ABSTRACT: The main aspect of the present invention comprises a binary adder stage which comprises two switches controlling a total of six mechanical changeover contacts arranged in two interconnected sets, each comprising two changeovers of one switch and one changeover of the other switch with the static contacts of the one changeover respectively connected to the movable contacts of the two changeovers, potential connecting terminals, a condition indicator, and Carry-in and Carry-out connections.
FIG. 1

FIG. 2

Accumulator Store
Number-Indicator Lamp Banks

Number Input Switches

Capacitor Store
Dec. Cycle Counter
Control Unit
Summation Store
Addendum Store

ILB

ILA

MX

RLA

STC

RLB

RLS

ISW

Decimal-To-Binary Translator Matrix

DEC

CU
FIG. 4B

RM
b1, Figs. 3B, 5B

†30 v
CU
RLY/3
RB
C
RLX.3
RLY.2
MR
0 v

RLY.3

FIG. 3B

FIG. 6
BINARY ADDER IN WHICH BINARY NUMBERS IN DIFFERENT MULTI-STAGE STORES ARE ADDED TOGETHER INTO A THIRD STORE

This invention relates to electrical binary arithmetic devices particularly devised for demonstrating the principles used in data processing and computer equipment for use in schools, programming and managerial courses, and the like.

Whereas speed of operation is highly important in commercial equipment of this character, simplicity and clarity of expression is the aim of the present invention, and speed of operation must be geared down to these requirements.

The use of static electrical devices, solid-state diodes, transistors, and the like, for example, are essential to commercial requirements. However, the absence of movement of any sort makes it impossible to obtain any appreciation of the operational sequences of such equipment from physical examination, although the provision of indicator equipment operated therefrom can give an indication of the mathematical sequences at operational speed.

Reversion to the use of electromechanical devices, as in "pre-solid-state" equipment, and provision for discrete single-stage operations, together with indicator equipment, form the basis of the development of demonstration apparatus.

One object of the invention is to give clarity of exposition combined with economy of apparatus.

Another object of the present invention is to devise apparatus suitable for demonstrating arithmetic principles clearly and economically.

The invention will be described with reference to certain embodiments shown in the accompanying drawings in which:

FIG. 1 is a circuit diagram showing the basic addition/subtraction circuit used in the equipment.

FIG. 2 is a block schematic diagram of a relay-actuated binary calculator based on the arithmetic unit of FIG. 1.

FIG. 3 comprises FIG. 3A, the left side of a circuit schematic of the arithmetic apparatus of FIG. 2, and FIG. 3B, its right hand side.

FIG. 4 comprises FIG. 4A, the left side of the controller unit of the FIG. 2 Calculator, and FIG. 4B its right hand side.

FIG. 5 comprises FIG. 5A, the left side of the circuit diagram of the arithmetic unit for FIG. 2, FIG. 5B the central part thereof and FIG. 5C its right hand part.

FIG. 6 comprises FIG. 6A, the left side of a diagram of cycle counter for FIG. 2, FIG. 6B its center and FIG. 6C, its right hand part.

Referring first to FIG. 1, the circuit shown utilizes two electromechanical, contact-making, light-current relays, the contact-pairs of which comprise three change overs only; that is 3-pole switches, as compared with pairs of 6-pole and 4-pole switches already known. The known 6-pole switches used, for example, four changeover sets and two make-and-break sets each: the known 4-pole switches used four changeover sets each, but the present 3-pole switches only comprise three changeover sets each, thus saving two changeover sets at the least.

The purpose of the circuit is to form one stage of a binary adder performing the functions of adding, storing, and 'carry' and to indicate the current storage condition.

The circuit has a DC power supply of which terminals E and + are shown.

The a and b vertically arranged sets of terminals are each controlled by a corresponding switch, which may be a manual key or an electromagnetic relay. IC is an incoming Carry, which can be controlled from a preceding stage of a binary counter, or by a manual key, to apply earth or battery. OC is an outgoing Carry which can be applied to a further stage, or to a Carry indicator, or both. ILP is a 'condition' indicator, to indicate if '1' or '0' is stored in the circuit as a result of a previous operation.

