88th birthday series

The detached contact system for telephone switching circuit schematic drawings: the longer story

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ABSTRACT

Electromechanical telephone switching systems are extraordinarily complex, and the schematic drawings that define their circuits are nightmarish. In the early-1950s, the Bell Telephone System introduced a new scheme for these drawings, known as the “detached contact schematic system.”

Especially in a training or maintenance context, the new drawing system allowed much more clearly the visualization of the circuit paths, by which the circuit operated, than with the previous drawing system. As a result, often it would be often no longer necessary to prepare a separate set of “clarified” drawings for training or maintenance use.

The labor required to make and revise drawings under this system also was substantially less than with the prior system.

In this article, the important principles of the detached contact schematic system are described, as well as the rather curious story of the evolution of the system.

1 INTRODUCTION

1.1 Scope and context

The scope and context of this article is circuit schematic drawing systems used in the (former) Bell Telephone System for elctromechanical telephone switching systems.

1.2 Telephone switching systems

Telephone switching systems were always “complicated”, and the degree of complication escalated with each successive genre. Often a useful measure of the degree of complication of such systems, during the era of fully elctromechanical implementation, is the number of relays within a “circuit”.

In manual switchboard systems, a *cord circuit* might (in the more elaborate forms) contain 8 relays. In the step-by-step dial system, a *switch* might contain up to 20 relays. In the panel dial system, a *sender* might contain almost 100 relays. In the crossbar system, a *marker* might contain almost 1000 relays.

1.3 The circuit schematic drawing

The circuitry of any of these units was defined by the official *circuit schematic drawing* (whose identifier has the document class prefix "SD", and which accordingly was often called "the SD drawing".

The separate *wiring drawing* (often with prefix "T"), which showed all the components in essentially their actual physical positions in the equipment unit, and showed all the actual wiring between their terminals, including the physical paths that the leads took across the equipment unit, was derived from the SD drawing.

Even though the equipment unit had an equipment drawing number (sort of the "final assembly" drawing–with prefix "ED"), and in implementing an installation it would be ordered in terms of that identification, in engineering discussions a particular unit was most often identified in terms of its "SD" number.

2 THE "ATTACHED CONTACT" CIRCUIT SCHEMATIC DRAWING SYSTEM

2.1 Introduction

Prior to the emergence of the drawing system described in this article, circuit schematic drawings used an approach to relays (which were the preponderant players in most switching circuits) that later (after there was another system) came to be called the "attached contact" system, because of the way relays and their contacts were represented. I will use that name for the older system from here on.

2.2 An example

To help put this story in perspective, Figure 1 is the main circuit schematic sheet of the actual circuit schematic drawing for a certain type of switch (a "connector") used in the step-by-step switching system. Within the entire realm of telephone switching systems, this is a relatively-simple unit. It consists of only 14 relays and 3 electromagnets.

Don't worry about the component symbols—I'll come to that soon. But you can probably already see that to follow the circuit paths that, for example, operate each of those relays will take a full box of colored pencils, many hours of pondering, and perhaps a few fresh copies of the drawing.

