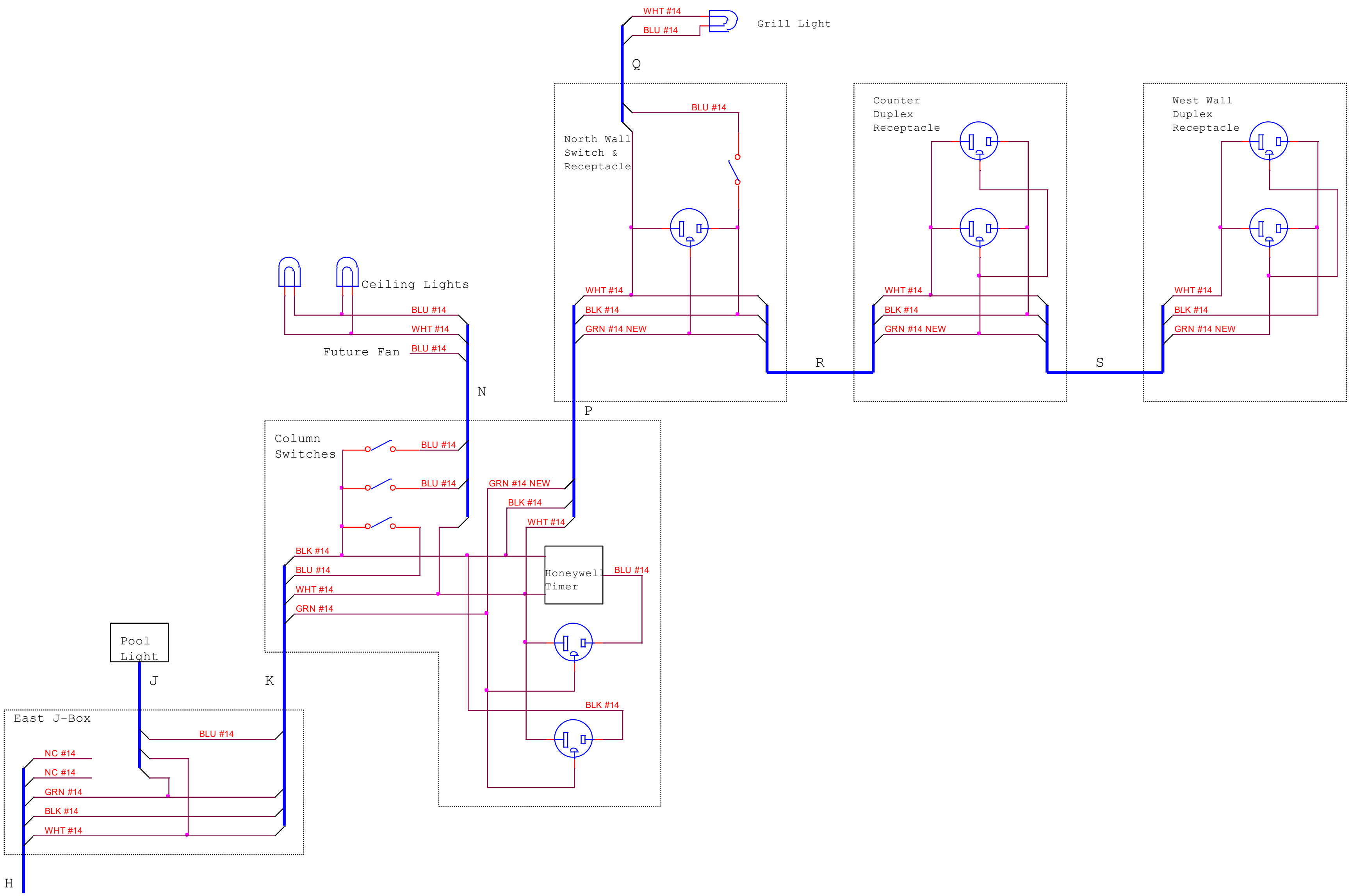


Figure 9-8 Pool Upper Level New Wiring

All of the items needed to make these changes were available in Mexico except the 4-11/16 inch extension ring.

Photos of the new wiring are shown below.

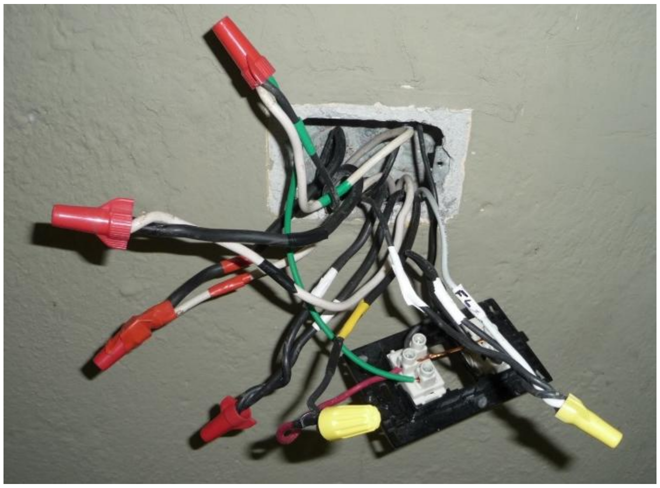


Figure 9-9 Basement Light Switch New Wiring

The new #14 black and #14 white conductor were added to conduit B and the light switch and outlet were rewired to use these. This turned out to be very easy as the nylon pull tape (snake) ran cleanly through the conduit to the North J-box without having to remove the existing conductors.

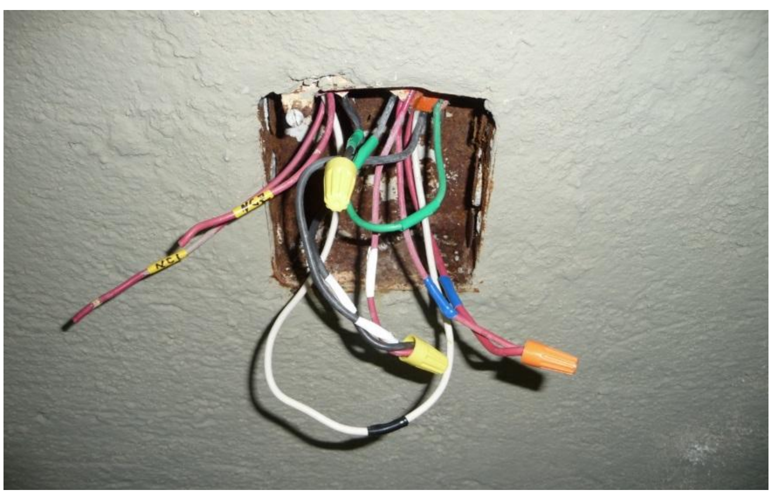


Figure 9-10 East J-box New Wiring

The two previously unused conductors marked NC1 and NC2 were left in place.

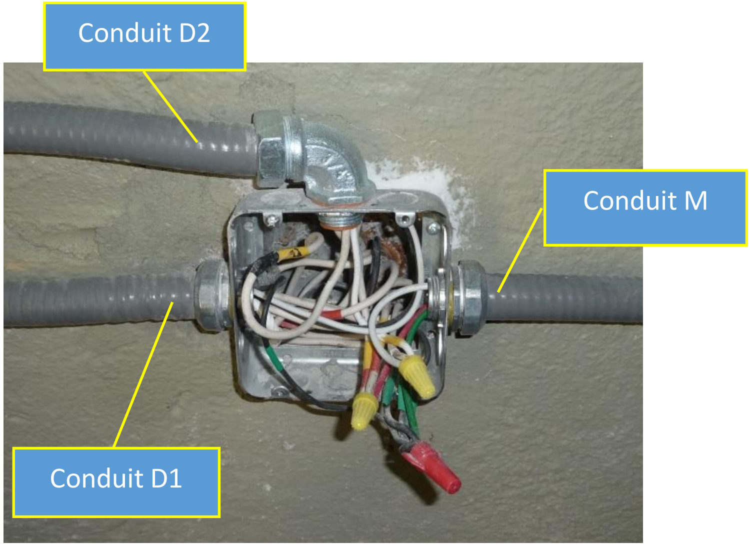


Figure 9-11 North J-Box New Wiring

The number of conductors that needed to run from this J-box to the Control Panel exceeded what could be pulled through a single ¾ inch flex conduit. So two were run—one using the straight adapter on the left side of the box and the second using the right angle adapter at the top. The conduit on the right goes to the pool heater handy box outlet. Note how adding an extension ring allowed these conduits to mount flush to the wall.

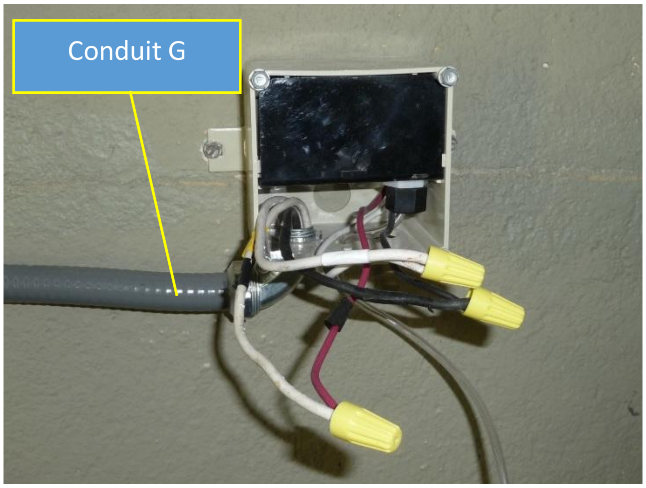


Figure 9-12 Pneumatic Switch New Wiring

A ½ inch waterproof flex conduit now connects the pneumatic switch to the control panel.

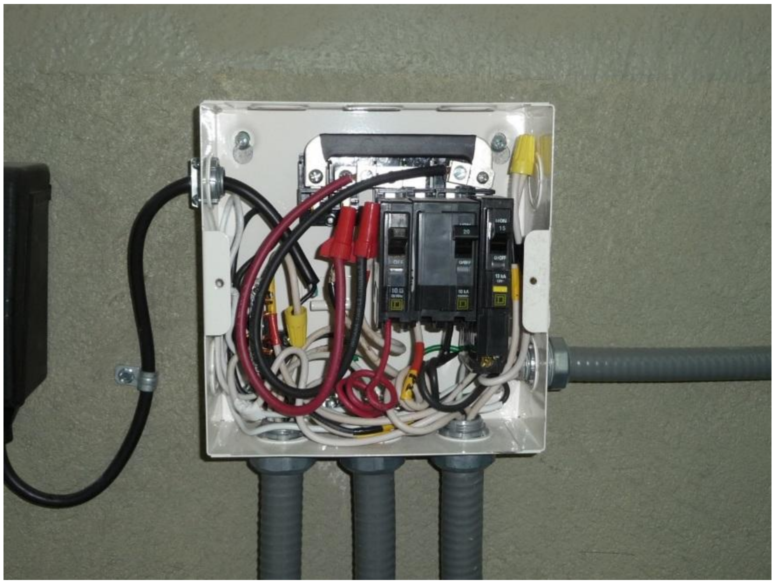


Figure 9-13 New Circuit Breaker Panel for Pool Area

The new circuit breaker panel contains the buses for line 1 and line 2 at the top. The neutral bus is at the lower left and the earth ground bus at the center bottom. Note the GFCI breaker on the right.

Figure 9-14 New Subpanel for Pool with Timer on Left

Figure 9-15 Newly Rewired Pool Lower Level

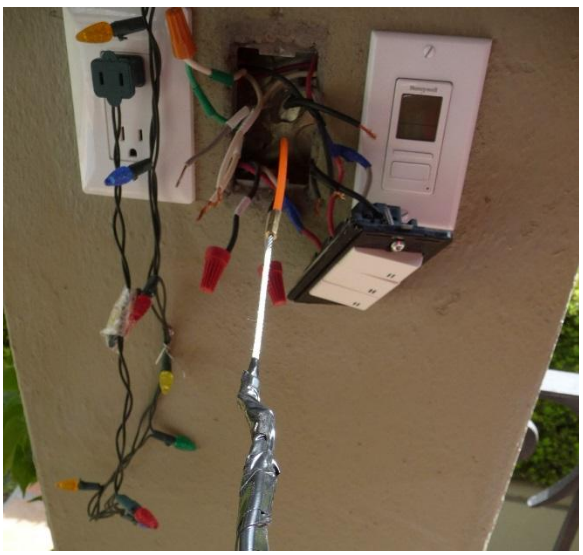


Figure 9-16 Pulling New Green Wire through Conduit P at Column Switches

Here it was necessary to first remove the original black and white conductors from the conduit, then pull all three conductors at the same time back through it.

Figure 9-17 Rewired Upper Pool Area

Fixing the problem of the pool light's wiring being submerged when the pool level was too high presented several options. The pool itself lacked a functioning overflow system. The pool light junction box could have been relocated per US code to the wall on the right and raised 18 inches, however this would have involved major surgery to the decking around the pool. Another option would have been to simply plug the end of conduit G going to this junction box with Silicone and also apply it around the wire nut connectors. This would keep the pool from draining through the electrical wiring and the East J-box. The third option was to prevent the pool from overflowing by providing a leveling drain.

I decided to implement both options 2 and 3. Fixing the overflow problem without having to cut into the pool decking involved adding a drain/leveling pipe to the existing filter pump inlet piping in the basement area. By making the open end of this pipe equal to the desired pool level, the pool would drain through it, and the proper level would be maintained. Of course, this drain path had to be closed when the pool pump was operating or the pump would simply suck air through the pipe. A passive check valve was considered, but the problem with these is that they typically require 2 psi differential to open. This does not seem like much, but 2 psi corresponds to about 4 feet of water! A better solution was to use a normally open solenoid valve between the pump inlet and the open end of the drain line. This was actuated by plugging the solenoid into the same switched duplex outlet that was used to enable the pool heater. Figure 9-18 through Figure 9-20 show the plumbing and wiring. (It actually works).

Figure 9-18 Overflow Pipe Connected to Pump Inlet

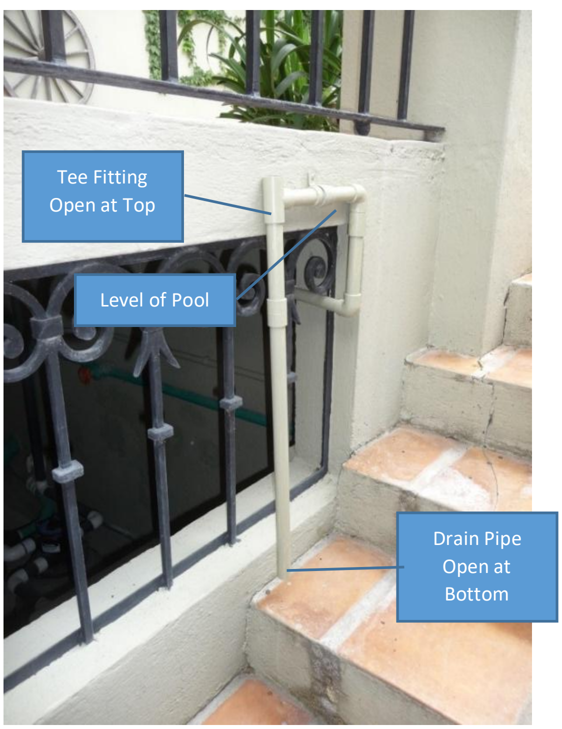


Figure 9-19 Drain Pipe

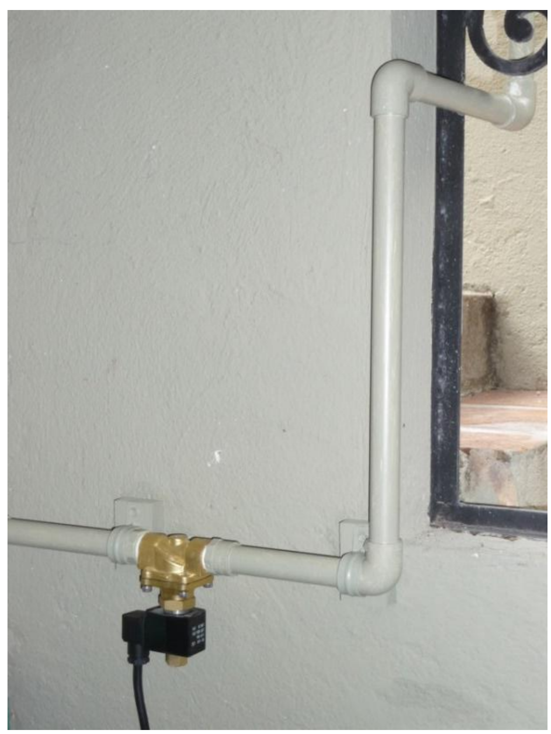


Figure 9-20 Solenoid Valve

10 Rewiring the Entry Panel and Subpanels at Casa Erres

10.1 Introduction

In this Section, the wiring associated with the entry panels and the subpanels is discussed. Only the wiring upstream of the subpanel circuit breakers is considered. (The branch circuit changes are covered in Sections 9 and 11).