Assuming that the circuit is idle, and ILP indicates '0', the operation of one of the contact sets a, or b, or application of battery to IC, will set up a '1' condition in the circuit as follows:

1) \( +: a \ 4, 5; b \ 3, 2; \) ILP: E on IC; or
2) \( :/ a \ 3, 2; b \ 1, 2; \) ILP: E on IC; or
3) \( E: a \ 6, 5; b \ 3, 2; \) ILP: + on IC

In each case, earth or 'No Carry' is applied to OC.

(1) E on IC; b 6, 5; a 7, 8; OC
(2) E on IC; b 7, 8; a 9, 8; OC
(3) E: a 6, 5; b 9, 8; a 9, 8; OC

Both a and b operated but E on IC, gives a positive Carry on OC, but no operation of ILP: +; a 4, 5; b 4, 5; a 7, 7, 8; OC Either a or b contacts operated, and battery on IC, gives a positive Carry on OC, but no operation of ILP:
(1) + on IC; b 6, 5; a 7, 8; OC
(2) + on IC; b 7, 8; a 9, 8; OC

If both the a and b sets of contacts are operated, and battery is applied to IC, then battery is applied to OC and ILP is also operated.

(1) battery; a 4, 5; b 6, 5; a 7, 8; OC
(2) battery on OC; b 2, 1; a 2, 1; earth

An alternative arrangement of the contact sets is to operate (i) \( a/ 3; a 4, 5; b 4, 6; \) and \( b 7, 9 \) by one key or relay, and (ii) to operate \( a 7; 9 \) and \( b 1, 3 \) by the other key or relay.

Then if group (I) alone is operated with earth on IC, ILP is operated: +, a 4, 5; 6, 7; ILP: E. If group (II) alone is operated with earth on IC, ILP is operated: +, a 3, 2; b 1, 2; ILP: E. If battery is applied to IC with both groups of contacts idle, then + on IC; ILP: b 2, 5; a 6, 5; E: operates ILP.

Both contact groups operated with E on IC gives battery on OC without operating ILP: +, a 4, 5; 6, 5; a 7, 8; OC.

Battery on IC with one or other contact groups operated gives battery on OC without operating ILP:
(1) battery on IC; b 7, 8; a 9, 8; OC
(2) battery on IC; b 6, 5; a 7, 8; OC

All contacts operated with battery on IC gives battery on OC with ILP operated:

(1) battery on IC; b 7, 8; a 9, 8; OC
(2) battery on IC; b 6, 5; a 7, 8; OC

(A) + on IC; ILP: b 2, 1; a 2, 1; E
(B) +; a 4, 5; b 4, 5; a 7, 8; OC

Referring now to FIG. 2 the binary relay Calculator comprises two banks of relays RLA, RLB arranged to receive two binary numbers interconnected with a third bank of relays RLS so that the binary sum can be set up thereon. The relays are set up from changeover switches ISW or decimal-to-binary translator matrices MX and are provided with electrical or mechanical holds.

The relays have associated indicator lamps to show their states, and the sum relays RLS each charge associated capacitors STC when they are operated. The Calculator operation is controlled by a Control Unit CU in each cycle of which the holds on one bank of relays RLA are removed, and the charges on the capacitors STC associated with the sum relays RLS are used to transfer the sum digits to the RLA relays on a straight or shift basis. The power to the adder is also switched during each machine cycle to cause relays RLS to release. The discharge, and routing of the discharge currents, of the capacitors is controlled by diode gates and switches, to inhibit false transfers during manipulation of the setting controls.

The cycling of the machine is controlled by two interconnected relays in the Control Unit giving four spaced switching periods, the relays being slowed by capacitors, which are discharged during each cycle to give adequate charging times. A resettable electromechanical counter DEC shows in decimal form the number of machine cycles completed, which
can be increased one at a time by a "single shot" button. The diode matrix MX has open spring switches which set up a bank of relays to encode in binary form a decimal input switch condition.

The circuits are arranged to perform subtraction by complement addition, and the most significant Carry-Out controls the cycle counter so that division is automatic, the machine stopping when the contents of its sum store change sign.

Similarly, the machine stops, when adding if its sum store is filled, and during automatic multiplication when an auxiliary binary relay machine cycle counter reaches a desired count.