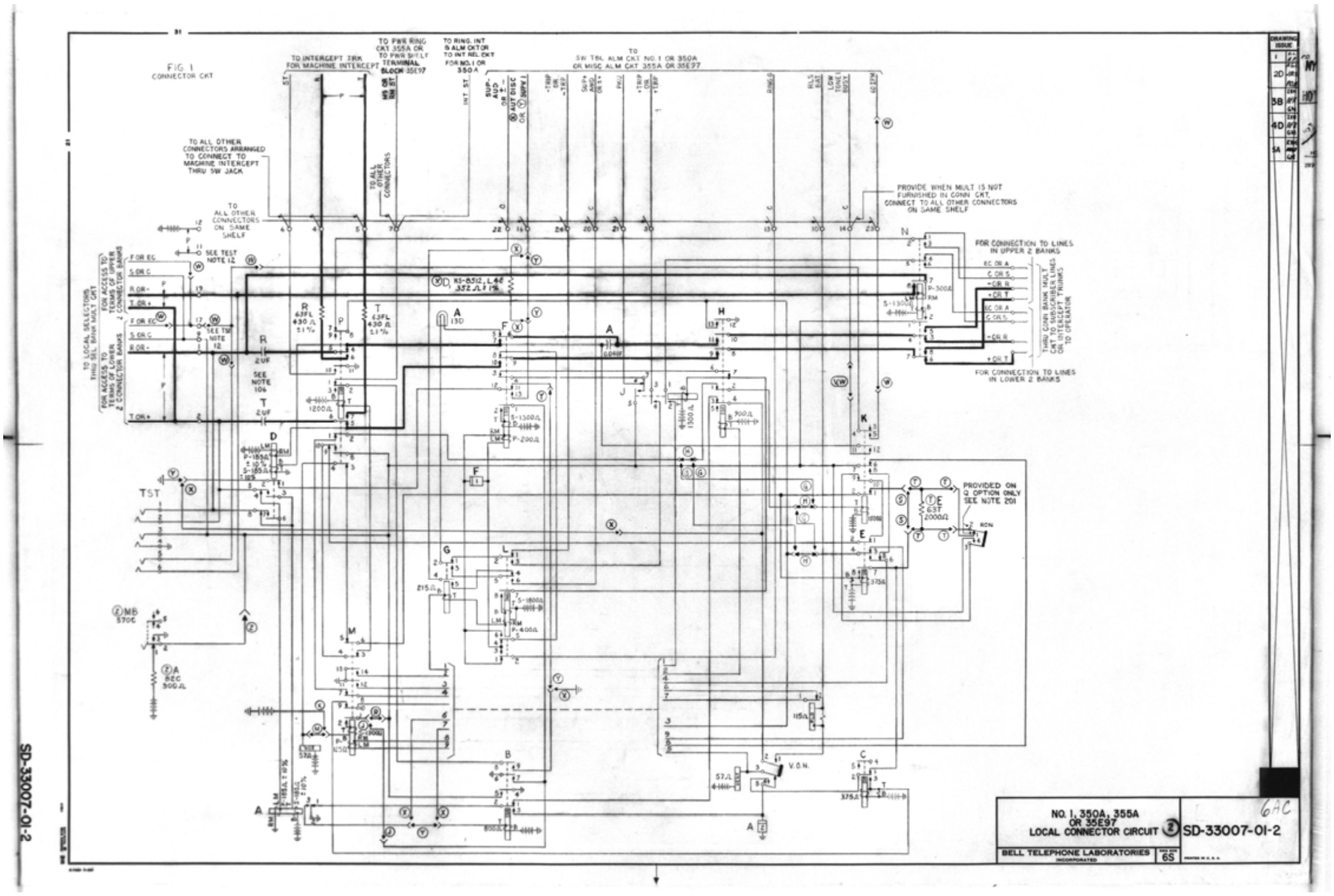

Figure 1. Step-by-step connector—attached contact circuit schematic

Imagine how this would work out for an equipment unit with about 100 relays—or more.

The overall “protocol” for these drawings was gigantic, going well beyond the basic matter of the symbols to be used (which however will be the focus of this article). As the systems became more complex, new aspects had to be added to the protocol. One such aspect was how did we show the circuit for a device with, say, 85 relays on multiple sheets of the drawing (so as to not end up with a drawing the size of a bedspread).

2.3 A typical relay

Let me digress to, by way of introduction, show in Figure 2 a relay of the family used almost exclusively in the step-by-step switching system.

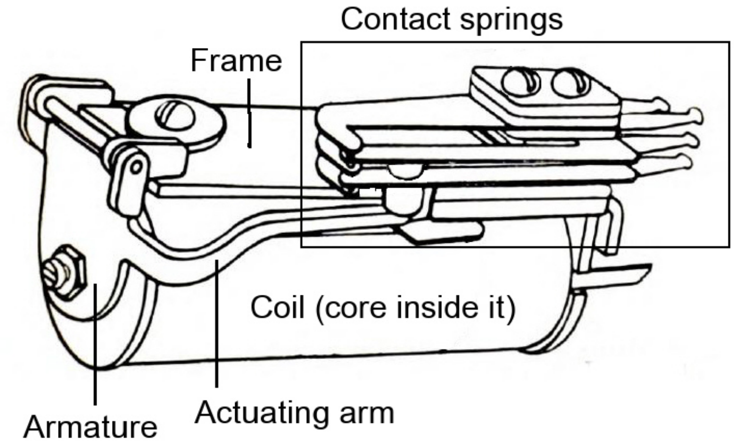

Figure 2. Typical step by step system relay

It is a very old design, actually "inherited" by the Bell Telephone System from an "outside the family" manufacturer.

The cylindrical object is the coil, wound on a steel core. The steel frame completes the magnetic circuit through the armature. On the upper right, we see the contact springs (5 of them in this particular type).

When the coil is energized, the magnetic force created pulls the armature toward the left tip of the core. As the armature rotates, its actuating arm, through an insulating stud at its tip, pushes up one of the contact springs, making its contact button separate from the contact button on the spring below it, thus opening that "contact" (which was closed with the relay idle). Then its contact button contacts that on the spring above, closing a second contact.

That moving spring in turn, though another insulating stud, moves up another spring, closing a third contact.

2.4 The attached contact relay symbol

As I mentioned, it is the relay that is the major player in these switching system circuits, and its symbol is a major ingredient in the drawing system. We see an example in Figure 3.

This hypothetical example relay is, as a part of a specific hypothetical circuit, designated "V". This is not the "type" of the relay, just its identity as a particular ingredient in this specific circuit. Note that it is not unusually complex among the relays used in switching systems. It has a different complement of contact springs than seen in Figure 2.

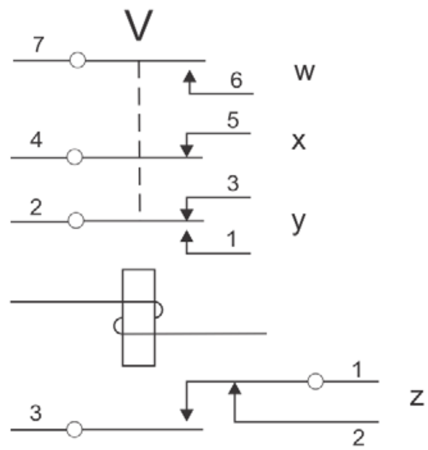

Figure 3. Basic relay symbol (attached contact)

This symbol is essentially a caricature of the physical relay itself.

We recognize the part of the symbol for the relay core and its coil winding, the graphic evoking an actual "winding". Here I will refer to that overall as the "coil".

The relay has four *contacts*, which I have identified for reference here with the letters w-z. Each contact is composed of two or three *contact springs*.[1] Each spring is identified by a number. (We need not be concerned with how those numbers are assigned, but they will be referenced elsewhere.)

We note that all the contacts of the relay are drawn adjacent to the coil (the premise, in fact, of the moniker "attached contact"), making the relay symbol an integrated graphic unit.

The dashed line (a "ganging" symbol") reminds us that the three contacts it "joins" are all operated by the relay coil (the movable springs—the ones without the arrow tips—being "drawn toward the coil" when it is energized)[2]. Of course the single contact ("z") below the coil symbol is also operated by the coil; if there were two contacts below, they would have a dashed line between them as well.