10.2 Mapping the Existing Wiring

There was a main entry panel that consisted of two large multiple pole knife switches with fuses. There were also three subpanels. One was in the pool area and is discussed in Section 9.

In the kitchen closet, there were two adjacent subpanels. The larger panel contained 10 circuit breakers for circuits used throughout the house. The adjacent smaller panel contained another 5 breakers used for the kitchen appliances. It had been added when the kitchen was remodeled.

The feed between the main entry panel in the carport and the pool area was straightforward. A single conduit ran all the way to the pool area where as described in Section 9, this circuit connected to a subpanel in the basement of the pool area.

The feed to the house subpanel passed through a junction box located on the East side of the South wall and from there through another conduit to the house subpanel. However, there was another feed, partially disconnected, that ran first to a junction box in the carport, then to a junction box on the East wall of the house, then to a junction box on the North wall, and finally to the house subpanel. The reason for this wiring and why it was partially abandoned is unknown.

When the kitchen was remodeled and the kitchen subpanel was added, a third feed was added to supply the oven. This ran through a junction box on the West side of the South wall, then to the kitchen subpanel. The two subpanels were then wired in parallel. As is probably already apparent, there were a number of problems with this arrangement. All that can be said is that it did work, but there was a lot that could be done to improve it.

Tracing the existing wiring was quite a task. Using the method described in Section 3, the conduits were first identified by making the diagram shown in Figure 10-1 where the number and color of each conductor in each junction box was matched up with those in other junction boxes. Then the conductors were identified according to their function and color coded with tape. Eventually the diagram shown in Figure 10-2 was developed.

10.3 Analysis of Existing Wiring

The path from the entry panel through conduits C, F, G, and H contained two live AWG8 conductors which were disconnected inside the N J-Box. These were immediately disconnected from the fuses and marked NC. The neutral conductor which followed the same path and alternated between AWG8 and AWG12 was connected to the neutral bus inside the House Subpanel, but this bus was grounded to the panel. The green earth ground also followed this path alternating between AWG8 and AWG12, and it connected to several other wires inside the House Subpanel. These provided an earth ground to the outlets in the kitchen and the laundry room.

The neutral and earth ground buses in each of the two subpanels needed to be separated. One of the NC#8 continuous conductors which ran through conduits C, F, G could be used as the earth ground for the two subpanels.

Note that the two line side conductors were tied together inside the house subpanel. These needed to be separated so that the conductors in B and E would feed just the kitchen subpanel and the conductors in A and D would feed just the house subpanel. To keep the entire feed to the panel #8, the WHT#8 conductor running through conduit H could be swapped with the GRN#12.

Rewiring the original house and kitchen subpanels to provide separate neutral and earth ground buses would not be easy to do using the existing panels. Each had only one bus and these were both fastened to the chassis in each of these panels. A better solution was to simply convert the two existing breaker panels into junction panels by removing all the internal hardware from them. Two new modern subpanels could then be installed immediately above them. This would require more work, but in the long run would result in a cleaner layout. These would be wired as shown in Figure 10-3.

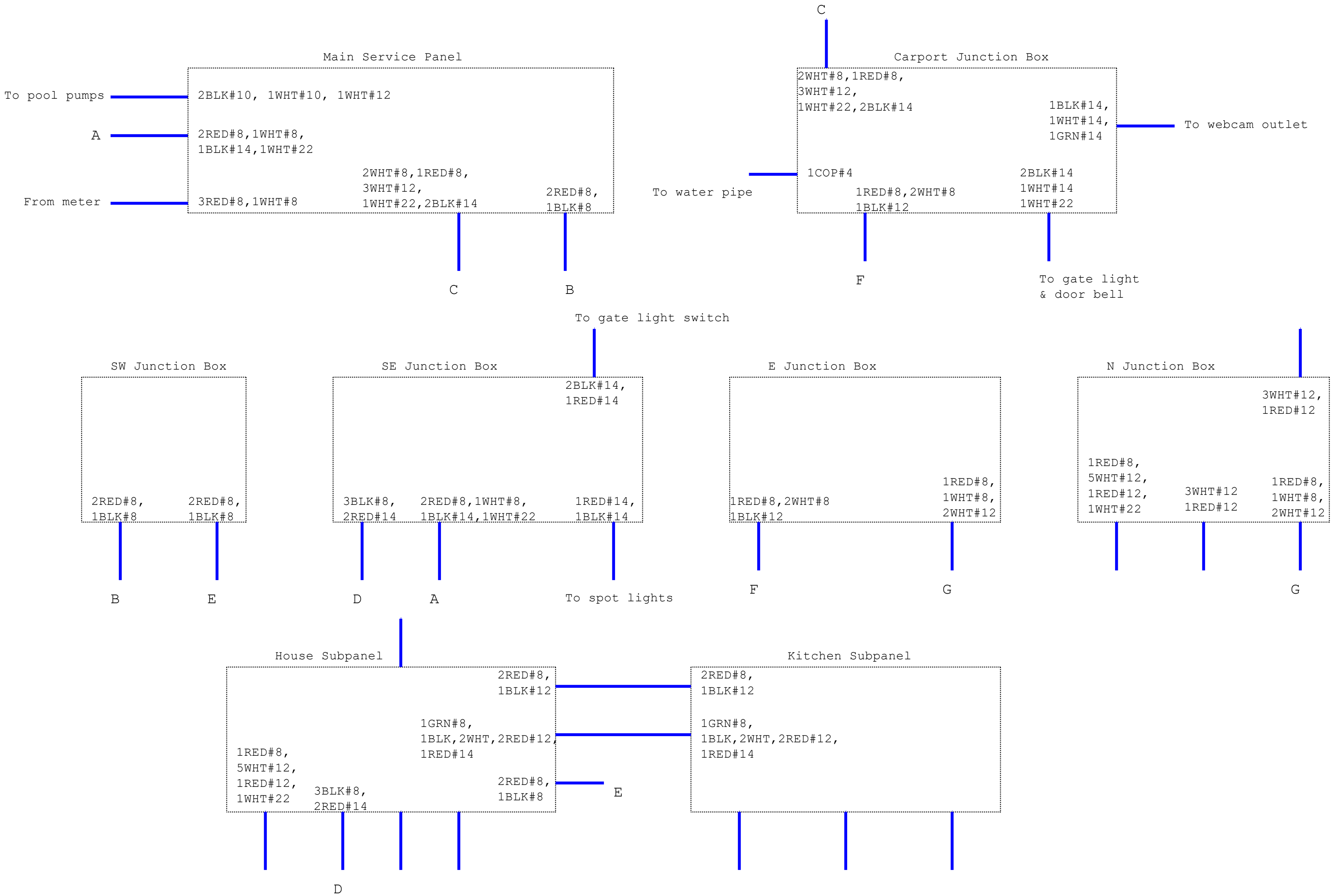


Figure 10-1 Conduit Identification

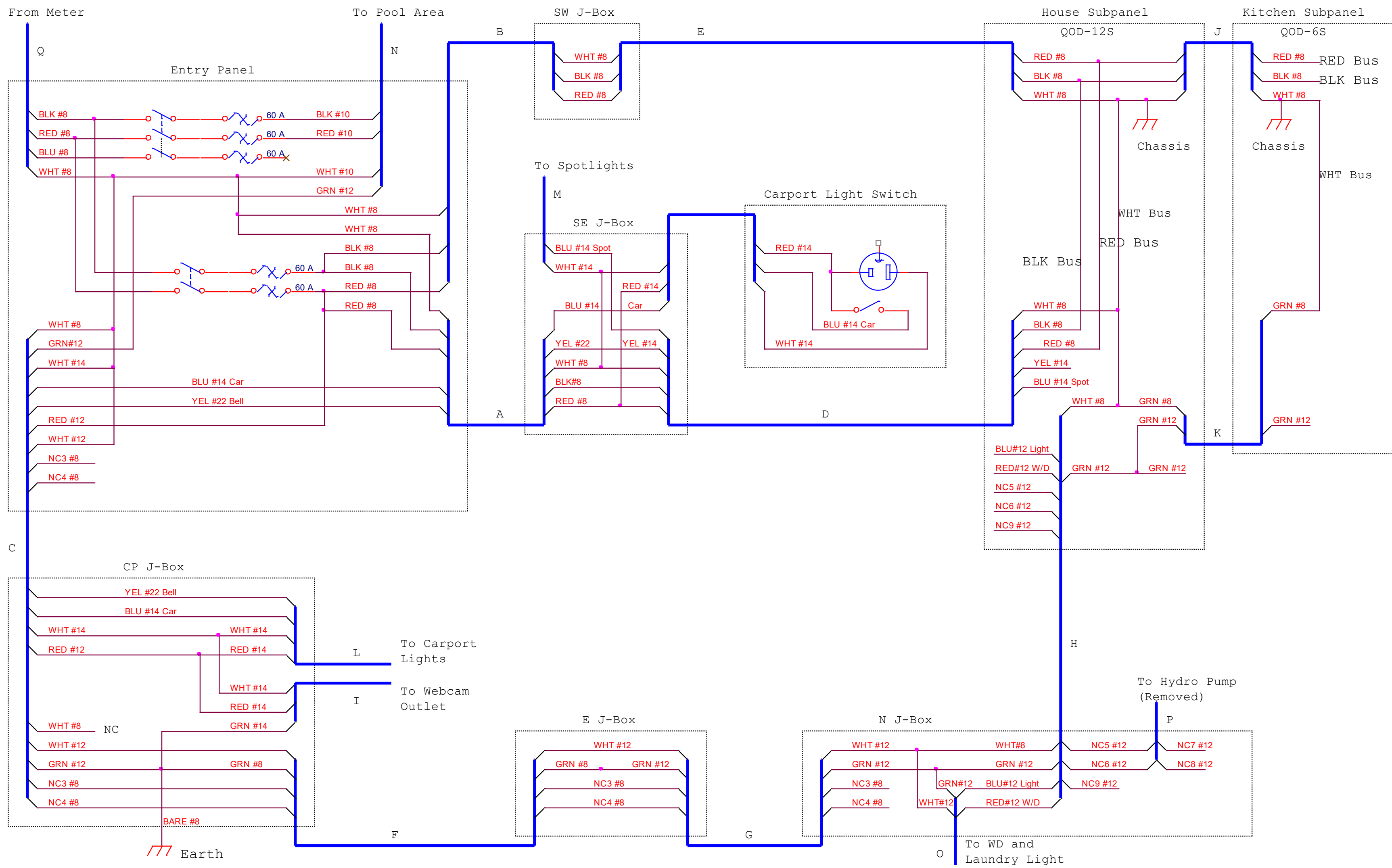


Figure 10-2 Original Wiring

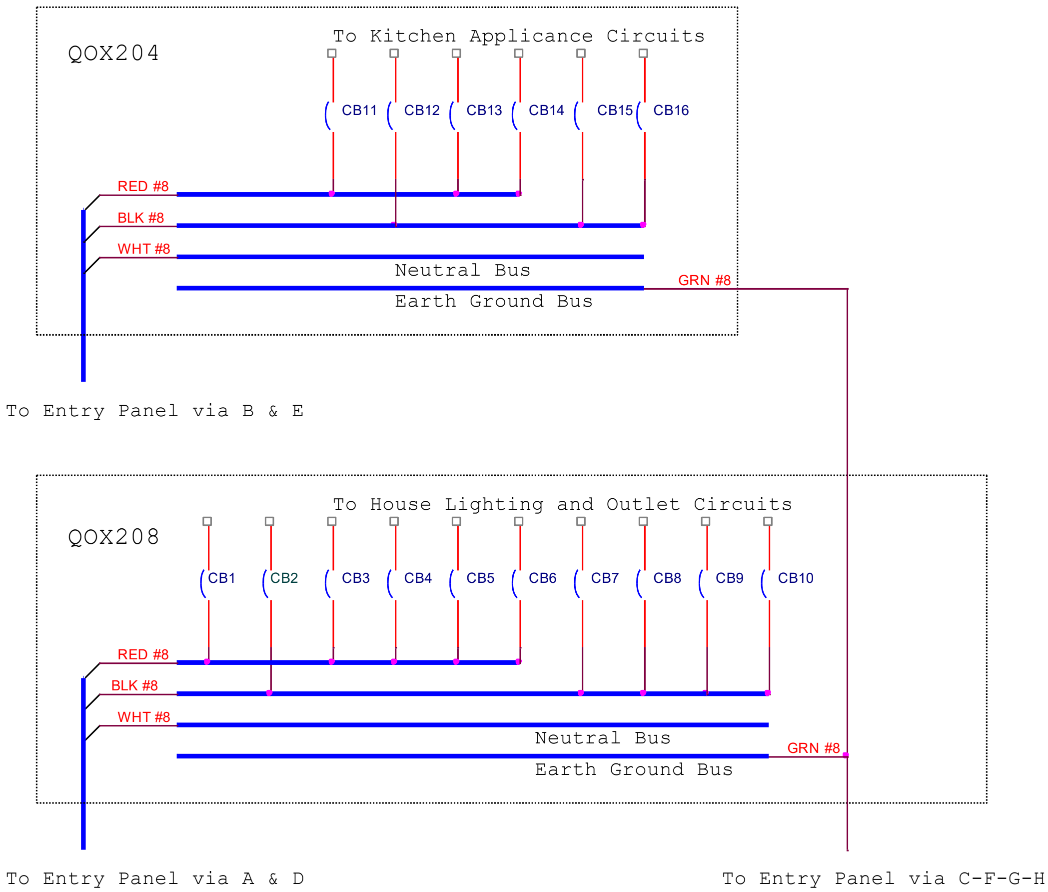


Figure 10-3 New Subpanels for Kitchen & House

Although this section is primarily concerned with the entry and subpanel wiring, some branch circuits were wired through the same conduits and are shown in Figure 10-2.

The YEL#22 wire shown in conduits A, C and L was actually a multiple conductor low voltage cable used for the original doorbell that had been disconnected and replaced by a wireless device.

Also note that as wired in the SE J-Box, the carport lights were not fused, other than from the 60 amp main. When upgrading the main entry panel, a separate circuit breaker can be installed for this circuit thus eliminating the connection from the RED#8. To keep down the number of conductors in Conduit A, the YEL#22 wire might be replaced with a RED#14 conductor. The wiring of the duplex outlet was poor because, for its location, it should be grounded. It could be eliminated and replaced by a grounded outlet on the main entry panel instead.

Also, the neutral for the spot light should have come from the house subpanel and not from the WHT#8 feed. The YEL#14 might be used for this purpose.

With these changes, the SE J-Box and Carport Light Switch would look like that shown in Figure 10-4.

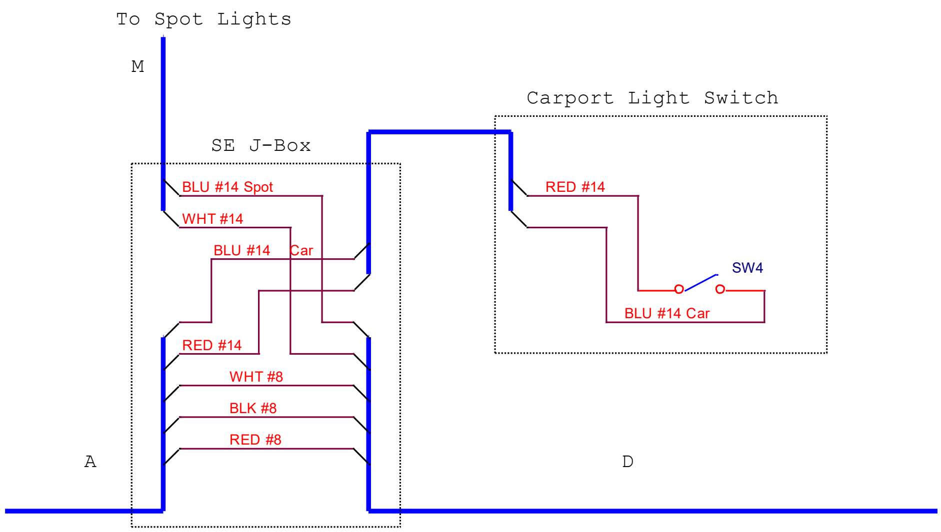


Figure 10-4 Possible Rewired Spot and Carport Light Wiring

Unfortunately, it proved impractical to replace the #22 conductor in conduit A with the RED #14 shown in Figure 10-4 because the conduit was kinked at two places where it ran under the carport. An alternative solution was to simply connect the spot lights to the overhead carport lights. This was in fact the way we used them anyway. Doing this, the separate carport light switch could be eliminated and the SE J-Box wiring could be simplified even further as shown below.