Relays RLA Fig. 3 form an accumulator store into which a binary number can be set directly, if desired, using a decimal-to-binary input matrix.

The relays RLA have electrical holds, so that once set they retain their configurations until the holds are removed, and associated indicating lamps display the value of the binary number stored, as a pattern of lights.

Relays RLB, set up from input switches I, represent a number or its complement, depending on the sense in which the input switches are supplied with power.

The two sets of contacts on RLA and RLB are interconnected so that the binary sum of the two numbers they represent is displayed on sum lamps, operated by sum relays RLS.

The pattern of bits on relays RLS is also represented by a pattern of charged capacitors C, switched by relays RLS, each of which when operated charges a capacitor.

To transfer a sum into the accumulator, the power to relays RLS is removed, so their contacts fall, allowing any charged capacitor to discharge through its appropriate relay RLA, thus replacing the previous number in the accumulator with the sum.

The single-shot press-button P1 must arrange to do six things in order:

1. Cut off the power supply to the adder, so the sum relays fall.
2. Cut off the power supply to relays RLA, to erase the number previously stored.
3. Reconnect the power to the relays RLA, ready to hold if they are now set.
4. Reconnect the power to the adder, to set up a new pattern of sum relays.
5. Operate the decimal counter, to increase its count by one.
6. Operate the binary counter, to increase its count by one.

A controller unit Fig. 4 is used to perform these six tasks, with the correct timing and press button P1 will initiate one cycle of action of this controller at a time, through its contacts P1, Fig. 4A, and P2, Fig. 5A.

Automatic operation switch Q arranges for the controller unit to begin its action, and to carry out its cycle of operation through its contacts Q1, Fig. 4A, and Q2, Fig. 5A.

An ADD/SUBTRACT manual function switch F of which contacts F1, F2 are shown in Fig. 4B, and F3, F4 in Fig. 4B, is arranged to do three things:

1. It alters connections in the controller, so that the operation of the controller is stopped either when the sum applied to relays RLS exceeds 15, or when this sum is negative.
2. It supplies either "carry O" or "end-around-carry" signals to the input of the adder, to provide the correct result when adding, or when subtracting, by complement addition.
3. It selects whether or not the input switches I of ISW, Fig. 3B, shall operate relays RLB directly, or whether the negation of an input switch shall operate a relay opposite relays.

In Fig. 3, the relay sets are shown schematically, examples of their detailed circuits being given in Fig. 5. Since the equipment is for demonstration purposes, alternative methods of applying bit-words to the relay sets RLA, RLB are used.

Words are also applied to the RLA set as such, whereas words or their complements can be applied to the RLB set.

The RLA set can receive words from an external source, or from the 'sum' relay set RLS. To demonstrate that problems in decimal notation can be accepted by suitably designed input equipment to binary stores, relay set RLA is fed through a conventional decimal-to-binary matrix converter with 15 digital keys arranged to apply potential to a corresponding one of 5 parallel leads in coordinate relation with four parallel leads to four RLA relays, there being the usual diode cross connections at the crossing points between each decimal digital lead and the corresponding selection of the four binary leads, so that operation of a decimal digital key e.g. 4 or 5, results in operation of the corresponding binary relay or relays, e.g. the 2R binary relay RLA/C or both the 2R and 2/2 binary relays RLA/A and RLA/C.

The digital keys can be pieces of springy wire, and the coordinate array and cross connections are visible.

The 1, 2, 4 and 8 decimal keys are directly connected by L-shaped wires to the four binary relays and these wires are coloured, red for example, and numbered so that the translation process is practically self-explanatory even to 10 year-olds.

The relay set RLB receives words from manual or relay-controlled changeover contacts IA-ID, in ISW, Fig. 3B, the front and back fixed contacts of which are respectively multiplied to front and back fixed contacts of a further changeover F3 of an ADD/SUBTRACT changeover key, the movable contact of F3 being connected to battery +. The movable contacts of IA-ID are connected to the respective RLB relays.

According to whether changeover F3 is in one position or the other, a selection of relays RLB are operated corresponding either to the selection of keys IA-ID which are operated, or to their negation, corresponding respectively to digits 0 and 1.