2.5 Contact types

In the following "key" to the different contact types, I identify the contact by the reference letter on Figure 3, then give the usual formal

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[1] Note that there can be some inconsistency in the terminology. Sometimes springs 1 and 2 are said to constitute a "contact", and springs 1 and 3 to constitute another "contact". (Note for example my usage in Section 2.3.) Other times (as in my usage here) springs 1-3 are said to constitute a single "contact".

[2] Of course in reality it is the movable *armature* of the relay that is attracted to the core when the coil is energized, and this armature moves the contact springs.

name of that type of contact (in the telephone switching context). In parentheses, I give alternate names for that type of contact, also as used in the telephone context. Then in square brackets I give the name or names for that type of contact often used outside the telephone context.

w. Make contact. (“front contact”[3]) [“Normally open”, “NO”, “form A”]

x. Break contact. (“back contact”[3]) [“Normally closed”, “NC”, “form B”]

y. Transfer contact. [“SPDT”; “break before make”; “form C”]

z. Transfer contact. (“continuity transfer”) [“make before break”; “form D”]

2.6 Top vs. bottom

Most of the types of relays with a substantial number of contacts typically have contact springs in two different sets on the relay which, when the relay is mounted in its “normal” way [4], can be considered to be “above the coil” and “below the coil”. We see this in Figure 4, a photo of a Western Electric E-type relay:

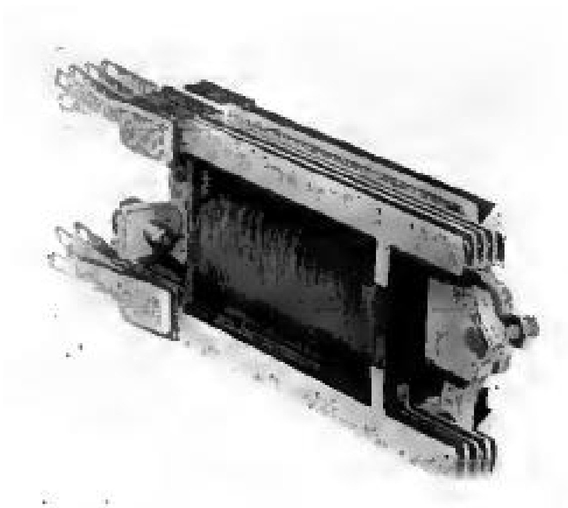

Figure 4. Western Electric E-type relay

In an attached contact drawing, that physical reality is usually recognized directly by drawing “above the coil” those contacts that are physically above the coil, and vice-versa. We in fact see that in the

[3] Originally applied to telegraph relays, where it related well to the physical construction, but later an important “jargon” term for that type of contact in any relay. That term is often used in narrative descriptions of how a circuit operates.

[4] In that regard, note that for a relay of the type seen on Figure 2, the face that it toward us in the illustration would in reality “normally” be up.

relay in Figure 3. Contacts w, x, and y are physically above the coil and thus are drawn “above the coil”. Contact z is physically below the coil and thus is drawn “below the coil”.

The springs in each “pileup” are numbered in their own series, both starting with “1”. As a result, in this example, there are two springs numbered “1”, and two numbered “2”, and two numbered “3”.

On the symbol, in the circuit schematic drawing, there is no need to distinguish by some notation a “top” springs from a “bottom” spring of the same number. Which are in the top set and which are in the bottom set is readily apparent from their position in the symbol. (If the relay has to be drawn “sideways”, then the “top” end is labeled.)

But when a contact spring is referred to in another document (such as a narrative description of the circuit operation), a “T” or “B” suffix will be applied to the spring number to make it unambiguous.

In more modern genres of relays (such as the “wire spring” type), the contacts themselves, rather than their individual springs, are given identifying numbers. We will see later how that plays out.

3 EMERGENCE OF THE DETACHED CONTACT SYSTEM

3.1 Historical context

The reality of circuit schematic drawings for all but the simplest circuits was that it was impossible to look at the drawing and quickly grasp how the various circuit paths operated. As a result, for use in training on the various systems, and in fact for reference in the field during maintenance, a second set of circuit drawings (often called “operational sketches”) were made, with a pivotal difference in concept to make the circuit paths easier to follow.

3.2 The concept

That difference was that the contact symbols were freed from being drawn nearby each other and the relay coil. Rather, each contact could be placed wherever on the drawing that was needed for the various circuit paths to be most easily delineated. In Figure 5, we see this concept on a fragment of a fictional operational sketch (although this specific convention was not adopted).