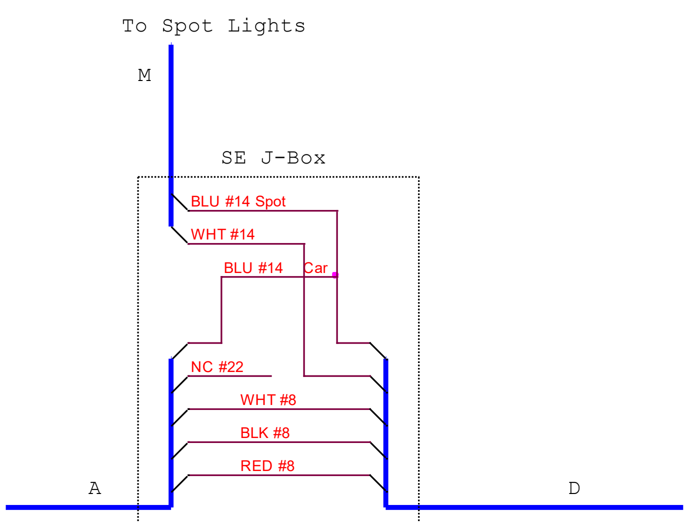


Figure 10-5 Final Rewired Spot and Carport Light Wiring

The earth ground connected to the main entry panel through a #12 conductor. This could be moved to the unused WHT #8 in conduit C and the #12 conductor used as the earth ground for the webcam outlet.

The main entry switches and fuses needed to be replaced with one or more panels that would provide a main disconnect as well as individual disconnects to each of the 3 subpanels. In addition, I wanted to provide a surge protector for the whole house at this location and a few additional circuit breakers for the carport light circuit and some grounded service outlets.

For simplicity, I did not show in Figure 10-2 the connections to the 60 amp fuses of a carport gate opener and a high voltage security fence controller. These connections were made with zip cord and were especially ugly. They needed to be wired through duplex outlets adjacent to the main entry panel.

Two panels QO816L100DS were selected for the main entry panel. They are wired like one larger panel but were chosen because they fit better into the space available in the protected cabinet. Each of these panels has space for 8 double breakers. One space was used as the main breaker by back feeding it and using retaining kit PK2MB. A QO217SB surge protector was added to provide whole house surge protection.

Table 10-1 below lists the configuration of the two main panels fed through the 70 A breaker in slots 1 and 2. This configuration works with either a single 2 or 3 phase meter, or with two single phase meters.

Table 10-1 Single Meter Entry Panel Configuration

Slot	1	2	3	4	5	6	7	8
Panel 1	70 A Main 1	70 A Main 1	Surge Protector	Surge Protector	30 A Pool	30 A Pool	50 A House	50 A House
Panel 2	NC	NC	NC	NC	50 A Kitchen	50 A Kitchen	15 A Webcam	20 A GFCI Duplex

10.4 Updated Entry Wiring

With all these changes, the new wiring for the entry panel and feeds to the subpanels looks like that shown in Figure 10-6.

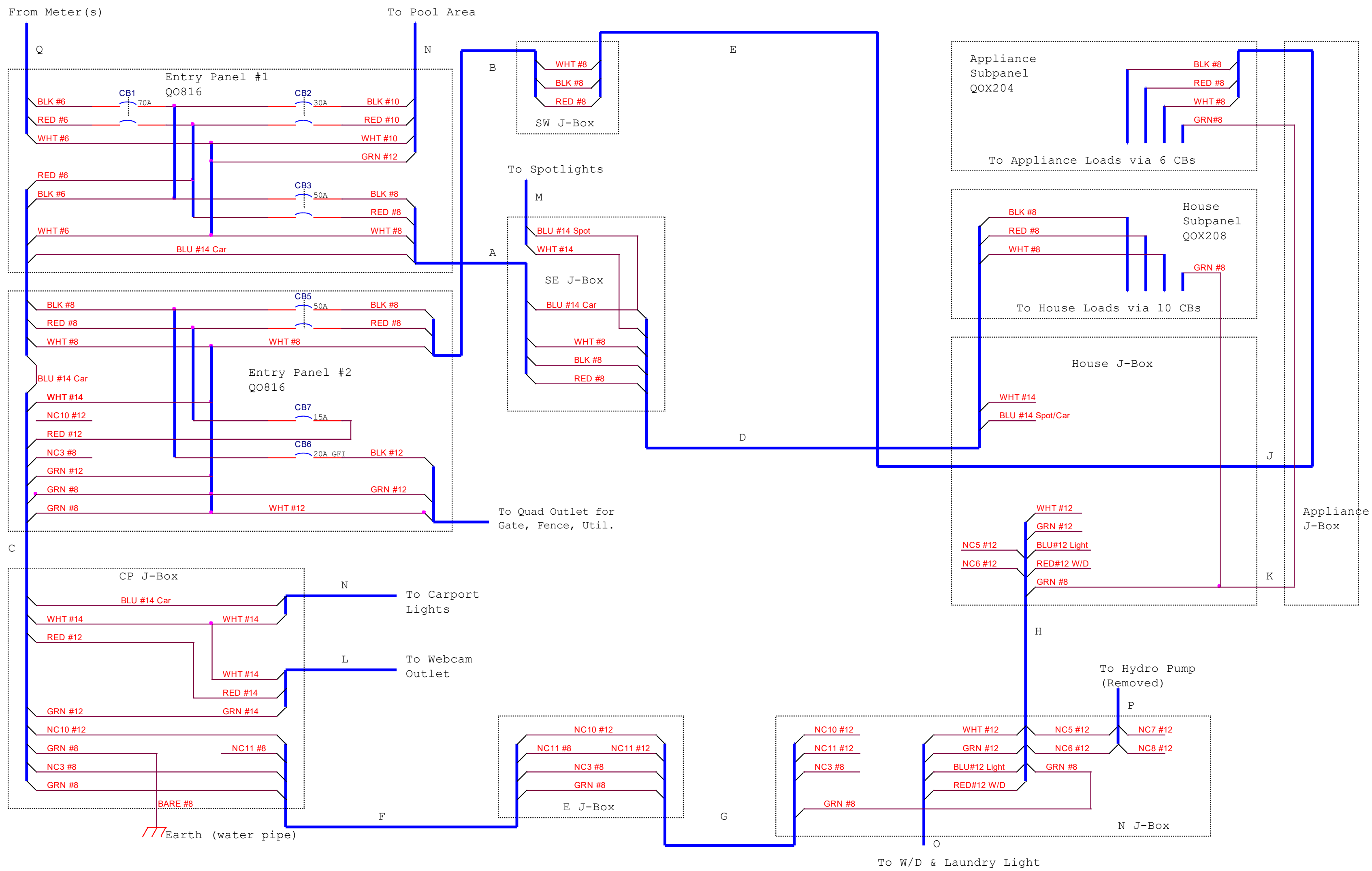


Figure 10-6 New Entry Wiring

The original and new entry panel is shown in Figure 10-7 and Figure 10-8 below. Waterproof flexible tubing sold as "Licuatite" in Mexico was used to connect the new circuit breaker panels and to enclose the wiring up to the point where the flexible (orange) tubing is used inside the walls. Most of the tubing shown is 1-1/4 inch non-metallic. The fittings are metal, but non-metallic fittings could just as easily have been used. If I had to do this over again, I would have used 1 inch tubing because it bends easier and would still be large enough to accommodate the wiring. Figure 10-9 shows the final result with the covers installed.

Figure 10-7 Original Entry Panel Switches and Wiring

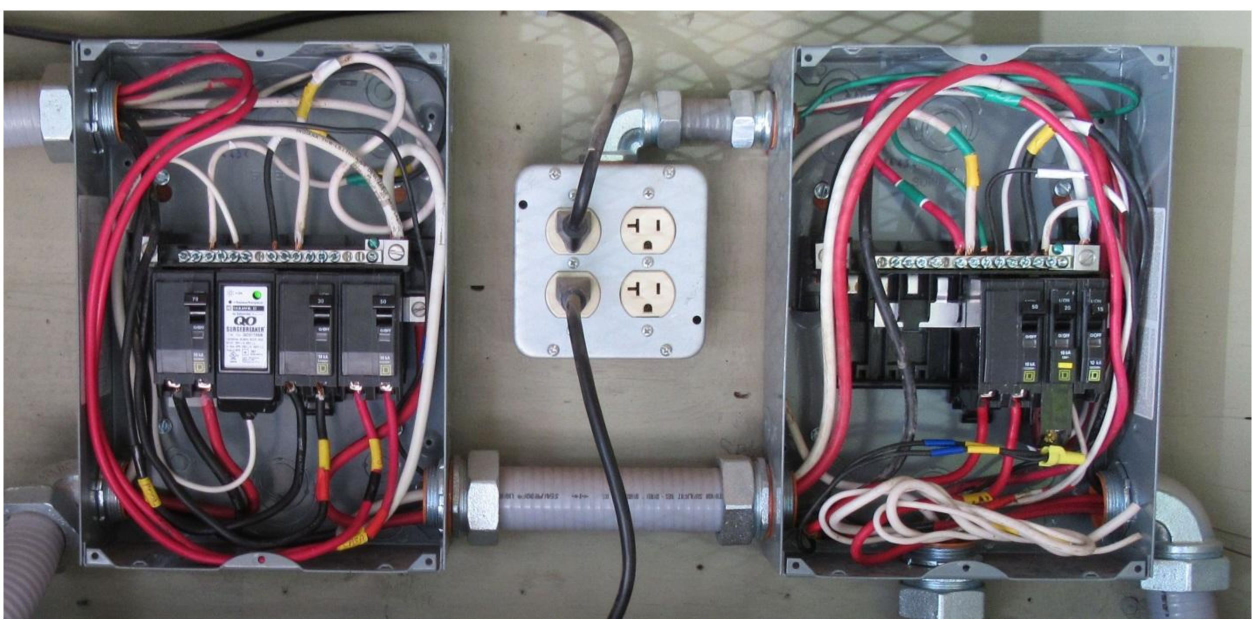


Figure 10-8 New Entry Panel Wiring

Figure 10-9 New Entry Panels with Covers

The red wires shown on the left side are the meter input wiring (CFE). These were removed when the new meters were installed about one year later. The upper power cord is for the electric fence and the lower cord is for the carport gate opener.

The original circuit breaker panels for the house and kitchen were located on adjacent walls inside a kitchen cabinet that was about 14 inches wide and 24 inches deep. The panels were virtually inaccessible. The first step was to have the kitchen cabinet modified. The panels are still inside the cabinet, but it is now 28 inches wide so it is possible to stand inside the cabinet to work on these panels.

The wall was then opened (via the usual chisel and hammer technique) to install the new subpanels directly above the old one. Figure 10-10 shows the QOX208 (House Subpanel) and Figure 10-11 shows the QOX204 (Appliance Subpanel). At the time these pictures were taken, none of the wiring had been changed, and the new subpanels were not yet plastered in so the tubing is visible. The white box at the bottom of Figure 10-10 is the security system. A new handy box was added just to the right of the new House Subpanel for a duplex outlet for the security system transformer that had been located inside the security system box and wired to unfused connections in the old subpanel using bell wire.

Figure 10-10 New House Subpanel Installed above Original House Subpanel

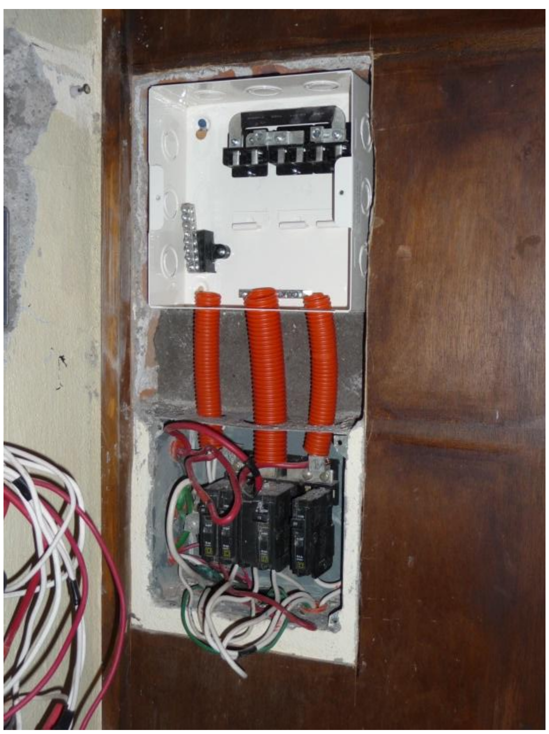


Figure 10-11 New Appliance Subpanel Installed above Original Kitchen Subpanel

After plastering and rewiring, the new house subpanel is shown in Figure 10-12. The transformer for the security system is shown plugged into the new duplex outlet.   Figure 10-13 shows the new appliance subpanel with wiring exposed.