Addition and multiplication are performed by single and repeated addition of N, whereas subtraction and division are performed by single and repeated addition of -N with a closed-looped carry.

The relay-set RLS does not receive inputs from any external source but only from the RLA and RLB relay sets, and transfers its record only to the RLA set, which acts first to receive one of two initial words to be added or subtracted, and then to receive each partial sum in turn from RLS during a succession of additions and subtractions, the relay set RLS operating in an identical manner for each operation by receiving and either adding or subtracting partial sums from RLS and addendum 'words' from RLB respectively.

It will be understood that each of the four vertical sets SA—SD, FIGS. 3A and 3B, of three relays RLA, RLB, RLS each, are interconnected in an individual binary changeover circuit (indicated by broken line rectangles) as shown in Fig. 1 with relay RLS replacing the lamp ILP, and in FIGS. 5B and 5C between the broken vertical lines III—IV for relay RLA, IV—V for relay RLB, V—VI for relay RLS. Each relay has a letter suffix indicating the stage to which it belongs, and a diagonal followed by a figure which indicates the number of contacts in its contact pile-up. The relay contact sets are distributed in the circuits in the various FIGS. and are referenced, for example, as RLS.A1 and RLS.A2 for the relay RLS A/2. The diagonal lines between the rectangles indicate the 'carry' connections between the binary stages of the relay sets. It will be seen that the lowest denomination 'carry' line LSC is itself connected to the movable contact of changeover F4 of the ADD/SUBTRACT switch. For a single functional operation F4 in normal position connects the said 'carry' line LSC via point a 1 in the Controller Unit, Fig. 4A, and changeover RXX 1 to earth (0 volts), but for a sequence of functional operations, F4 operated contacts the least significant Carry line LSC via lead + 1 to the most significant Carry line MSC to allow closed-loop operation.

The relays RLS.A—D control the operation of indicator lamps ILPS/A—D, FIGS. 3A, 3B at contacts RLS A2—D2, when a power-switch switch S is closed, via a common circuit connected to the Most Significant Carry MSC via a blocking diode MB1, and a lamp ILPSE for indicating the existence of a Most Significant Carry.
The Most Significant Carry line is also connected via another blocking diode MR2 to lead d of the Controller Unit, FIG. 4A, which is connected to the front contact of manual changeover F1, closed during subtraction/division operations.

To ensure power supply to lead d when the final subtraction in a repeated-subtraction/division process removes potential from the Most Significant Carry MSC, a capacitor store C is connected between earth and the lead from MR2 to d 1, which lead is also connected via a resistor RD to battery. Capacitor C is charged from battery while there is battery on MSC, but discharges to provide a final potential pulse to lead d 1 at the termination of division when the result of the final subtraction removes potential from MSC. This final pulse indicates to the Controller Unit that division is complete.

The blocking diode MR2 prevents discharge via MSC at this final stage.

Resistor RD provides a high impedance energy source to keep C charged during addition/multiplication, so that charging of the capacitor does not take place during switching of relays RLS and so preventing unwanted relay-hold conditions.

During addition/subtraction, there is an earth condition via MSC on lead e 1, FIG. 4, while the ‘sum’ content of relay set RLS is less than or equal to 15, that is, providing the capacity of the store is not exceeded. Too large a positive number, or a negative number, that is the carry condition from the fourth stage, in the relay store RLS, results in battery on MSC to inhibit operation of the Controller Unit as described below.

The power supply for the lamps ILPS is a 5-volt AC circuit via transformer LT which allows cheap torch bulbs to be used. DC can of course be used with 30 V lamps, in which case the rectifier MK and the lamp resistors RLP can be omitted, and the connection of lamp ILPSE will be transferred from the common return wire via switch S and transformer LT-R to a 1, FIG. 4, via another switching contact of the summation switch S.

FIG. 5 shows the circuit of the final stage in full detail, including on the left the indicator lamp circuit; between section lines II and the transfer capacitor CD, FIG. 5A, for transferring the condition of the RLS relay to the RLA relay; the circuit for binary digit insertion into the RLA relay between II and III; the arithmetic circuit between III and VI; and the circuit for binary digit insertion into the RLB relay on the right. FIGS. 5A, 5B, SC also indicate bus-bar arrangements for operating like sections of all the stages, e.g. the indicator lamps ILPS from the bottom of FIG. 3 are shown in echelon in FIG. 5A connected via ILPSE and MR1 to the Most Significant Carry MSC.