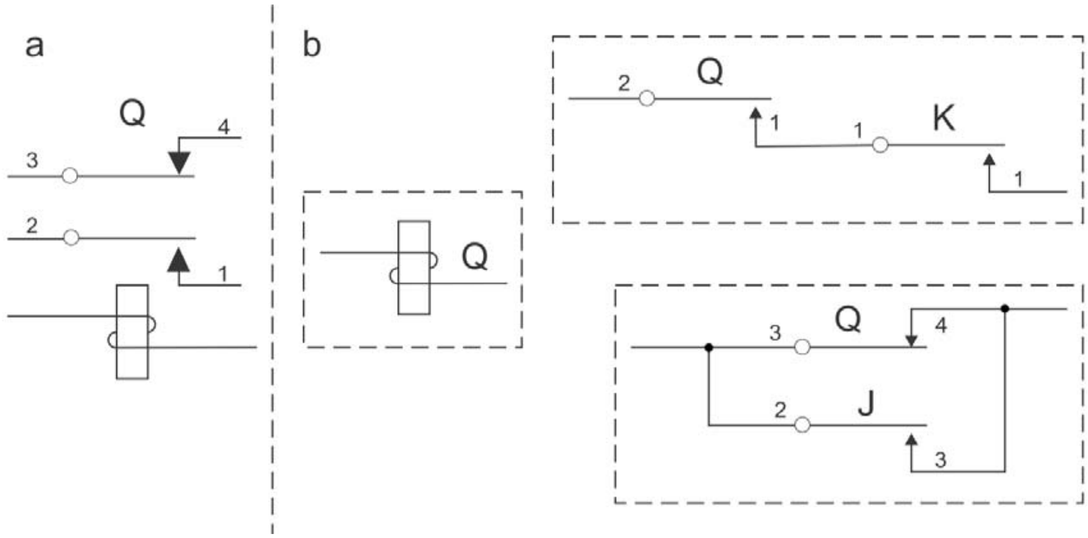

Figure 5. "Detached contact" principle

In panel a we see relay Q drawn in its attached contact form. It Panel b. we see how it might be represented under the detached contact concept.

The three dashed line boxes represent different locations on the circuit drawing (possibly even on separate sheets, for a complex circuit).

We see here contacts "2-1" and "3-3" of relay Q drawn where they, in cahoots with the contact "1-2" of relay K and the contact "5-6" of relay J, participate in two separate circuit paths (the rest of which are not shown here). These contacts are of course labeled with the designation of the relays of which they form a part, and with the applicable contact spring numbers.

The result is that often the reader can "sight read" the circuit paths, generally far from possible with the original system.

Note that this system fulfills the moniker "detached contact", although it is not the system used in what eventually came to be called the "detached contact schematic" drawing system.

The term of course means that the contacts of a certain relay, and its coil, were not all drawn as an integrated graphic unit. Rather, each of these subordinate portions was drawn where it could best contribute to the clear illustration of the circuit path(s) in which it participated.

3.3 Further evolution

As the principle seen in Figure 5 was considered for use for operational sketches, the thought emerged that while the operational sketch wonks were making what would be a major change to their drawing protocol, they should perhaps attack another problem: the very labor-intensive nature of drawing the various relay symbol parts.

Perhaps now that we did not draw an integrated symbol evocative of a picture of the entire relay, we would no longer feel the need to draw relay contacts as "caricatures" of the actual contacts.

3.4 The symbology

3.4.1 *The relay symbol*

The eventual result was that the system seen in Figure 6 was adopted for operational sketches.

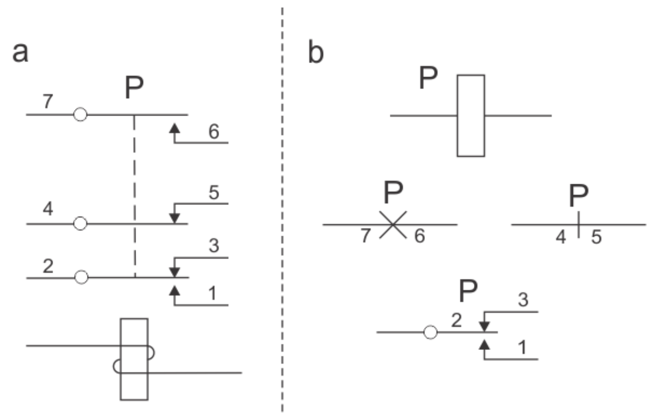

Figure 6. Relay symbols—detached contact form

In panel a, for reference, we see the relay arbitrarily designated "P", drawn in full attached contact form (as it would have been drawn on an SD- drawing of the time). In panel b, we see its components in the "detached contact" system as adopted for operational sketches.

3.4.2 *The relay coil*

Note that on the symbol for the relay coil we no longer draw the little curlicue that is evocative of an actual winding. This greatly simplified the drafting process. The symbol is more symbolic, less representational.

3.4.3 *The contacts*

Note that "simplified" symbols were adopted for the "make" and "break" contact, but the "transfer" contact was essentially drawn in the same way as in the "attached" form. (This may seem curious; I will return to that issue shortly.)

The new symbols for a "make" or "break" contact were very easy to draw when the drawing for a circuit was first made. Beyond that, if a circuit was revised, and a new contact was now inserted in series with some circuit path, the drafter, updating the drawing, would not have to erase anything—the new symbol was just drawn across the path and, *voilà*, it was in series with the path.

But the astute reader may think that the people who did this missed an important opportunity by retaining essentially the existing "attached contact" symbol for a transfer contact (springs 1-2-3), as we saw in Figure 4, above. Would it not have been better to adopt what we see below in Figure 7?

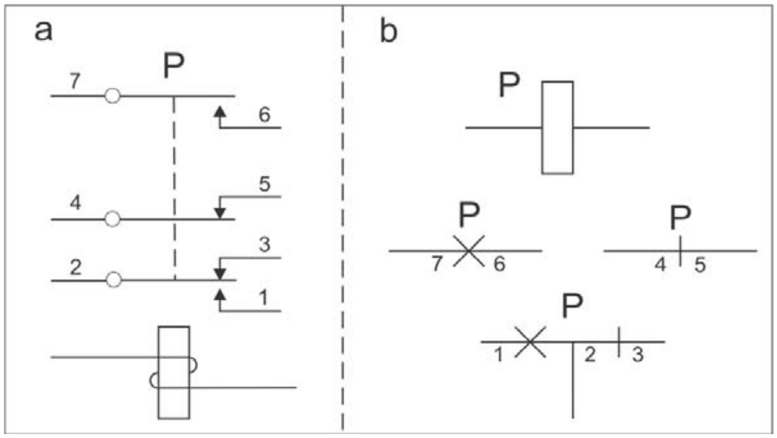

Figure 7. Relay symbols—alternate detached contact form

So it might seem. But that was not done for the operational sketches. (There were some rationalizations for that, but I will not indulge in those here.)