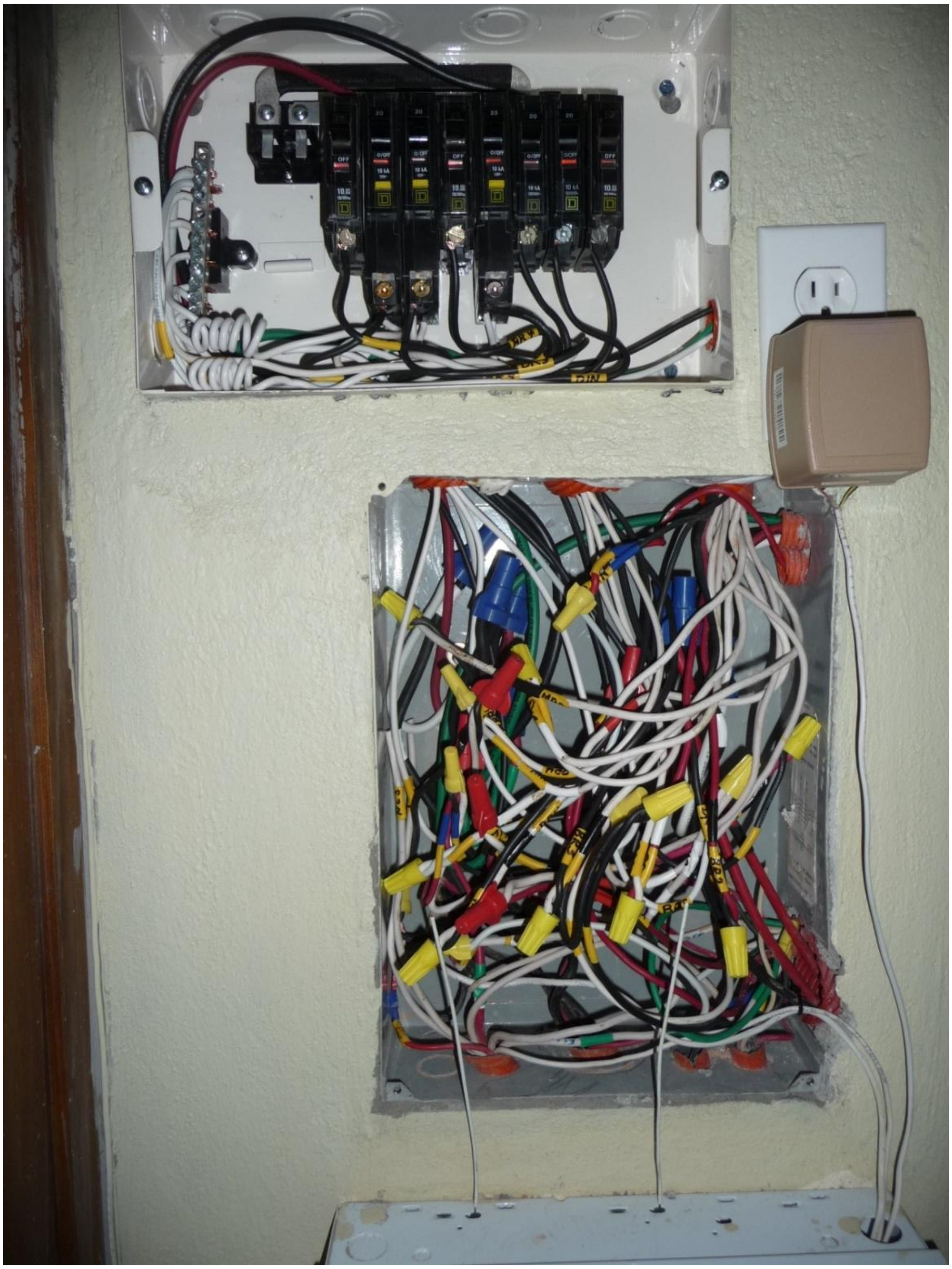


Figure 10-12 New House Subpanel after Rewiring

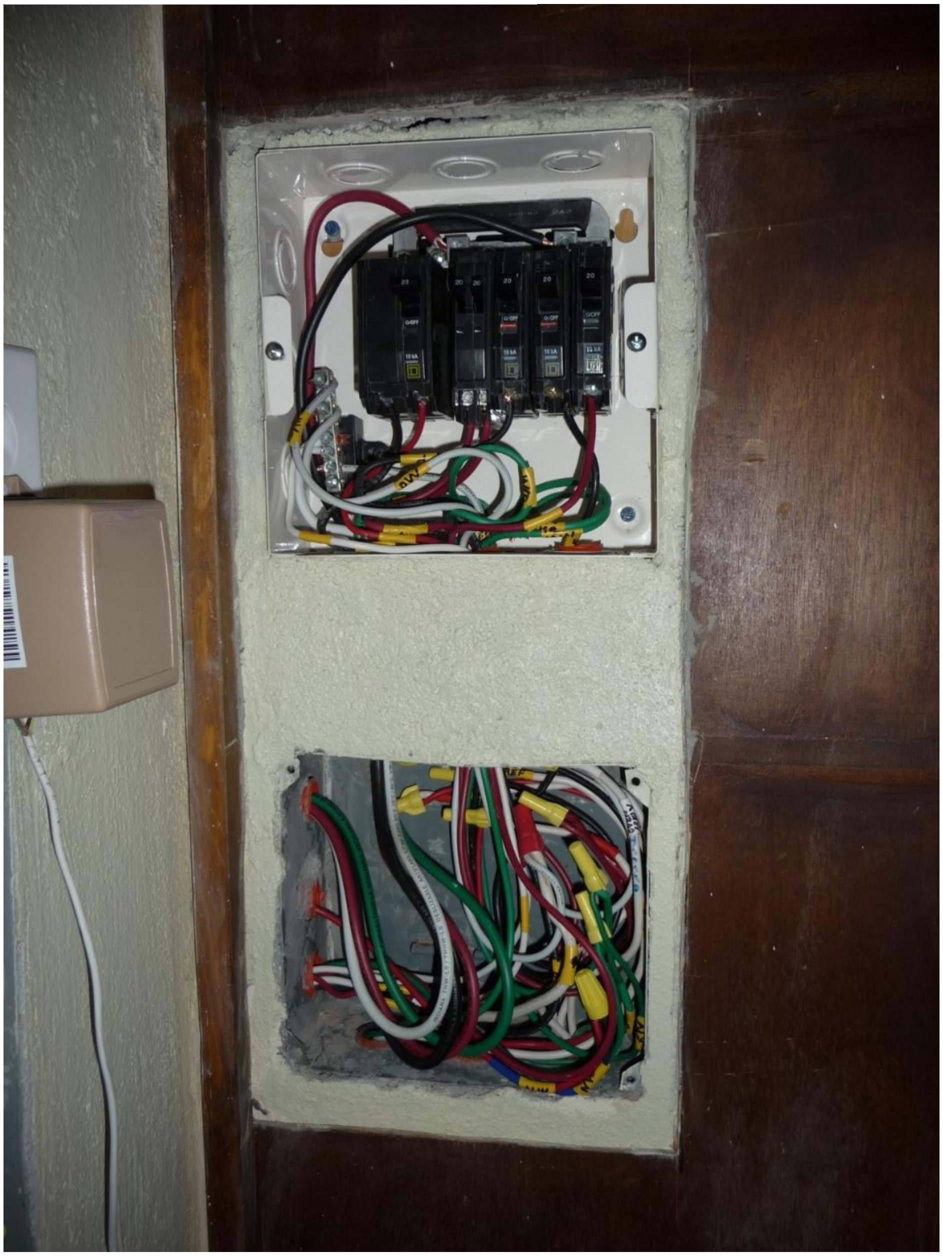


Figure 10-13 New Appliance Subpanel after Wiring

New blank covers were made for the old circuit breaker boxes. Figure 10-14 shows the final result.

Figure 10-14 New House and Appliance Subpanels with Junction Boxes Covered Below

The final change made to the Erres entry wiring was to change the meter. Originally, it was a large 3-phase meter mounted in a box with loose contacts. The meter was actually held in place by the front cover of the box and not the contacts so it had the tendency to fall out of its socket. Two new single phase boxes were installed, and new meters ordered from CFE. The wiring between the meter boxes and CFE was replaced with AWG#6 cables running through a new waterproof conduit. This wiring was originally AWG#8. Figure 10-15 shows the original meter and the new two meter installation.

At the same time, a new 1 meter ground rod was installed below the meter and connected with a green AWG#6 cable. CFE now requires a ground rod to be installed in this manner. Figure 10-16 shows the top of the rod with the earth ground cable connected.

Figure 10-15 Original Erres Meter (Left) and New Meters (Right)

Figure 10-16 Earth Ground for Meters

11 Rewiring Branch Circuits at Casa Erres

11.1 Branch Circuit Breaker Assignments

The original subpanels for the house were both located in a kitchen closet and connected together as discussed in Section 10. The larger house subpanel contained a total of 10 circuit breakers and the smaller kitchen panel contained another 5 breakers assigned as follows.

Table 11-1 Original House Subpanel Branch Circuits

Circuit Breaker #	Size of Breaker	Branch Circuit(s)
1	30 A	Laundry light Lower hall light Bedroom 2 Living room Powder room Carport lights
2	20 A	Water purifier & pump
3	30 A	Kitchen ceiling light
4	20 A	Dining room Sitting room Lower patio
5	20 A	Loft Bedroom 4
6	15 A	Bedroom 3 Stairway light Upper hall light
7	20 A	Master bedroom Upper patio
8	30 A	Basement Lower patio W side outlet SW sitting room outlet Living room N wall outlets
9	15 A	Washer and dryer
10	15 A	Not connected

Table 11-2 Original Kitchen Subpanel Branch Circuits

Circuit Breaker	Size of Breaker	Branch Circuit(s)
1	30 A	Kitchen outlets
2	30 A	Dishwasher & disposal
3 & 4	15 A dual	Oven
5	20 A	Refrigerator and microwave

As discussed in Section 10, I decided to put all the appliance circuits into the new smaller panel and everything else in the larger new panel. Where it was possible to isolate the neutral for a branch circuit, and where this circuit included a bathroom, a GFCI circuit breaker was used. The size of all breakers was changed to protect the smallest wire gauge used in that branch circuit. The new branch circuit assignments are listed below.

Table 11-3 New House Subpanel Branch Circuits

Circuit Breaker #	Size of Breaker	Branch Circuit(s)
1	20 A	Master bedroom Upper patio
2	20 A GFCI	Bedroom 2 Lower hall light
3	20 A GFCI	Bedroom 3 Stairway light Upper hall light
4	20 A	Bedroom 4 Loft
5	20 A GFCI	Basement SW sitting room outlet Lower patio W side outlet
6	20 A	Living room Powder room Carport lights
7	20 A	Dining room Sitting room Lower patio Kitchen ceiling light
8	20 A	Security system outlet

Table 11-4 New Appliance Subpanel Branch Circuits

Circuit Breaker #	Size of Breaker	Branch Circuit(s)
0	20 A Dual	Oven
1A	20 A Tandem	Kitchen outlets
1B	20 A Tandem	Dishwasher & disposal
2	20 A	Water purifier & pump
3	20 A	Refrigerator & microwave
4	20 A	Washer & dryer Laundry light

Tracing, diagramming, analyzing and modifying each branch circuit was an adventure. However, only three will be shown here to illustrate the types of changes that can be made.

11.2 Basement Branch Circuit

The original circuit was wired as shown in Figure 11-1. Because of the number and location of the outlets, this circuit was a natural for using a GFCI circuit breaker. So the line side was marked BLK-BAS and the neutral WHT-BAS to check that they were in fact isolated from other branch circuits.

Note that there was a buzzer located inside the original house breaker panel that was wired through a #22 gauge wire to a circuit in the basement. At one time a transformer and a second buzzer were located in the basement which had been used as a servant's quarters. This was used as part of the front door bell which no longer worked, so removing the buzzer and abandoning the #22 wiring was an obvious change to make.

The wiring for the basement passed through an outlet box on the NE side of the living room where it was used to power two living room outlets. The rest of the living room lights and outlets were part of an entirely different circuit. I was able to disconnect these outlets and reconnect them to the living room circuit by using one of the NC wires located in the conduit marked 2R2B1W1Y. When redrawing the new circuit diagram, these two outlets and their wiring disappear, because they were then part of the new living room diagram.

There were two other outlets which really did not belong to the basement circuit, but they could not be easily rewired and did no harm being connected to it. These were the lower patio W outlet and the SW sitting room outlet.

There was an unused junction box on the W side of the patio connected to the line and neutral conductors. It had been used for a messy switching arrangement of the lower patio lights which was cleaned up as part of the dining room and lower patio wiring upgrade. It served no purpose and could be disconnected and eliminated.

The basement kitchen area had a bank of 4 switches used for the entry light, the bedroom light, the bathroom light and the kitchen light itself. There was a good reason for a 3-way switch at the entry as there is a small stairway there, but the bedroom light could be better controlled by a single switch mounted on the wall next to the bedroom door. So the switch marked SW Bed1 was eliminated and BLU-B1 disconnected.

Not shown on the schematic is the poor physical placement and wiring of the bedroom switch, overhead light, the kitchen wall light, and the storeroom lights and switches. Much of this had been wired using zip cord. These were all rewired using surface mounted wire mold channels and boxes for a much safer, neater and brighter lighting system. The main reason for using wire mold rather than channeling out plaster for flexible conduit was that it was much easier to install – especially in this case since some of the ceilings and walls in the basement area were concrete and not plaster. In a basement area, wire mold does not look out of place as it would inside the house proper. I used the ¾ inch wide raceway which easily accommodates 3 #12 conductors. I anchored it every two feet or so using #6 plastic anchors and screws.

Figure 11-2 shows the updated branch circuit wiring and Figure 11-3 shows some of the new raceway wiring.

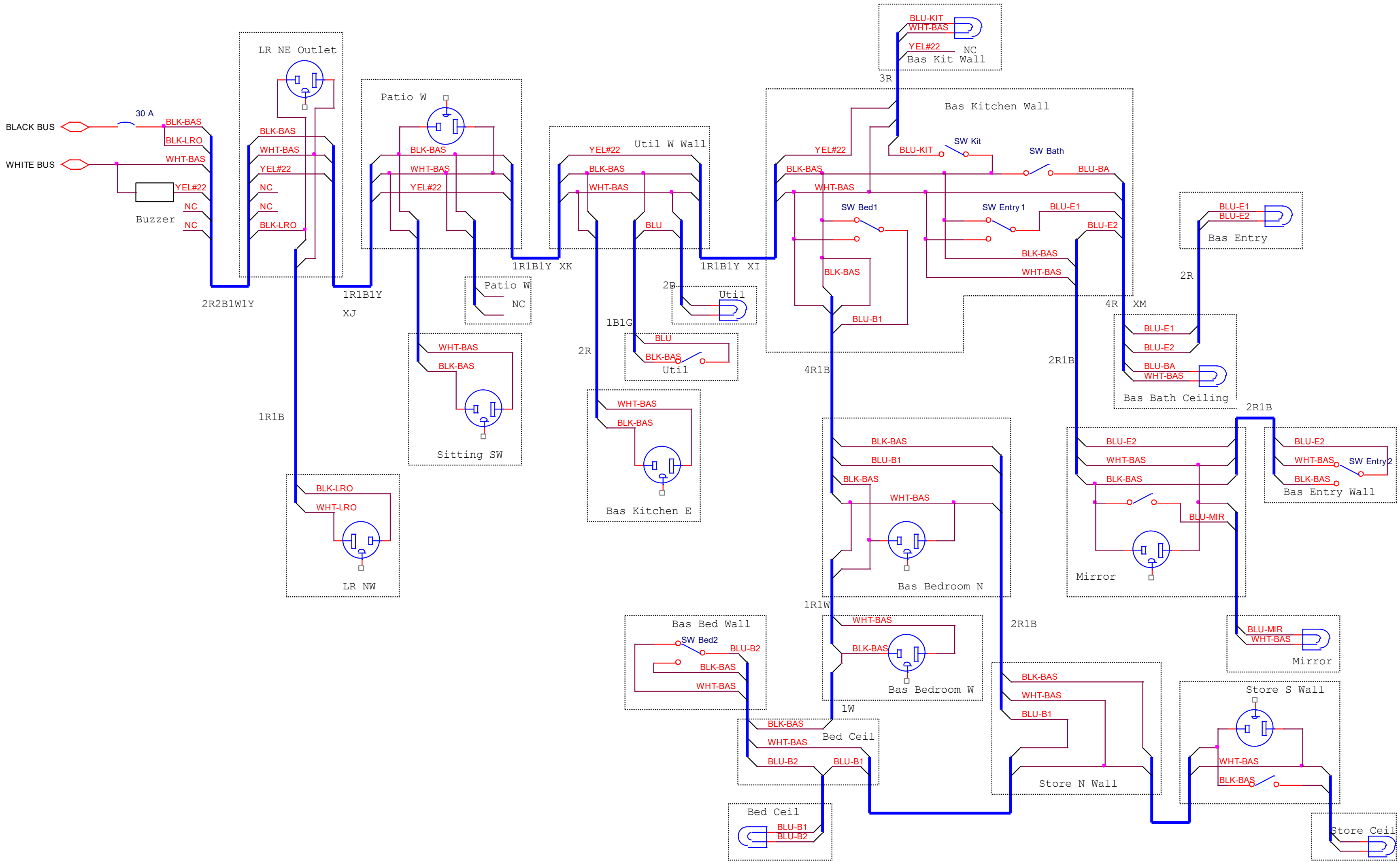


Figure 11-1 Original Basement Branch Circuit

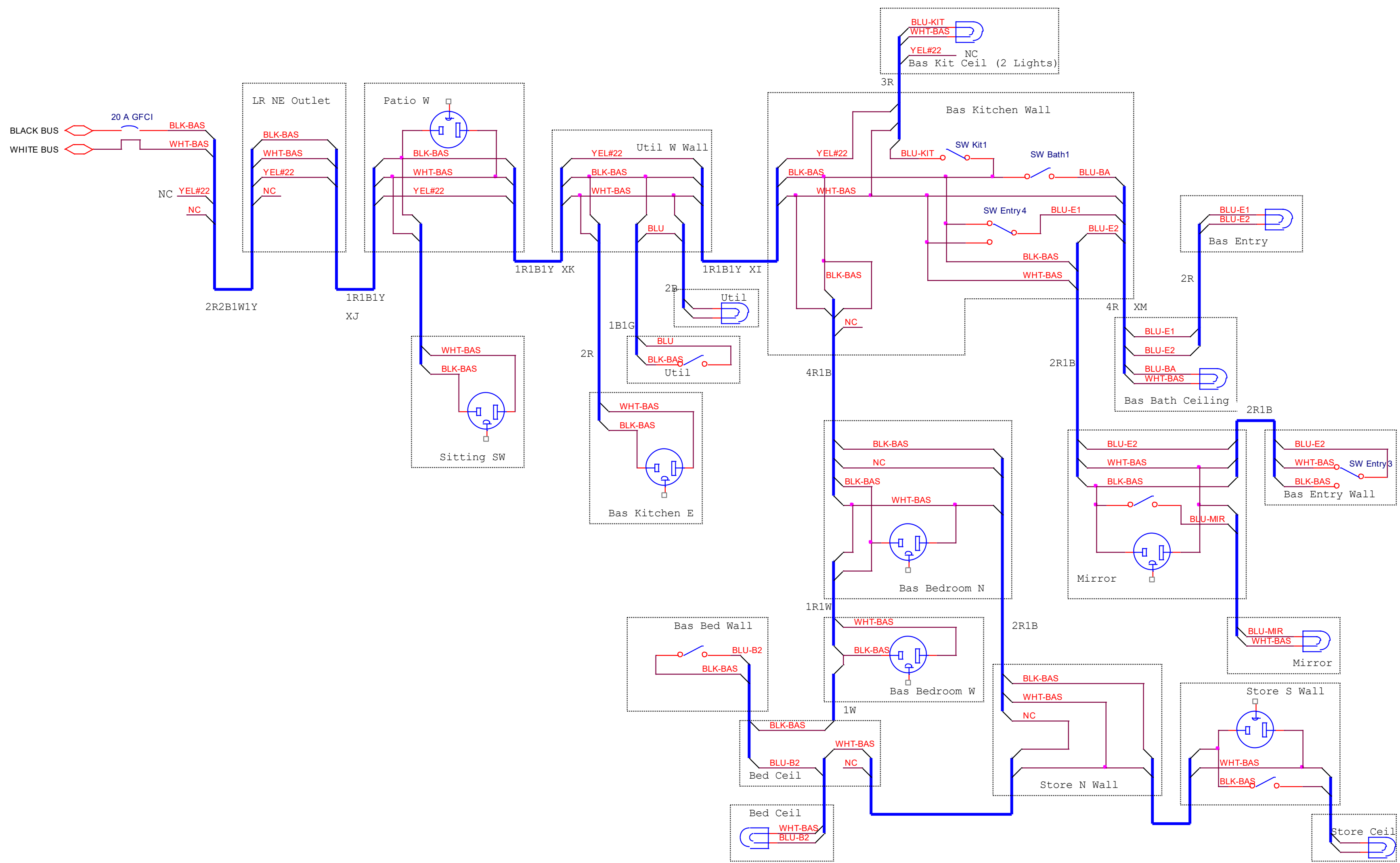


Figure 11-2 Updated Basement Branch Circuit

Figure 11-3 Wire mold raceway and boxes in basement

11.3 Bedroom 3 Branch Circuit

Figure 11-4 shows the original bedroom 3 branch wiring along with the interconnected wiring for the master bedroom and bedroom 4. The upstairs branch circuits were very intertwined because all the wiring for them passed through a single conduit marked 6W from a junction box in the kitchen to an outlet box in the master bathroom. From there, circuits branched off to a junction box in the loft for bedroom 3 and part of bedroom 4, and to another outlet box in the master bathroom for the master bedroom and the rest of bedroom 4. I wanted to separate the neutrals for all three upper bedroom circuits, but it turned out to be easily done only for the bedroom 3 branch.