The storage capacitor CD for the final stage is shown in a circuit between a battery rail and a capacitor rail, which circuit is controlled by a changeover RLS.D1 of relay RLS.D, FIG. SC. The four capacitors all have similar circuits, the respective changeover contacts RLS.D1, RLS.C1, etc. being arranged to connect the capacitors alternately to battery and to the respective RLA relay: in this case RLA.D.

A separately-controlled discharge circuit is also provided for the capacitor via key-controlled changeovers Q3 and P2.

Between the relays RLA and RLS are the arithmetic circuits controlled by relays RLA and RLB which are similar to that shown in FIG. 1, while to the right of FIG. SC is relay RLB with part of the digital input circuit for the RLB relays. The RLA.D relay, operated via its input lead MD from the decimal-to-binary matrix, also has a back circuit from battery via resistor R, locking contacts RLA.D1, RLA.D2, b 1 connected to the Control Unit, FIG. 4B, RLA.X unoperated of relay RLA.X, FIG. 4A, to earth; and thus can act as a bit store under control of relay RLX.

A bank of lamps ILPA is installed, of which IL.P.A is shown, each of which has a circuit similar to that of lamps ILPS FIG. 3, and is operated by a low voltage AC bus-bar, via individual rectifiers MR1 which block during the connection of earth via a 1 from the Controller Unit, FIG. 4A, and via RLA.D3 unoperated, but which passes AC when 30 volt battery is applied thereto via RLA.D3 operated.

The storage capacitor operation is controlled by three rectifiers: MRA prevents the capacitor being charged via RLA.D1 when RLA.D is held operated, but allows RLA to be operated from the charged capacitor; MRB allows CD to be discharged when it is connected via RLS.D1, MRB, resistor RS, P2, Q2, MEC to earth, while MRC is activated in response to the operation of P2 or Q2 to short circuit MRC.

The logical operation is controlled by the Controller Unit of FIG. 4.

Assuming that everything is at normal, closure of a selection of locking switches IA—ID, FIGS. 3A, 3B (for example, snap action light switches), energizes the corresponding RLB relays.

Since no other relays are operated, an operated B relay, for instance RLB.D, FIG. 5B, will immediately operate the corresponding RLS relay: battery, RLA.D2, back, FIG. 5B, RLB.D1 up; RLS.D; earth from preceding stage via RLA.C4 back, RLB.C3 back, RLA.C3 back, a 1, FIG. 4A, RLX.1 back, earth; or at the first stage from LSC, FIG. 3B, F4 back, a 1, FIG. 4A, RLX.1 back, earth.

If now a word is inserted into relay set A, it is immediately transferred into the sum relays RLS, being added to the record already therein in the manner described in detail with regard to FIG. 1.

It is now necessary to transfer the record in the RLS relays to the RLA relays in readiness for a further operation. This can be done as a discrete operation, under control of manual key P or as part of a repetitive operation under control of manual key Q. Capacitor CD, for example, can be charged from battery via contacts RLS.D1, FIG. 5A, CD, MEC, earth immediately RLS.D is operated.

When key P is operated, the changeover of contacts P3, FIG. 5A, closes a circuit to discharge any incorrectly charged capacitor; e.g. earth, P2 front, Q2 back, CD, RLS.D1 back, winding of relay RLA.D, via a 1, FIG. 4B, to earth.

Closure of contacts P1, FIG. 4A, by key P completes a circuit; battery, F1 normal; RB, winding of RLA.X, P1, P2 normal, rectifiers MR2, MBE to earth on terminal c 1 via Most Significant Carry MSC as before. Relay RLA.X operates and closes contacts RLX.3 to energize relay RLY. The opening of the back contacts RLX.1 removes earth from terminal a 1, FIG. 5, releasing relay RLS.D.

Back contacts RLX.3, FIG. 4B, open simultaneously with the opening of back contacts RLX.1, and remain open momentarily from terminal b 1, FIG. 5, until the operation of RLY, FIG. 4, closes contacts RLY.2 to reconnect earth to b 1.