3.5 The next step

Of course, as the principle seen in Figure 6 came into use for operational sketches, it was realized that if that same principle were applied to the circuit schematic drawings themselves, they would themselves be easier to understand, and easier to draw, and perhaps it might be no longer always necessary to create a parallel set of operational sketches for training and maintenance use.

So planning began for the adaptation of the "detached contact" scheme for use on the actual circuit schematic circuit drawing. This was actually one aspect of a massive overhaul of the entire circuit schematic drawing structure. (The numerous further aspects of this are beyond the scope of this article.) This system came into effect in the early 1950s.

As to the detached contact symbol aspect, not surprisingly, the use of the scheme seen on Figure 6, rather than that seen in Figure 7, was revisited. There was spirited debate, and while at first (perhaps out of inertia) the Figure 6 scheme was slated for adoption, very quickly that was superseded by the scheme of Figure 7.

That is, for the circuit schematic drawing system itself.

But, oddly enough, this decision did not "blow back" into the sphere of the operational sketches, which mostly retained the use of the "Figure 6" scheme for the reminder of its life. [5]

3.6 Top *vs*. bottom again

In Figure 8 we again see relay V.

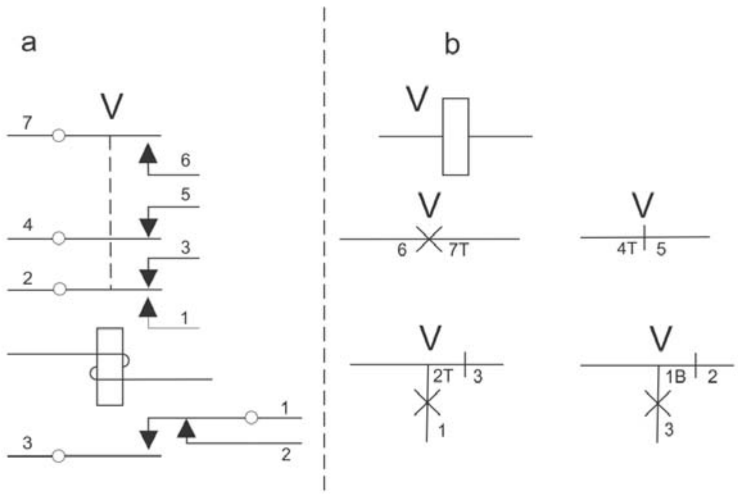

Figure 8.

Because now the contacts of a relay are no longer drawn in relation to its coil, we cannot graphically infer whether they are the "top" or "bottom" spring sets (when there are both) with only the numbers shown. So when a relay has springs in both top and bottom sets, the suffix "T" or "B" is applied to one of the springs in the contact symbol, as seen in the figure.

Why only one of the springs? Because if one spring of a contact is in either the top of bottom set, the other springs of that contact will of necessity be in that same set. Thus there is no need to put that suffix on more than one spring of the contact.

The convention is to apply it to the "moving" spring. In the case of a transfer contact, on this style of relay, that meant the "common" spring. In the case of the "make before break" contact (on the bottom), where there in fact two moving springs, the "B" is put on the "common" spring.

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[5] Although it had been hoped that the adoption of the "detached contact" scheme for the actual circuit schematic drawings might have eliminated the need for separate operational sketches, for many systems that did not fully work out, and so the system of operational sketches was kept in existence.

4 WHEN THE CONTACTS ARE NUMBERED

In a more modern genre of the general-purpose relays used in Bell System switching circuits (called the *wire spring relay*, from a prominent feature of its construction), the contacts (rather than contact springs) are numbered. Thus for such relays, the contact symbols carry the contact number rather than two or three spring numbers, as we see on Figure 9.

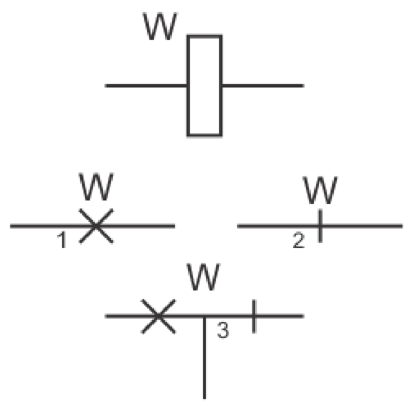

Figure 9. Contacts numbered

But we can tell, on the make or break symbol, which spring is which. The number is placed on the side of the symbol that corresponds to the "fixed" spring. That might seem a odd choice, contrary to some things we saw earlier. But on this genre of relays, on a make or break contact, the fixed spring is that one that would be, if this were a transfer contact, the common spring (and of course we see the result for the transfer contact in the example).

5 MORE DETAILS

5.1.1 *No dot*

Refer to Figure 7, at the bottom of Panel b, showing the symbol for a transfer contact (drawn intact). Note that there is no "dot" at the junction in the center of that symbols, as would be used at other junctions of circuit paths in the detached contact schematic format. This is said to remind us that this "junction" was not attained through wiring but was rather inherent in the construction of the relay contact.

Of course, the "junctions" shown in circuit paths by dots did not usually at all correspond to where two wires were joined in the physical implementation of the circuit. So that explanation was a bit of fantasy.

5.1.2 *A "make before break" transfer contact*

In Figure 8, we see (on springs 1B-2B-3B) a transfer contact that is "make before break". On SD- drawings using the detached contact schematic drawing system, there is no indication of this on the contact symbol itself.