Note that WHTBR3 and WHTMBR were connected inside the master bath SE outlet box. Also, WHTMBR connected to the conduit 1R3W which was unused. These connections were removed.

In the loft NE junction box, WHTBR3 and WHTBR4 were connected. This connection was removed also. The neutral that ran through conduit 1B1W1G to the hall switch box became WHTBR3.

Both BLKBR3 and REDBR4 were used in the switch box at the top of the stairs. REDBR4 was used for the 3-way cupola switch and continued through conduit 2R2G to outlets and lights that were part of the BR4 schematic. BLKBR3 was used for the 3-way switches for the hall and stairs. But only one neutral was available. I saw that I could gain a second neutral and simplify the wiring by eliminating the 3-way switches for the hall and cupola lights at the top of the stairs location. In practice, we never used these 3-way switches anyway; the top of the stairs was simply a useless location for them.

This this freed up the conductor marked BLU-HallA that ran through conduit 1R1B2W1G between the top of the stairs switch box and the loft NE junction box. I now had two separate conductors – one for WHTBR3 and the other for WHTBR4 in this conduit.

With these changes, the circuit breaker for BR3 can be changed to a GFCI type. The revised schematic is shown in Figure 11-5. The wiring for the master bedroom and bedroom 4 is no longer shown because it is no longer connected to any of the bedroom 3 wiring.

The alternative to using a GFCI breaker would be to use a GFCI outlet in the bathroom for bedroom 3. This would have been difficult however because the outlet box was also used for 2 switches as well as the outlet.

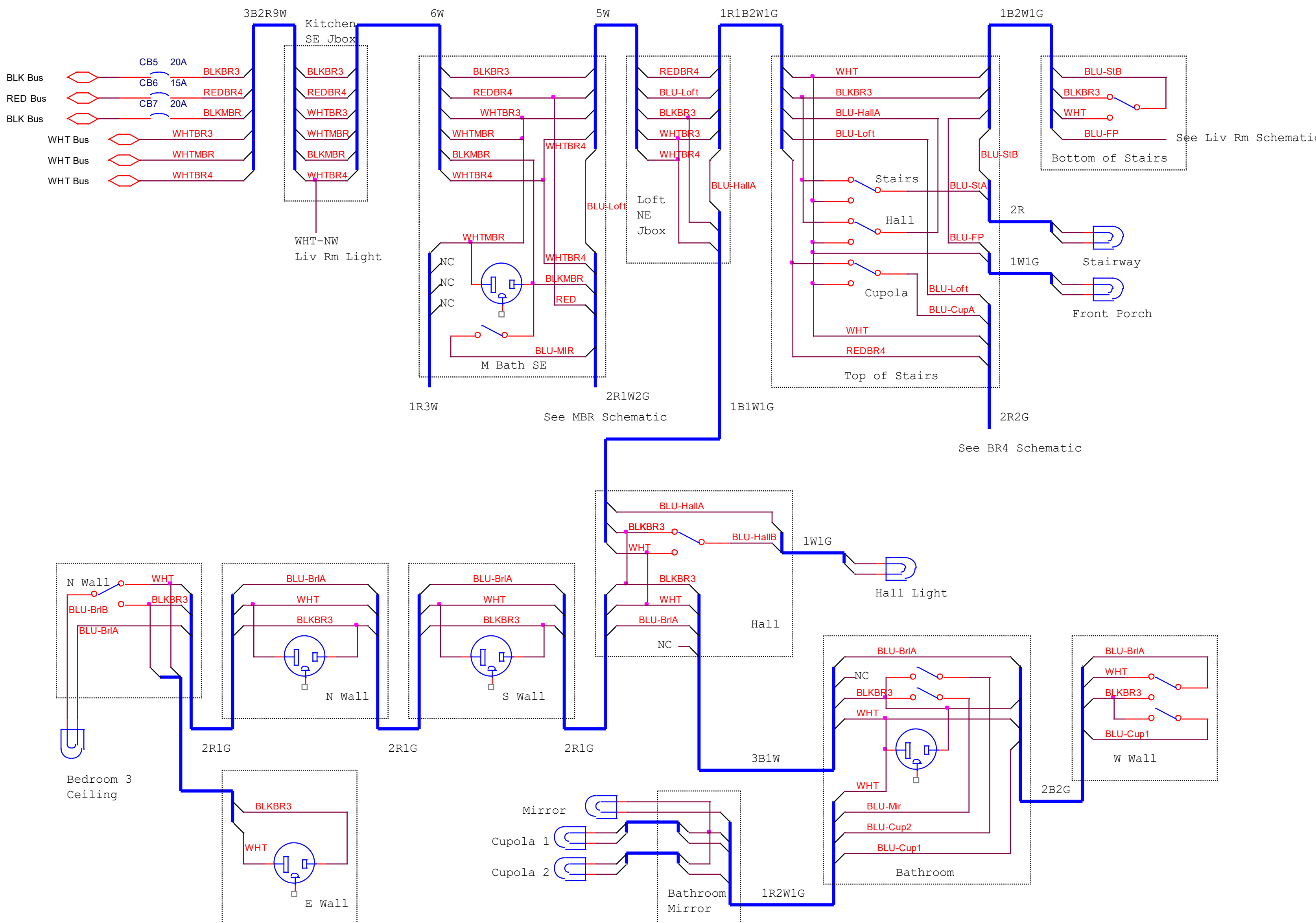


Figure 11-4 Original Bedroom 3 Branch Circuit

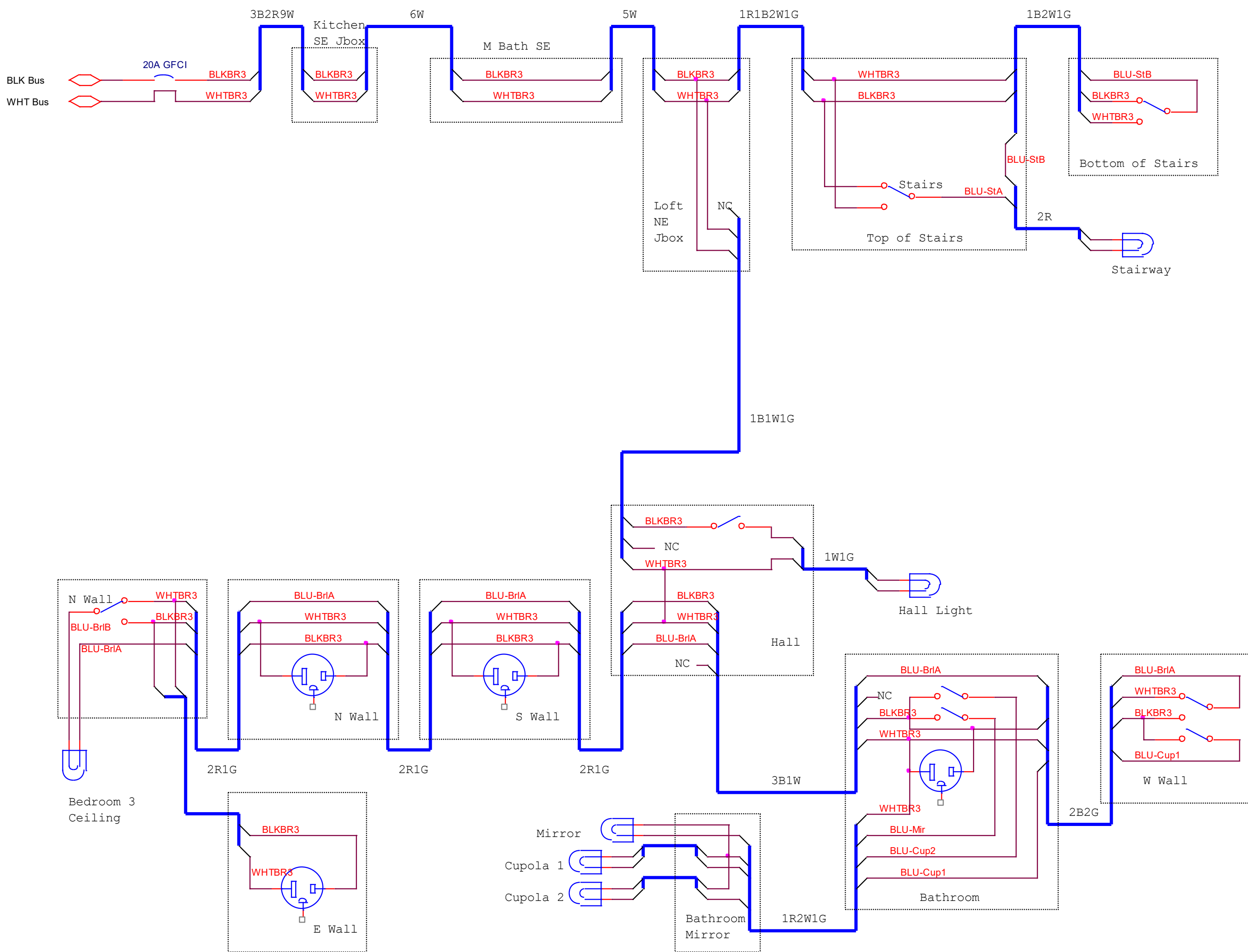


Figure 11-5 Updated Bedroom 3 Branch Circuit

11.4 Living Room Branch Circuit

This is an example of a branch circuit that could not be entirely isolated from the others. Figure 11-6 shows the original wiring. Note that the powder room lights and outlets were connected between BLK-LR and WHT-BR3. That could be fixed by disconnecting the NC wire in the front entry switch box and reassigning it as a WHT-LR conductor in conduit XD.

The living room NE and NW outlets which were disconnected from the Basement branch circuit (Section 11.2) could be connected to the living room light and outlet branch inside the circuit breaker junction box.

With these changes made, I ended up with the diagram in Figure 11-7. However, there were still 3 living room loads that did not connect to the living room neutral. The NW sconce light connected to WHT-BR4, the front porch light connected to WHT-BR4 and the carport lights connected to the neutral bus in the entry panel. There was really nothing wrong with these connections, but the current in the lines BLK-LR and WHT-LR was not equal, so a GFCI breaker could not be used.

The only place where GFCI protection was really required in this branch was the powder room outlet. This was easily be changed to the GFCI type shown.

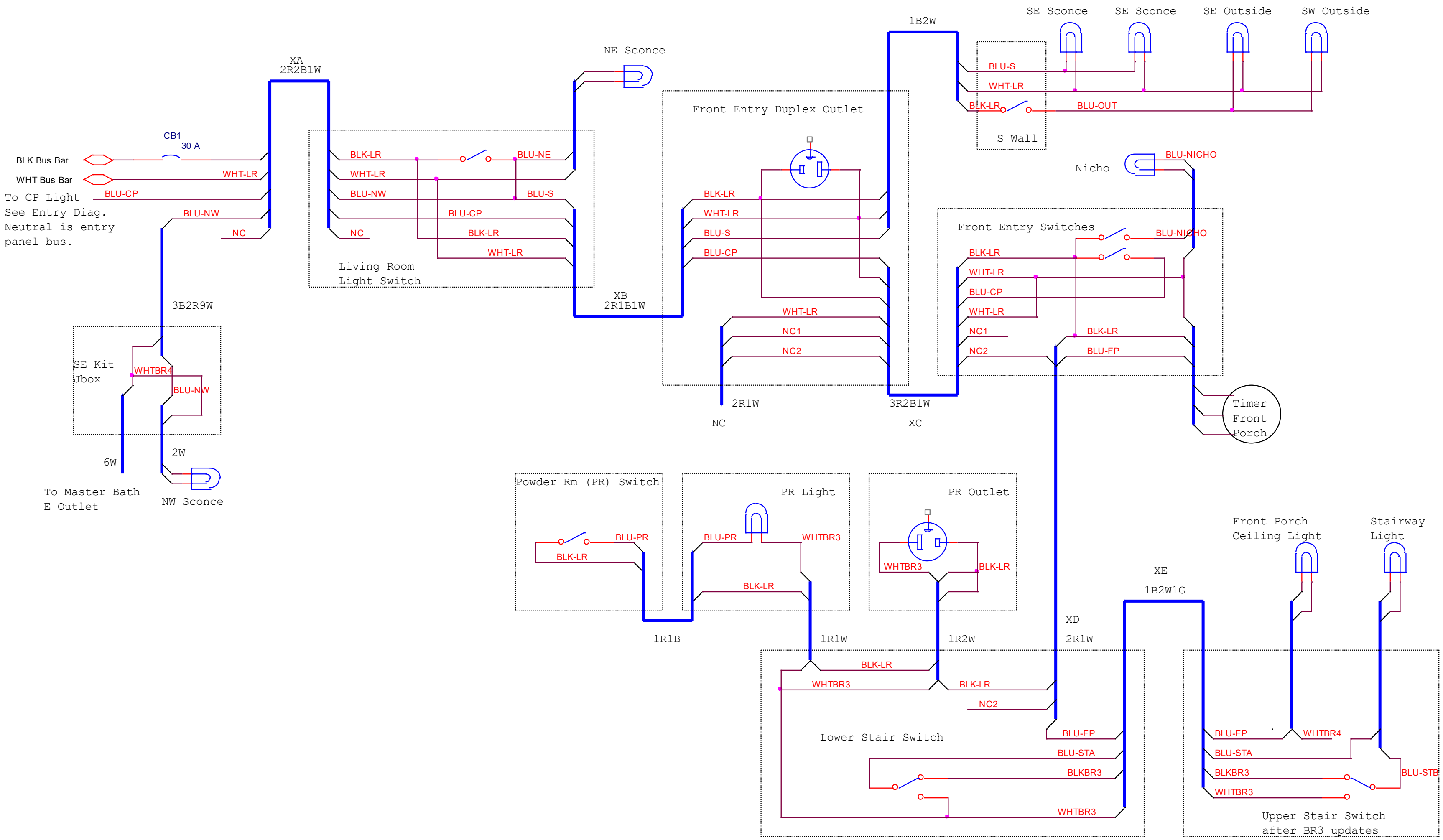


Figure 11-6 Original Living Room Branch Circuit

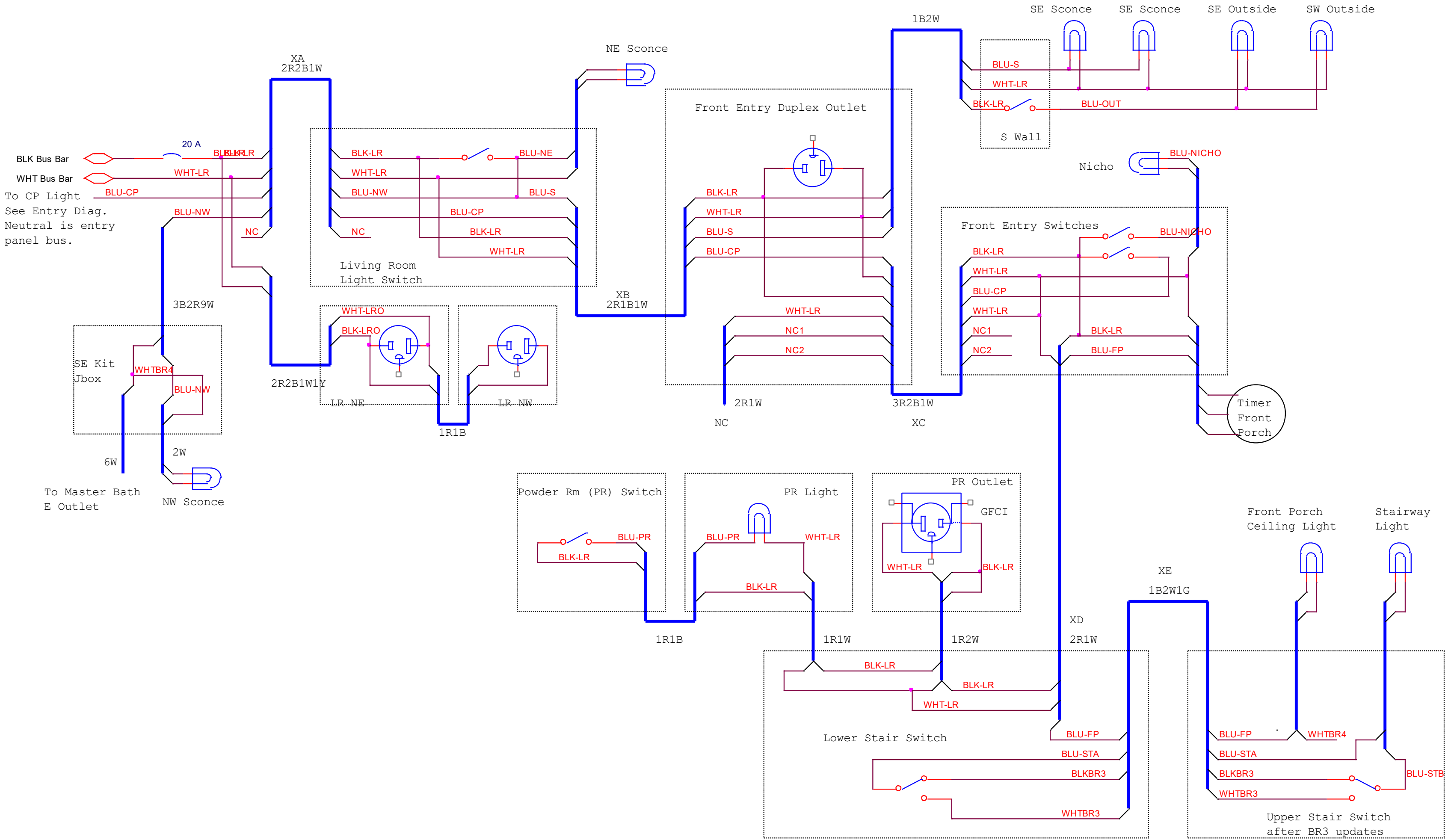


Figure 11-7 Updated Living Room Branch Circuit

12 Casa Colibrí

12.1 Introduction

Casa Colibrí was built around 2000. It is about 3000 square feet in size and built on two levels. The house had two single phase electric meters on the upper street level and two subpanels in the lower level. It also had a series of small breaker boxes mounted together in a utility room off the garage. There was no main service panel although there was a large knife switch with fuses near one of the downstairs panels. There are two fountains and a water pressurization and purification system. Switches and outlets were all Decora style, but they were discolored and many were cracked. A quick test using a plug in type circuit tester indicated, falsely as it turned out, that the house was properly wired and grounded.

The house was unoccupied during a fairly extensive remodeling period of about 9 months during which the floor tile was replaced. This allowed us to have some new conduits run under the floor and in the walls to provide additional electrical outlets, Ethernet hard wiring between three locations, and to move some light switches to better locations. Most of this work was done by the contractor's electrician under my direction. I also began making changes to the branch circuits, and we installed a new main breaker panel in the outside wall near the electric meters. While tracing the branch circuits, a number of hidden junction panels were discovered inside the walls. These were modified so as to be accessible.

After we moved in, the branch circuit changes were completed and the Ethernet cabling installed. The existing breaker panels inside the house were replaced with new QOX types, missing earth ground wires were run, and the connection to CFE from the meters was redone. The final step was to upgrade the lighting to LED bulbs and fixtures.

All this took place over an 18 month period, but the actual amount of labor spent on the electrical system was probably about 3 man-months.

12.2 Branch Circuits

All of the branch circuits were wired with black, white and green conductors. Most of these were AWG12, but a few were AWG10. However the 10 gauge wires connected to 12 gauge wires, so all the branch circuits were treated at 20 amp circuits.

The original wiring is as shown in Figure 12-1. This is a simplified drawing of a typical branch circuit with one outlet and one switched light. Note that the standard colors were reversed for the line and neutral, the light switch was on the neutral line, the earth ground was not connected to the switch box, and the earth ground and neutral were not connected together at the subpanel or meter. Actually, the neutral and earth ground did have a high resistance connection that was sufficient to "fool" the simple outlet tester into indicating a correct connection, but in fact it did not provide the protection against a line to ground fault which is the whole purpose of having a ground conductor. (See Section 2.2 and the last entry in Table 5-1 for a discussion of this problem).

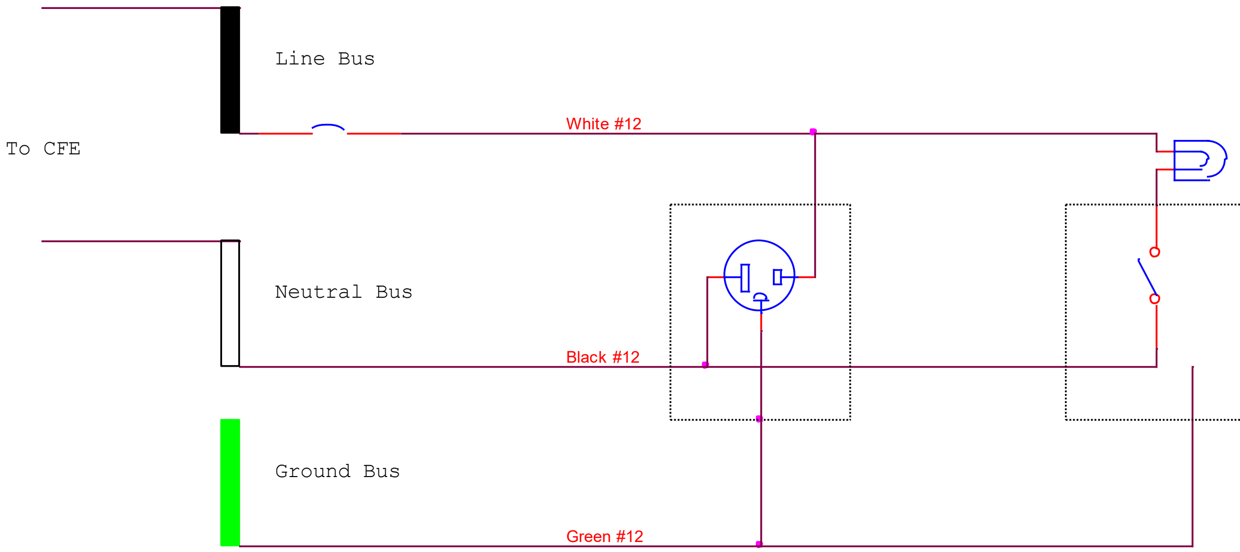


Figure 12-1 Simplified Original Branch Circuit at Colibrí

Fixing the branch circuits was straight forward and is shown in Figure 12-2. Since the house had already been wired using Decora style outlets and switches which I prefer anyway, no changes were required to the boxes themselves or the device rings. I replaced all of the old devices with new ones (white) that used "back wired" connections (Leviton 16252-W and 5621-2W). Since the old ones were ivory colored, this made it easy to keep track of progress. Replacing the old devices was definitely worth doing since these were wired with screw wrap or rear crimp insert connections, both of which are unreliable when using stranded wire. The ground wire connection on the Leviton outlets and switches is the standard green 10-32 screw. To make this connection to the stranded green AWG12 house wire, I used green grounding pigtails with spade terminals (Garvin PTST12GN) and a Wirenut. This is a lot easier than trying to wrap stranded wire around the screw. The Leviton devices provide a ground connection to the box via their lower mounting screws.

There are 4 back wire openings on the 16252 outlets for both line and neutral connections. This let me eliminate most of the twisted wire or Wirenut connections inside the outlet boxes. Once all the connections were made and tested, I wrapped electrical tape around the sides of the outlets and switches to cover the side screws. This is not absolutely necessary but it provides an extra measure of protection especially if someday someone removes the device from the box while it is energized.

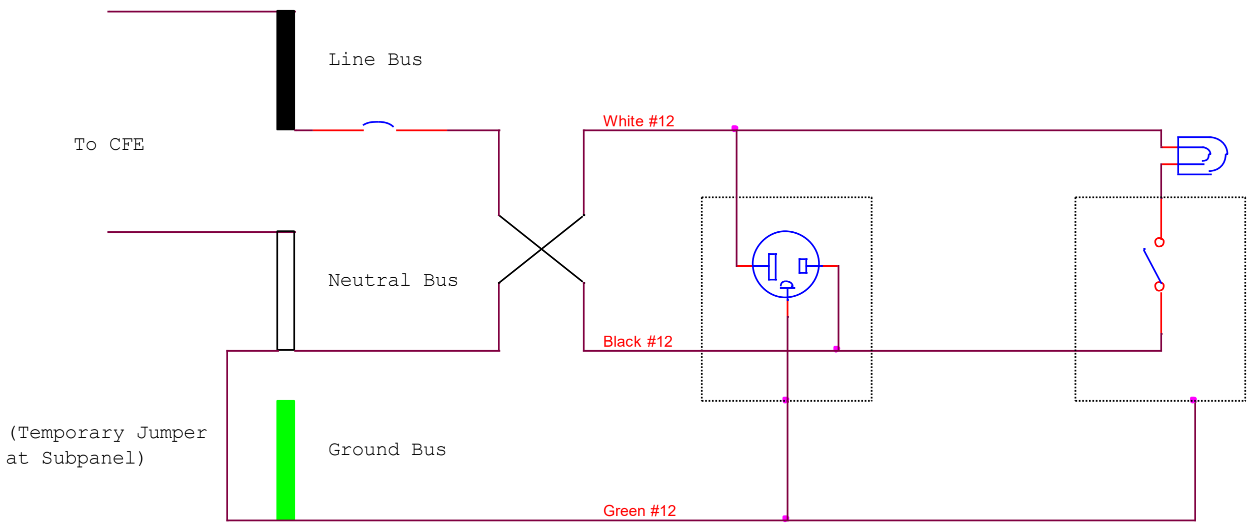


Figure 12-2 Simplified Corrected Branch Circuit at Colibrí

In Figure 12-2, note the temporary jumper that was placed at the subpanel between the neutral and earth ground. This allows the integrity of the ground connection to be checked at the outlets by measuring the resistance between neutral and ground. It should be less than 1 ohm. Once the new main panel was installed and the wiring corrected between the main panel, subpanels and meters, the temporary jumper at the subpanels was removed. When measuring the ground to neutral resistance, be sure to disable the circuit breaker. Otherwise current flowing through the neutral may affect the reading on the ohmmeter.

One other tip. Buy a selection of Phillips head sheet metal screws (#6 or 8) in lengths from 3/4 inch to 2 inches and do not waste time reusing the sheet metal screws that were used to mount the original devices to the mounting rings. Most of these were probably standard flat tip screwdriver types and probably the wrong length. Use care to select a screw length that reaches the mounting ring but does not extend too far into the box where it might puncture a flexible conduit and short circuit one of the conductors. Using Phillips head screws and an electric screwdriver will save a lot of time and frustration.

I replaced all the GFCI outlets with new ones (Leviton N7599-KW) that also have “back wired” connections and a small indicator LED. I also replaced the standard outlets with GFCI types in the garage, patios and kitchen.

There were a total of four 3-way light circuits in Colibrí. One of these was actually wired per US standard, one was wired per MX#1 and two per MX#2 (see Sections 2.9 and 4.7). It was possible to rewire all of these to the standard US configuration without having to pull any new wires. However, one of these required a lot of work to locate a hidden junction box. Figure 12-3 shows the hidden box after unearthing it in the wall behind a large utility cabinet in the garage. Note the dashed lines on the wall that were made by using the signal tracer (Section 5) to mark the conductors leading to this box. Since power was available in this box, it turned out to be a convenient location to add another GFCI outlet for the garage. In rewiring 3-way switch circuits, I found it easiest to simply disconnect all the existing wiring from the switches, then use the voltage probe to find the supply line. Using a 30 ft. long extension made from a length of #14 wire and two alligator clips, I was then able to identify the ends of each of the remaining conductors. It was then a simple matter of marking them using colored tape: the two runners (red), load (blue), line (black) and neutrals (white). I used Leviton 5624-2W DPDT switches for the new 3-way circuits since these also have back wired connections.

Figure 12-3 Hidden Junction Box Used in Colibrí Garage 3-way Light Circuit

Rewiring the kitchen turned out to be a challenging problem because there were two branch circuits. One of these was used for the igniter on the gas stove and the other was used for everything else (lights, outlets and all the appliances). These were all wired to a junction box that was located behind one of the base cabinets. Worse yet, it was behind the vertical support for the cabinet, so it was not even possible to access it by cutting a hole in the back of the cabinet. Since it was on an outside wall, it was possible to gain access by cutting through the back side, replacing the box with one facing outward, and adding an extension box to bring it out to the exterior wall. This might have been done entirely from the outside, but fortunately we decided about the same time to replace the kitchen countertops. This meant the offending cabinet could be moved aside so that both sides of the original box could be accessed for this work. Figure 12-4 shows the original junction box behind the cabinet and Figure 12-5 the new extended box from the outside wall. The box was entirely rewired to split the loads in the kitchen evenly between the two 20 amp circuits.

Figure 12-4 Kitchen Junction Box behind Cabinet

Figure 12-5 Kitchen Junction Box after Rotating and Extending to Outer Wall

Some of the conductors in the above box were too short to allow a reliable wire nut connection to be made, and were extended using the butt splices and crimp tool shown in Figure 5-9. Figure 12-6 shows one of the splices prior to wrapping it with insulating tape.

Figure 12-6 Butt Splice Used to Extend Conductors on Kitchen Junction Box

One of the existing branch circuits powered a fountain in the back yard though a switch mounted on the side of the fountain in a box below the water level. The fountain lost water continuously by draining though this box which caused it to rust out. While replacing the box and sealing the conduit to stop the leak, I added a number of water-proof outdoor boxes connected by a water-proof conduit along the back wall of the garden. The entire circuit which included a Honeywell type timer for the fountain and connections for a new drip watering system timer and low voltage path lights is fed from a GFCI outlet near the fountain. See Figure 12-7.

Figure 12-7 Waterproof Conduit and Boxes for Timer and Outlets at Colibrí

12.3 Entry and Subpanels

Figure 12-8 is a simplified diagram of the original wiring between the meters and subpanels. It is simplified in that the wiring for a branch circuit which shared some of the same conduits has been omitted. Also, the colors were not as shown. The ones in this diagram are the correct colors which I added after identifying the purpose of the various conductors. Finally, the ground buses shown in the subpanels as green were actually just wrapped and taped ground conductors; the original subpanels did not have separate screw type groun

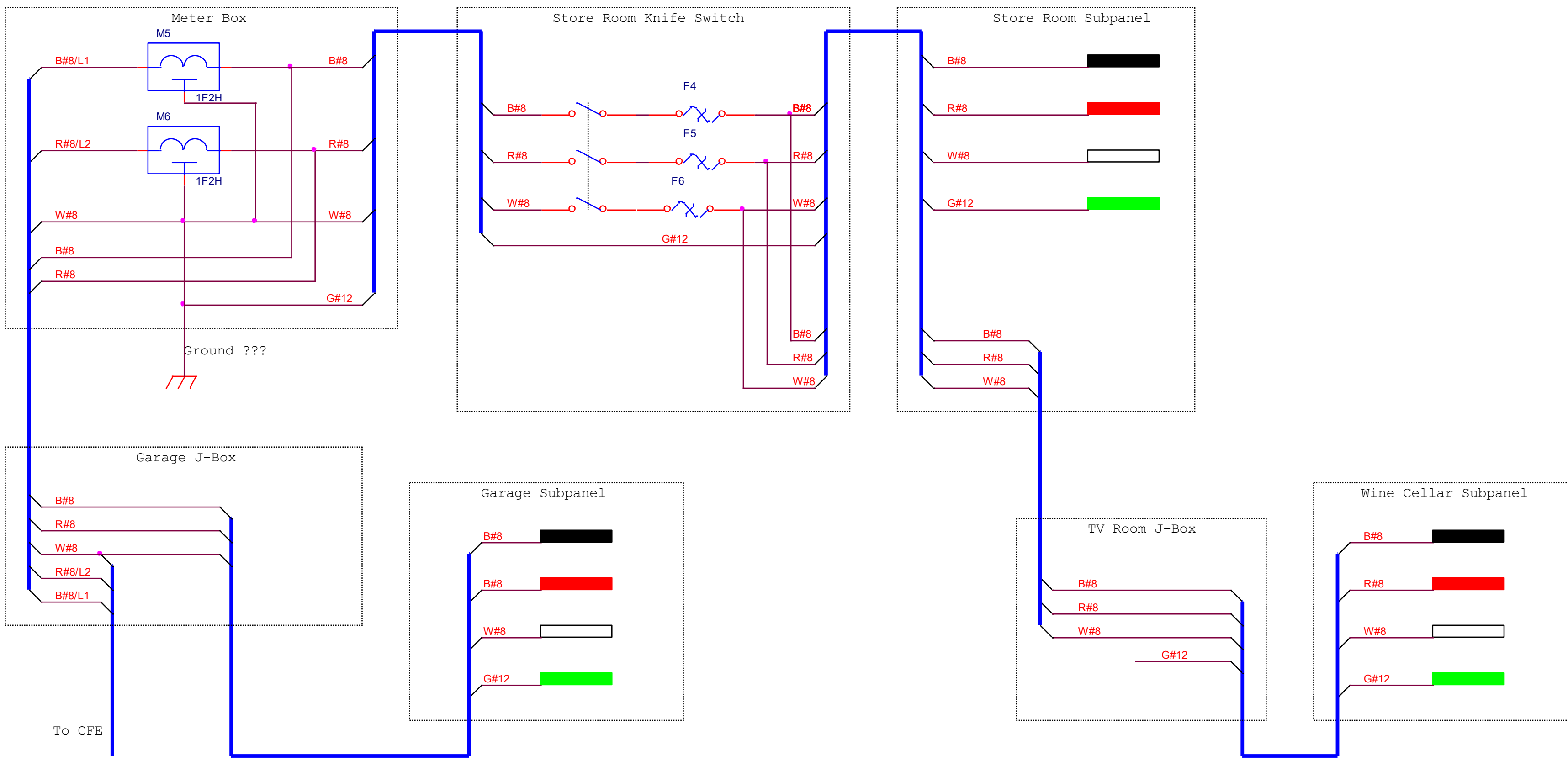


Figure 12-8 Original Wiring of Meters and Panels at Casa Colibrí

Note that the power connection from CFE takes a strange path through a junction box in the garage to the meters. This junction box was buried in the wall near the floor and plastered over. The output from the meters splits into two paths. One path returns through the same garage junction box to the utility room subpanel. This panel is actually a series of three interconnected double pole breaker boxes. The other path from the meters enters the house through a large 3-pole knife switch located in the store room on the lower level. Next to the knife switch is a large subpanel with 6 breakers. The feed from the knife switch divides to feed this panel and a third panel located in the wine cellar that contains another 6 breakers. It gets to the wine cellar through another junction box buried in the wall of the TV room which was also plastered over. Figure 12-9 shows the hidden junction boxes. As you can imagine, it took considerable work to locate and uncover these junction boxes and trace out the wiring shown.