Rather, in such a drawing, there is invariably a table that lists all the relays and all the contacts of each, showing for each contact its exact type and its sequence implications (there can be sequence subtleties far beyond “make-before-break”, which are beyond the scope of this article).

Often when the detached contact form is used on operational sketches or in other tutorial or illustrative contexts, contacts having a special sequence situation (most commonly, “make before break”) may be marked to reference a nearby note describing the situation.

5.1.3 *“Poling” of multiple coil windings*

An issue that invariably comes up when a relay has two or more windings is how they are relatively “poled”. That is we must be certain that when there is current through two windings, the resulting magnetic effects either add or oppose (as is appropriate to the operational principle involved).

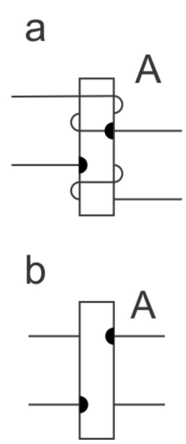

Figure 10. Poling of windings

On Figure 10, panel a, we see the traditional notation (in an attached contact drawing) for this matter for hypothetical relay A. The direction of the “curlicues” actually shows the relationship of interest, but it is a little tricky to follow. So for easier grasp, the little half-moon marks indicate the “corresponding” ends of the two windings: the ends that would need to have the same polarity if the magnetic effects were to add [6].

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[6] Actually, the formal definition is that the marks show the “inner ends” of the windings, the unsaid corollary being that it is assumed that they are all wound in the same direction from their respective starting points. Thus when the marked ends

In panel b, we see that in the detached contact system we retain those two half-moon marks, with the same significance (and now vital to showing that).

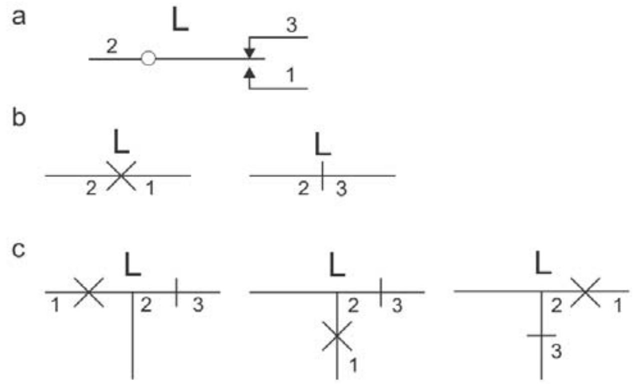

Figure 11. Transfer contact variations

5.2 Transfer contact variations

In Figure 11, Panel a, we see the attached contact symbol for a transfer contact (in this case, on relay L).

The detached contact schematic concept allows us to draw the make and break parts of a transfer contact in different places if they are in circuit paths that for various reasons we draw in different places. We see that done in Panel b.

In many cases, though, the two circuit paths are drawn nearby, and so we can draw both aspects of a transfer contact together (as we have seen previously). We can arrange this in different graphical ways, as seen in the three examples in panel c. Of course any of those may be rotated, or “flipped” in either direction.

5.3 Other symbols

The symbols for other components were also brought into line with the detached-contact philosophy. For example, for a jack having an auxiliary contact that is operated when a plug is inserted into the jack, separate from the jack’s springs that make contact with the plug, that contact is drawn with a symbol such as those used for a relay contact, and of course that may be drawn wherever allows its circuit function to be most clearly seen.

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have the same voltage (with respect to the other ends of the windings), the magnetic effects add.

5.4 Other simplifications

There were a number of other simplifications put in place by the new system. One was that the various points where DC voltage ("battery") was supplied to the circuit, where formerly the traditional battery symbol was used (labeled with the voltage), now there was only a label with the voltage (including the polarity)[7]. Among other things, this simplified the making of the drawing.

5.5 Drawing sizes

Under the attached contact system, circuit schematic drawings were made in various sizes (often as large as 26″ × 40″, sometimes larger), as needed to accommodate the complexity of the circuits they described. These were physically cumbersome.

Under the detached-contact schematic system, most circuit schematic drawings were issued at a size of 17″ wide by 11″ high. These could readily be put in a binder of that size.

Alternatively, the sheets could be given a simple "Z-fold" and be put in 8-1/2″ × 11″ binders. The fold was made such that the title block of each sheet was fully visible as one would leaf through the volume.

The original drawings were in fact normally actually made (on the original vellum or Mylar sheet) at exactly twice the final size, to facilitate the accurate drafting of the symbols.

The consistent use of this relatively-small size for the drawings as released means that in many cases the drawing for a complex circuit will take more sheets than under the attached contact system. But now more often the circuit paths of interest will each be confined to one sheet, and the notations for paths that involve more than one sheet are improved, so overall these large-circuit drawings are much easier to handle in their detached-contact form, even if they have more sheets.

6 OTHER ACTUAL EXAMPLES

6.1 The 4A crossbar marker circuit

In Figure 12, we see an small excerpt from the actual SD- drawing for a complex equipment unit, the marker of a 4A crossbar switching system (a very complicated electromechanical switching system once used in the long distance network). (My apologies for the poor reproduction.) It involves several hundred relays altogether, and the drawing is of course on several sheets.

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[7] On the operational sketches, battery was symbolized with a small line crosswise to the circuit path, and labeled with the voltage (perhaps with the polarity not shown).

Suppose we wanted to understand what controlled the operation, locking, and release of the RL relay (in the blue rectangle). We might start by marking in red are all the circuit paths involved, as we see on the drawing. (Several paths are completed on other sheets of the drawing!) You can imagine the tedious work that would follow this first step.