Figure 12-9 Hidden Junction Boxes in Garage (Left) and TV Room (Right)

I made a list of the problems with this wiring:

- The CFE input to the meters should not be routed through the house before connecting at the street.
- There is no main disconnect for the whole house. The knife switch only disconnects the power to the storeroom and wine cellar panels. It does not disconnect power to the circuits supplied through the garage panel(s). Wiring to the garage is also not protected by any fuse or circuit breaker.
- The knife switch disconnect the neutral as well as the lines. The neutral is also fused inside the knife switch. If the neutral fuse were to open, large voltages would occur throughout the house.
- The earth ground at the meter box was a wire that disappeared into the stone wall. There did not appear to be ground rod (1 meter minimum) driven into the earth as required by CFE.
- Earth grounds from the subpanels were not connected to the neutral anywhere. I measured the resistance between the neutral and earth ground at several branch circuits and it was between 10K and 100K ohms. This is low enough to indicate a correct connection using the 3-light circuit tester, but that indication is entirely wrong in that the fault current in the event of a short circuit from the line to a grounded exposed metal frame would never be enough to trip a circuit breaker.
- None of the original subpanels had ground bars. They did have neutral bars but these were not isolated.

- All of the wiring to and from the meters was AWG#8. This is acceptable for the feeds to the subpanels but it is too small for the relatively long run to the below ground CFE junction box on the street. That should be AWG#6 minimum.
- The meter sockets did not provide any mounting support to the meters and the contacts were loose, leaving the meters in danger of falling out or at least not making reliable contact.

Other than that, the original wiring worked fine.

The first step in fixing these problems was to mount a new entry panel outside on the wall behind the meters. The panel was a Square D Q08-16L100RBCP which would hold a 70 amp 2 pole breaker connected to the meters and three 50 amp 2 pole breakers that would connect to the three subpanels (storeroom, wine cellar and garage). The routing of the conductors between the meter panel and the storeroom switch and subpanel was traced using the circuit tracer and found to be along the garden wall close to the ground. The entry panel was mounted at a convenient height on this wall and two channels were chiseled into the wall down to where the main conduit was running. We then chiseled out this conduit and mounted a large (6 inch square) junction box that would act as a pull box between the meter and the entry panel and between the store room subpanel and the entry panel. As it turned out, the conduit we needed to expose and cut for the pull box was embedded in concrete, so chiseling this out for the 6x6 box was a lot of work. Still, everything installed fine and new wires were pulled – AWG#6 for the main from the meter and AWG#8 for all the subpanels. When installing the cables for the storeroom panel and the wine cellar panel, the knife switch was simply bypassed. Figure 12-10 shows the work in progress and the final result.

Figure 12-10 Installing New Entry Panel

The subpanels were then replaced individually using QOX204 panels for the garage and wine cellar and QOX206 for the store room. When the latter was installed, the knife switch was removed along with the old subpanel. All QOX panels have separate isolated bus bars for neutral and earth ground so when these were wired, the ground and neutrals were separated. The two are connected at the entry panel.

An AWG#8 green ground wire was run between the TV room junction box and the store room panel where it connected to another #8 green cable connected to the entry panel. At this point, all the wiring inside the house was completed. Figure 12-11 through Figure 12-14 show the old and new subpanels.

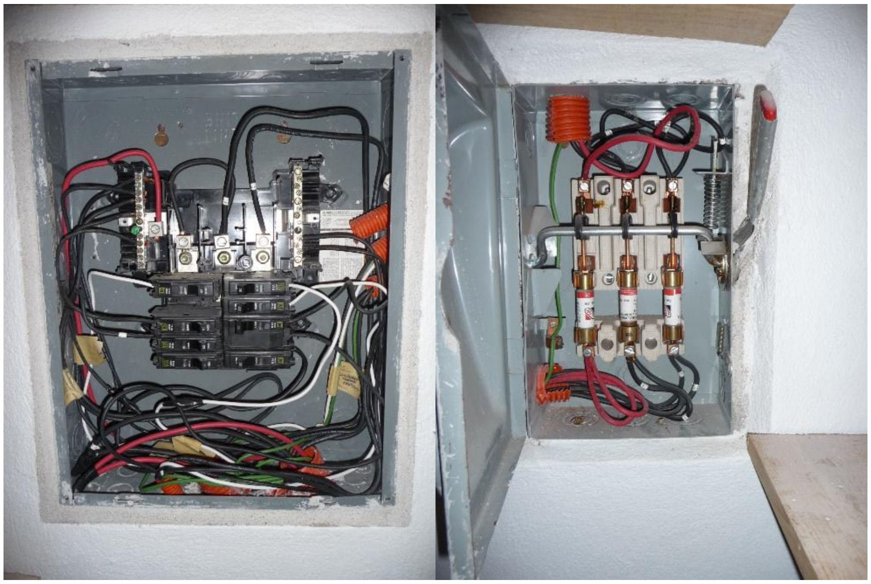


Figure 12-11 Original Store Room Subpanel and Knife Switch

Figure 12-12 QOX206 Subpanel which Replaced Store Room Subpanel and Knife Switch

Figure 12-13 Original and New Garage Subpanels

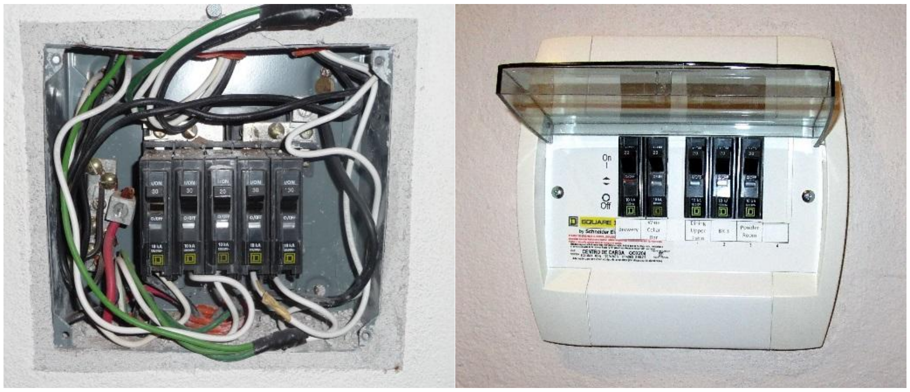


Figure 12-14 Original and New Wine Cellar Subpanels

The final step was to remove the CFE wiring through the garage junction panel and connect it to the closest underground junction box which was on the other side of the street. For this work, we employed a specialist electrician whose main qualification was that he owned a set of insulated gloves and knew how to splice #6 cables. The actual work of running the conduit across the street was done by my usual electrician and my handyman. The conduit used was flexible 2 inch diameter, and we also installed a 1 meter long ground rod through the sidewalk directly under the meter. See Figure 12-15.

Figure 12-15 Installing New Conduit between Meters and CFE Junction Box

Later my electrician returned to replace the old meter sockets with new ones which had metal boxes to support the meters. These look and work much better than the original ones. I offered him a pair of insulated gloves I had bought for him for this work since he would be working with live wiring, but he politely but firmly refused to accept them. I think it might have been a macho thing. The original and final result are shown in Figure 12-16.

Figure 12-16 Before (Left) and After (Right) Meter Installation

A schematic of the new entry wiring and subpanels is shown in Figure 12-17.

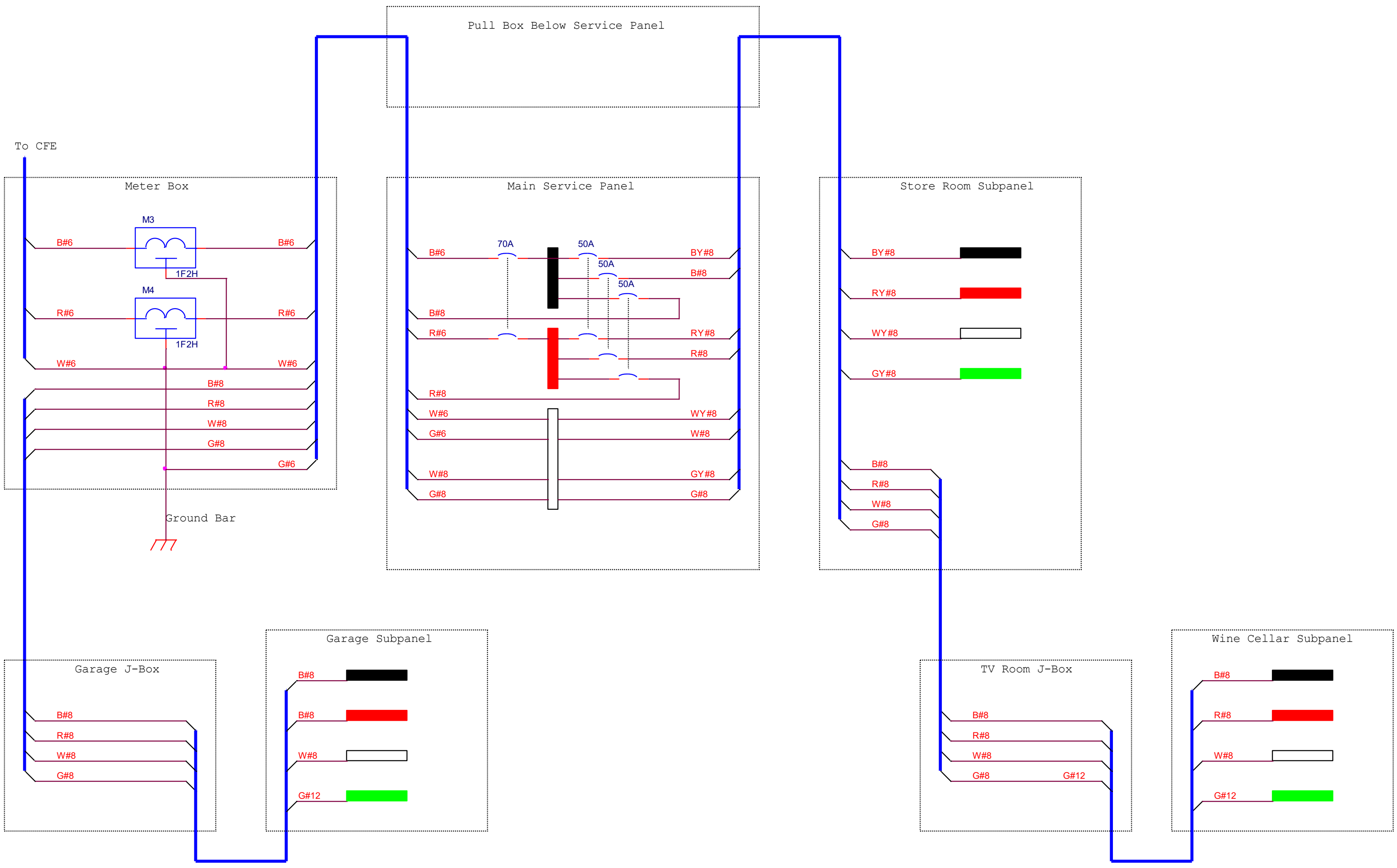


Figure 12-17 New Wiring of Meters and Panels at Colibrí

12.4 Low Voltage Wiring

Since Colibrí is a two story house and we wanted to have two offices – one upstairs and the other downstairs, it was highly desirable to have an Ethernet connection at both locations. Wireless throughout the house was also desirable, but Ethernet provides a higher speed and more reliable connection. With the floor removed during the remodel, a new conduit was installed across the downstairs that provided a path for a new Ethernet cable. The original conduits used for telephone and the intercom were also used to carry the Ethernet cable between floors and to the upstairs office. In Figure 12-18, the Infinitum DSL modem connects to the telephone wiring in the upper office. There are two wireless access points downstairs. The Linksys router is configured in bridge more as a wireless access point (See Section 6.2) and also connects to the smart TV using a wired Ethernet. The Dell router has its wireless capability disabled. It is configured as a simple non-routing Ethernet switch for a desktop PC and a stereo receiver that has an Ethernet port for Internet Radio. Between the Infinitum and Linksys devices, we get good wireless coverage throughout the house.

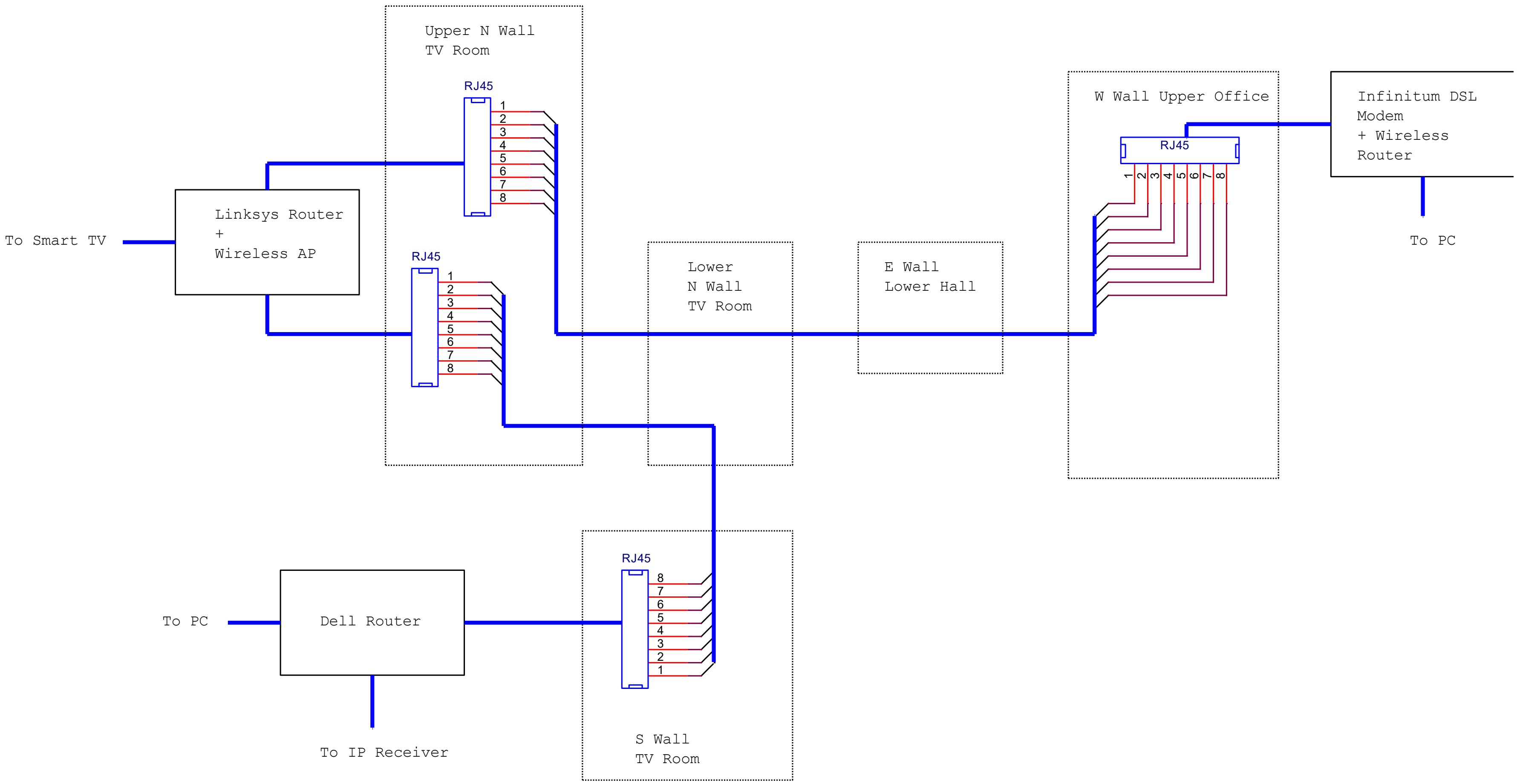


Figure 12-18 Ethernet Connections and Network Routing in Colibrí

For telephone coverage, I purchased two Panasonic KX-TG6591 cordless phone systems. Each of these includes a base station and a remote handset. One of the base stations is not connected to the phone line and is only used as a charger. But this is cheaper than buying extra handsets. The telephone repeater is a Panasonic KX-TGA405B mounted in the stairwell between the two floors. This provides much greater coverage of the lower floor than would be possible from the base station located on the upper floor alone. The phone system wiring is shown in Figure 12-19.

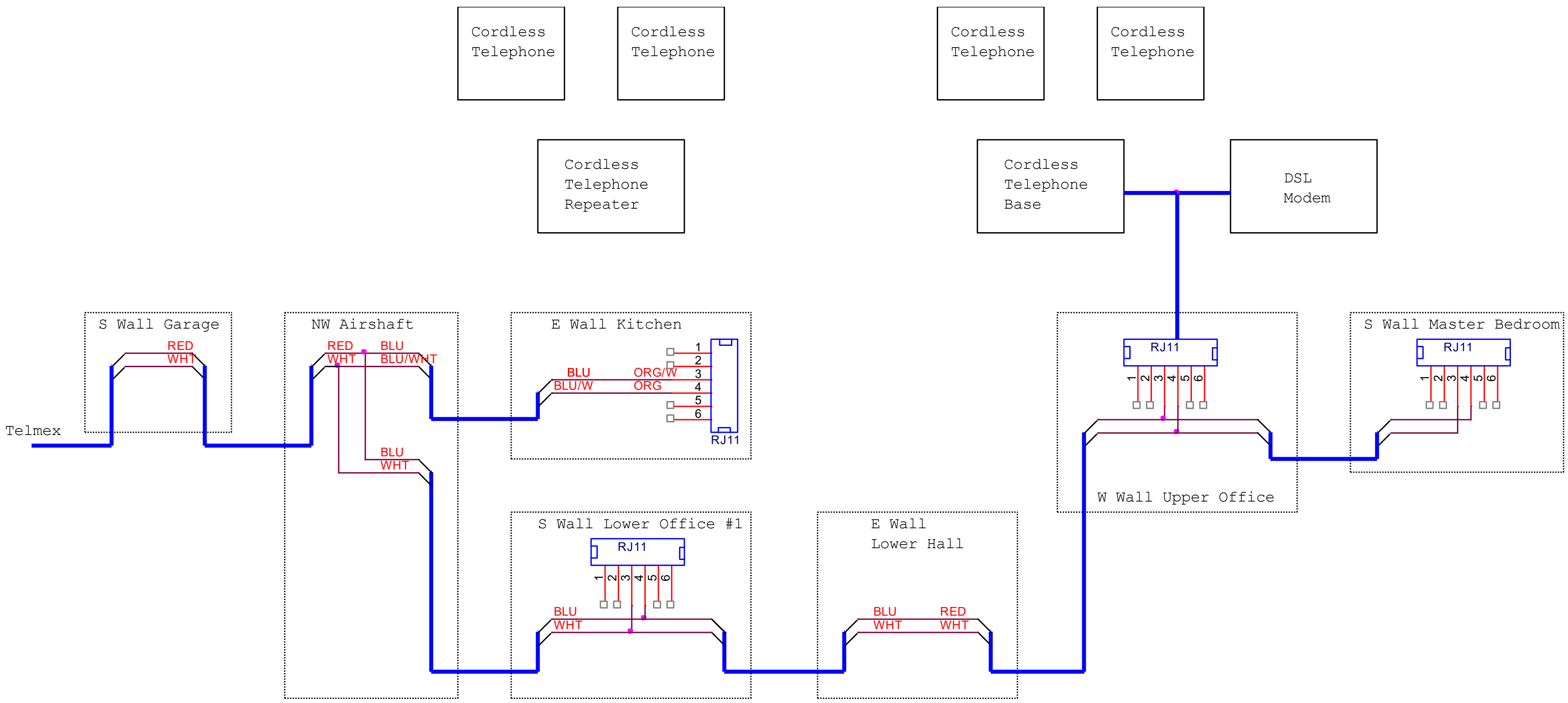


Figure 12-19 New Telephone System Wiring at Colibrí

I used low voltage 2-port wall plates with white keystone jacks for both the Ethernet RJ45 connections and the telephone RJ11 connections. Part numbers for these items from http://www.Discount-low-voltage.com are:

- DY-10600-P2WHT 2-port wall plate
- DY-10600K-6WHT RJ11 keystone jack
- DY-10605K-WHT RJ45 keystone jack

I used the same Kwik-jack crimping tool DY-KWIKTOOL for both of these keystone jacks. This is also available from http://www.Discount-low-voltage.com.

There was an existing wired intercom system connected to the front door bell button and intercom. The design allowed one additional remote unit to be installed which I did in the lower office. Figure 12-20 shows the wiring for this system.

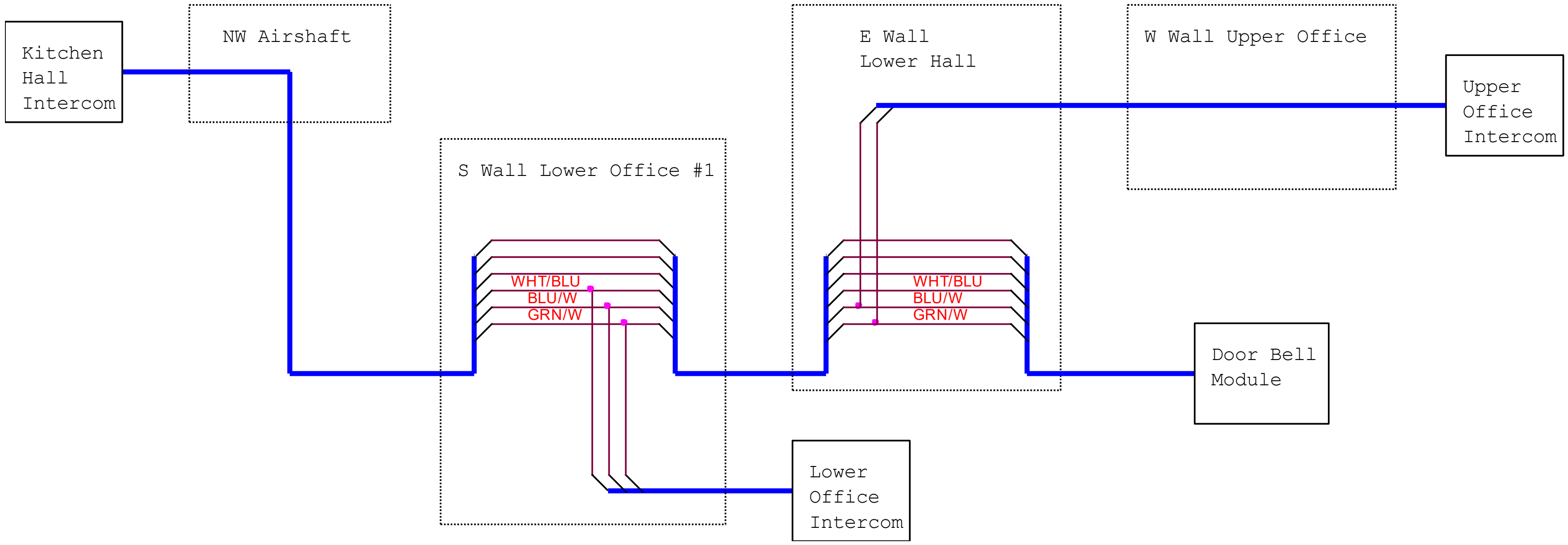


Figure 12-20 Intercom Wiring at Colibrí

In the above three low voltage diagrams, the wiring has been separated for clarity. However many of the same junction boxes and conduits were used for all three systems. I have found no interference between the telephone, Ethernet and intercom signals when wired this way.

The splices on the low voltage wires were originally done with simple twists covered by plastic tape. Since these are AWG24 or 26 solid copper, it is easy to either break the wires by over-tightening or getting a poor connection by under-tightening. A much better solution is to use the sealed crimp splices type 3M UR. These are sold by http://www.Discount-low-voltage.com. Use crimp tool ET-100-008.

12.5 Fans, Lights & Loads

I added two ceiling fans sold at the local Home Depot which did not come with remote controls. The house also had two existing ceiling fans which did have hand held remotes. However, these older remotes did not have a memory so when there was an interruption of electricity, the fans and their lights would come on after power was restored. This is very undesirable and besides the hand held remotes were always getting misplaced. I ended up purchasing a number of wall mounted remotes that included new control units that mount above the fans. These install in nearly every make and model of ceiling fan, and they have a memory so that if power is lost, the fan (and light) return to the same state they were in before the failure. The remotes simply replace the wall switch previously used to turn the fan or ceiling fixture on and off. And since they are mounted on the wall of the room they are used in, they never get lost or mixed up. See Figure 12-21. Home Depot (US) sells these remotes (Hampton Bay # 9050H) for about $25.

Figure 12-21 Wall Mounted Fan Control Used in Colibrí

The final step in modernizing the electrical system in Colibrí was to replace the old incandescent and CFL light bulbs. Section 4.11 discusses the choices available. The seven different style LEDs listed in that section were used throughout Colibrí.

The loads listed in Section 4.12 were measured in Colibrí. After balancing the fixed loads listed in Table 4-77, the total monthly usage has been running between 180 and 230 KWh per meter. This keeps us below the DAC rate on both meters. At the current the electric rate and exchange ratio, this works out to about $50 total per month. Without the LEDs and rebalancing, the total bill would have been between $100 and $150 per month, so it seems worthwhile.

13 Casa Soledad

In Mexico, architects also act as general contractors, and I had good luck with the remodeling at both Casa Erres and Casa Colibrí working with Marco Hernández (http://www.aharq.mx). An opportunity was presented to partner on a new house which we called Casa Soledad.

Marco and I agreed to make this house a "model project" to demonstrate how a better electrical installation could be accomplished in San Miguel. He prepared a complete set of house plans which included an electrical plan showing switch, light and outlet locations and gave me a set for review. At the same time, he initiated work because he had a crew of *albañiles* available, and no electrical work would be required for several months. I reviewed the plans, made numerous markups and prepared the specifications in English. These were eventually translated and the plans updated by Marco, but due to his busy schedule with other projects, this did not take place until about 5 months later. Meanwhile, the *albañiles* proceeded to install conventional boxes and conduit in places where they had to go during the masonry process (for example, inside stone faced columns). When questioned about this, I was told that the boxes would be exchanged for the correct boxes later when the electrician came on board.

I ordered most of the boxes and rings from Gavin which was a mistake because the shipping cost was higher than I expected, and most of the boxes and rings were stocked (intermittently) at Home Depot Mexico. However, the deeper boxes and rings had to be ordered. The entry panel was ordered from Home Depot US but the subpanels were stocked by Home Depot Mexico. Other special items like the ground wire pigtails that screw into the boxes were ordered from Garvin.

About 4 months into the construction, the time came to install some additional conduits to allow concrete to be poured for the second floor, and Marco sent the electrician out to do just this. But the electrician decided to install everything he could at this stage, because he had a large crew that needed the work. So most of the house was wired using the outdated plans, no specs, the wrong boxes, the wrong size cables, and the wrong circuit breaker boxes. This was all done in the space of 2 days when neither Marco nor I was watching what was going on. ***Disaster!***

When we all got together, it was agreed to remove and replace everything except the conduits, which were correct. This took several days, and surprisingly to me, the electricians were cooperative and actually agreeable about the whole thing.

The revised electrical plans fit on a single 24x36 inch sheet. It is provided as a separate PDF with this book and can be printed at an Office Depot or the like on a D sized sheet. A portion of the plan is shown in Figure 8-2 and the symbols are listed in Figure 8-3. The Specifications for the electrical work are provided as an attachment to this document in both English and Spanish. These are Word files so you can easily edit them for your project. There is also a BOM spreadsheet that was used for ordering the parts. The BOM is an Excel file and it includes hyperlinks to all the suppliers that I used so you can check current prices on these items.

Figure 13-1 Soledad Fascia

Figure 13-2 Soledad Meter Box

Figure 13-3 Soledad Main Breaker Panel – The 70 amp main breaker is on the left, the two 50 amp subpanel breakers are in the middle and the 20 amp water pump breaker is on the right.

Figure 13-4 Soledad Downstairs Subpanel

Figure 13-5 Soledad Upstairs Subpanel

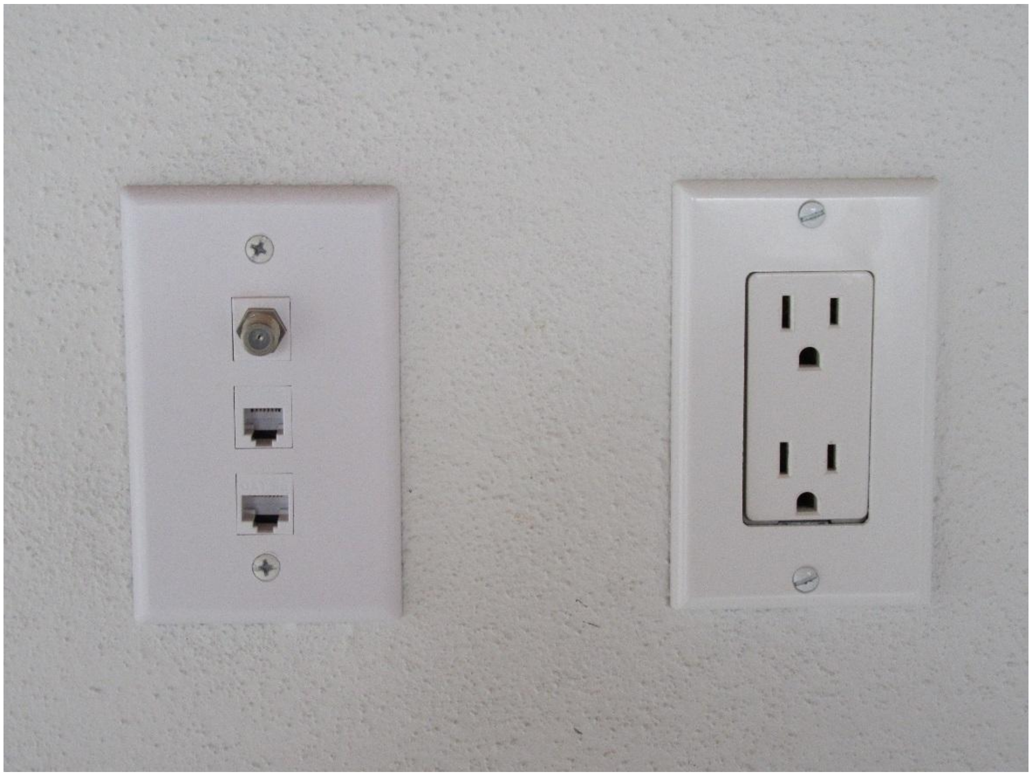


Figure 13-6 Soledad Typical Low Voltage Connectors (Left) and Decora Duplex Outlet (Right)

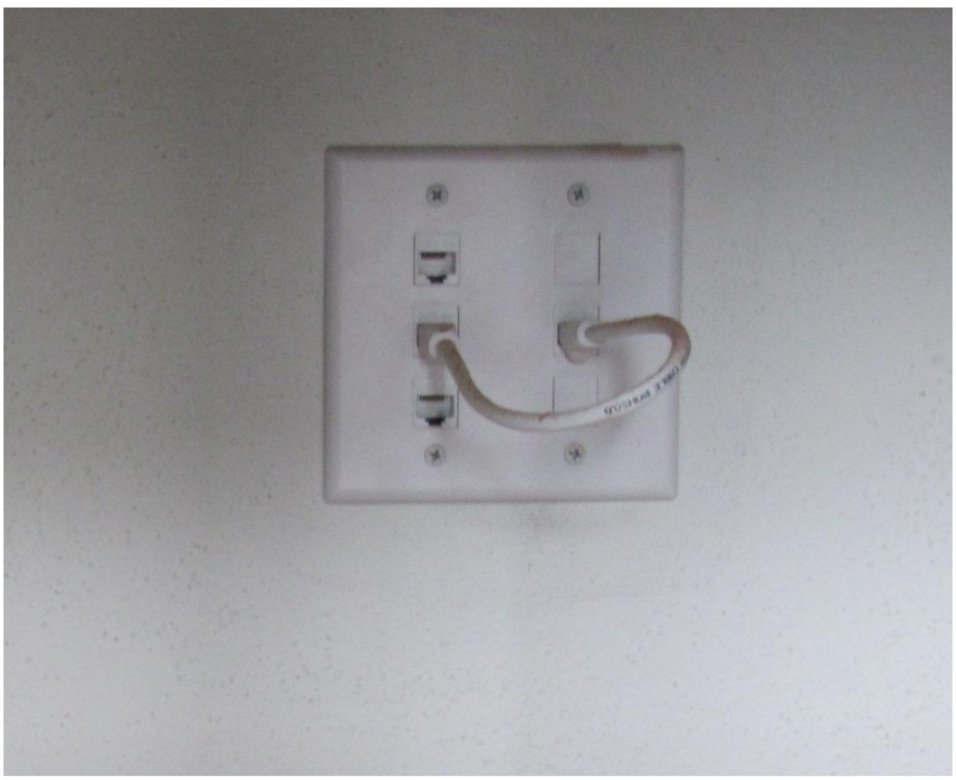


Figure 13-7 Soledad Upstairs Patch Panel

Figure 13-8 Soledad Downstairs Living Room, Dining Area (foreground), Kitchen (right) and Atrium

Figure 13-9 Soledad Boveda Ceiling