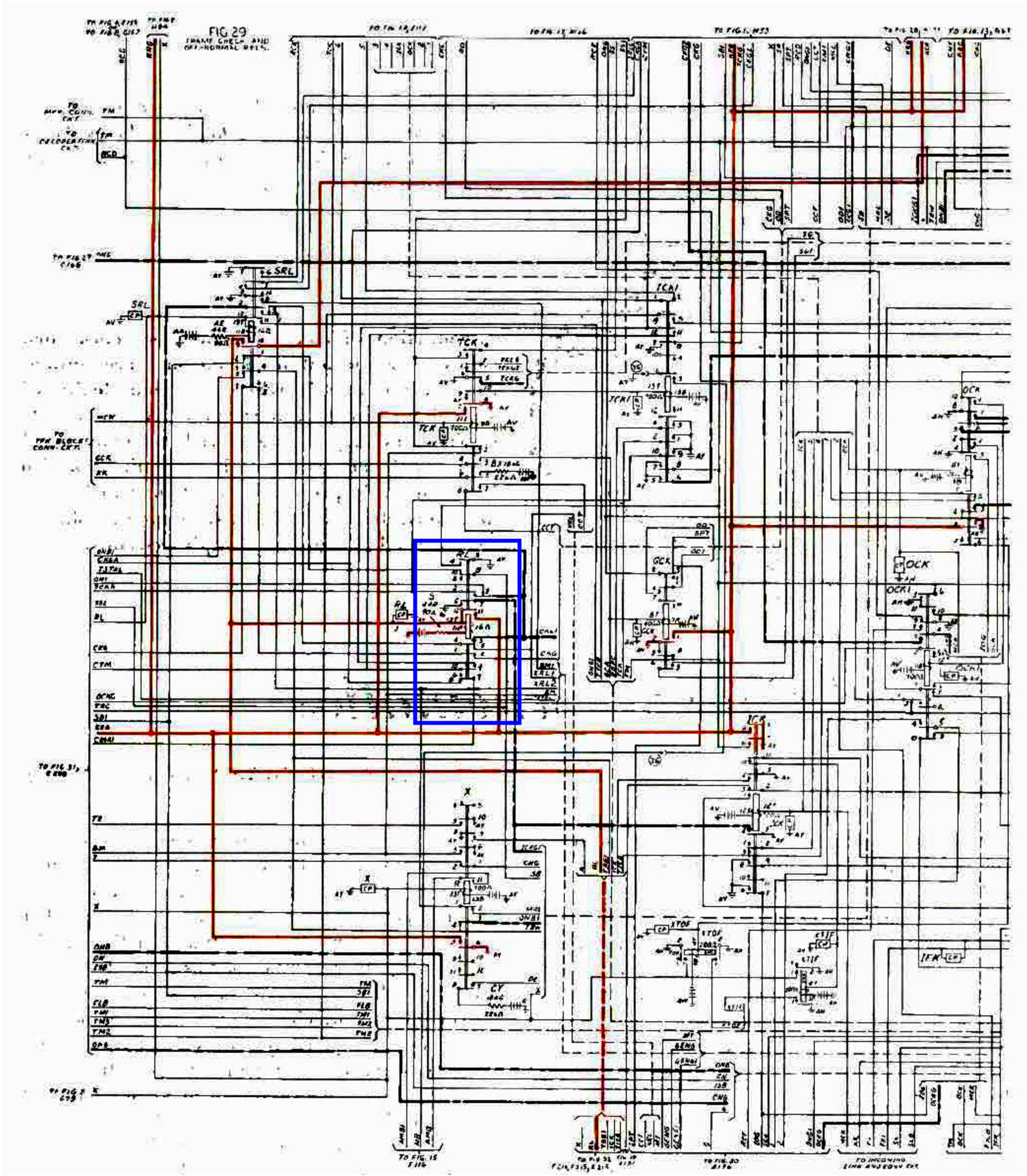

Figure 12. 4A crossbar marker—part of circuit schematic drawing—marked up

Now in Figure 13 we see what those paths would probably look like as part of the drawing for that circuit in detached-contact form.

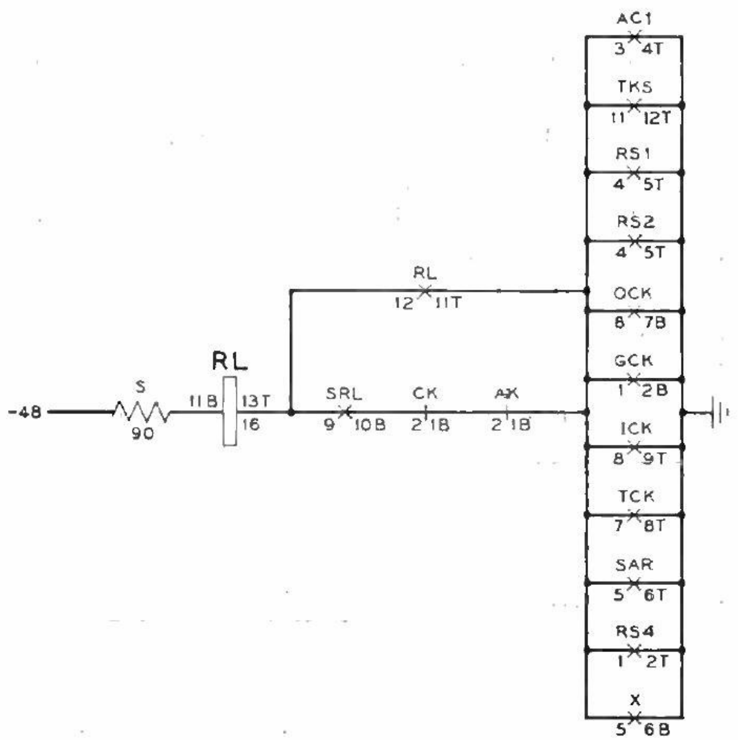

Figure 13. RL relay paths—detached contact system

We can readily see that relay RL will initially operate when:

- Relay SRL is operated, *and*
- Relay CK is not operated, *and*
- Relay AK is not operated, *and*
- one or more of the 11 relays on the right is operated

Relay RL will then be locked, through its contact 12-11T, if:

- one or more of the 11 relays on the right is operated

Relay RL will release if:

- All of the 11 relays on the right are released, *and*
- Relay SRL is released, *or* relay CK *or* relay AX is operated

Imagine figuring this out from Figure 12!

6.2 A step-by-step connector switch

In Figure 14 we see the circuit of a hypothetical step-by-step connector switch (a slightly different kind than the one in Figure 1), drawn in detached contact form. This is not from an SD drawing, but a drawing by this author to illustrate the operation of this switch in another article (rather like an operational sketch). The red highlight is added for its use here.

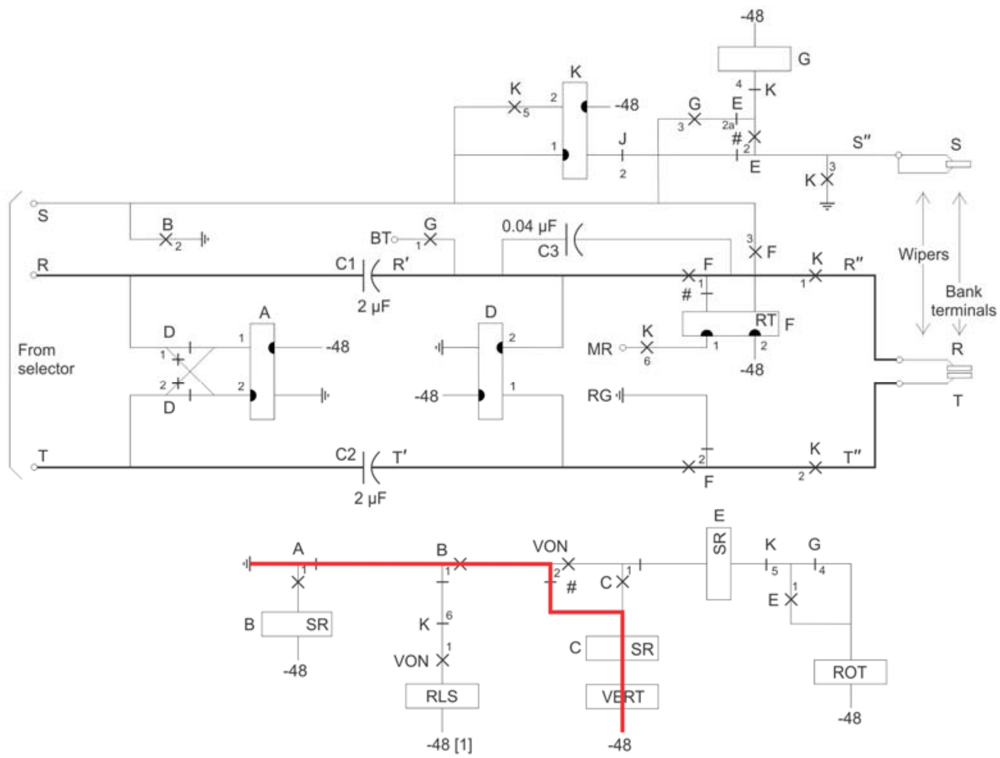

Figure 14. Typical step-by-step connector—detached contact form

You may notice that the contacts are identified by contact number, not by spring number (as they would invariably be in reality for the type of relay invariably used for a switch of this kind). That is no deficiency, as this drawing does not relate to an actual switch, and doing that made the drawing less cluttered.)

We can see how much easier it would be on this style of drawing, compared to what we see in Figure 1, to see just what, for example, controls the operation of the C relay (I have actually highlighted that path in red on Figure 14).

In all fairness to the comparison with Figure 1:

- This is actually for a connector switch that is not quite as complicated as the one in Figure 1 (and has a few less relays).
- Not included on this "tutorial" drawing are many "fussy" notations, included on the drawing we saw as Figure 1, covering such things as optional alternative circuitry (and which an actual SD- drawing, in detached-contact form, would still have).

Still, I think we can see how much easier it would be to understand the operation of the circuit from the Figure 14 form *vs*. the Figure 1 form.

7 DRAFTING AND SKETCHING

I referred several times to the greater ease of making schematic drawings using the detached contact system than in the prior (now called "attached contact") system.

This does not only apply to the "original issue" of a drawing. Suppose that the circuit design is later modified to add a certain relay contact in the path to another relay. Under the attached contact system, no doubt much of the circuit path would need to be erased and lines drawn to where the new contact is. Under the detached contact system, in many cases all that is necessary is to draw the new symbol astride the existing path (and properly label it, of course).

This same fluency is equally valuable when an engineer is trying to develop a circuit by sketching (perhaps doing this on a blackboard in a collaborative group). Want to add another contact in a certain path to provide some sort of interlock function? Just draw it. No need to erase anything, or draw long and complicated lines.

8 CONCLUSION

The development and adoption of the detached-contact schematic system was a gigantic step forward in making circuit schematic drawings easier to understand in the field, and brought with it substantial economies in the original preparation of the drawings.

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