This removal of earth from b 1 releases relay RLA.D if it is energized in readiness for reenergization by the discharge of capacitor CD a moment later via RLS.D1 back, RLD winding, when earth is reconnecting to a 1.

In this way, the contents of the RLS relays are transferred to the RLA relays and the RLS relays are deenergized.

The selected relays RLB are still operated so that on release of switch P and consequent release of relays RLY, RLY, the return of contacts RLX.1 normal will cause certain RLS relays to energize but this time to record the sum of the contents of the numbers in both the RLB and RLA sets. Thus the result of the first addition is recorded on the ILPA lamps, while the lamps ILPS indicate the result of a second addition of the RLB relay number.

A further operation of switch P will transfer the contents of the RLS relays to the RLA relays, and on release of switch P, a further summation will take place on the RLS relays.

Each time the contacts RLX.1 are operated, earth is connected via RLX.1 front contacts to denary (or decimal) counter DEC to add 1 to the contents thereof.

Counter DEC can be any form of electromechanical counter and indicator, so that the number of operations of switch P are recorded.

In using the equipment to multiply a number by another, one number e.g. 4, is inserted on the RLB relays, without any external insertion on the RLA relays, and switch P is operated a number of times equal to the other number, e.g. 3, after.
which the result will be on the RLA relays. Usually, the control switch SS for the ILPS lamps will be open, so that lamps ILPA alone will indicate the progress and finally the result of the multiplication.

The equipment is modified for automatic multiplication by utilizing the manual switch Q; with contacts Q1, FIG. 4A, and Q2, FIG. 5A, and the equipment in FIG. 6, which includes a binary counter comprising four electromechanical relay stages RLC A-D and an availability circuit comprising parallelled contacts 4 of the counter relays. In the controller unit, FIG. 4A, the switch contacts P1 referred to above are paralleled by a circuit Q1, ML, RLY.1, of which ML is a detachable link which can be replaced by the availability circuit RLC A-D, the terminals of which, indicated by the bracket reference ML, are connected to the terminals normally linked by ML. These ML terminals are shorted by the four back contacts RLC A-D, and remained closed as long as any one of the contacts RLC A-D is closed; that is, until the four counter relays, RLC A-D are simultaneously operated and the counter is full to capacity.

The binary counter operation is controlled by contacts RLY.3 of the Controller Unit relay RLY which are shown in the first binary counter stage, and which are also included in FIG. 4A, now that they belong to the relay RLY therein.

For automatic multiplication therefore, the checking circuit is inserted in place of ML, FIG. 4, and manual switch Q is operated.

The Binary Counter shown in FIG. 6 has four stages each comprising a relay, e.g. RLC A, and a relay-operating capacitor, e.g. CA.

The operation of the counter is initiated by operation of contacts RLY.3 of relay RLY, FIG. 4, of the Controller Unit. When power is applied to the equipment, the first stage capacitor CA is charged via RLY.3 and RLC A1 both in normal position. Changeover of RLY.3 when relay RLY, FIG. 4, operates connects CA to relay RLC A which operates and locks via contacts RLC A2 and normal contacts of the SET switch to battery. Closure of contacts RLC A3 closes a charging circuit for capacitor CB via RLC B1 normal.

Release of relay RLY, FIG. 4, closes a short circuit on CA via RLY3 normal, RLC A1 operated.

A second operation of RLY operates contacts RLY3 to connect the discharged capacitor CA across relay RLC A: because of the presence of hold resistor HRA, relay RLC A releases and connects charged Capacitor CB across relay RLC B, which operates and holds via RLC B2 Relay RLY releases.

Since RLC A is now released, capacitor CA will charge. A third operation of RLY will again operate RLC A without affecting the operation of RLC B. Thus the simultaneous operation of both RLC A and RLC B records 3 in binary notation, and CA and CB are discharged via RLY3 back, RLC A1, and via RLC A3 front, RLC B1, front respectively.

A fourth operation of RLY3 releases RLC A and RLC B, by first shorting RLC A via CA, and then shorting RLC B via CB, RLC A3 back, and operates RLC A, whose circuit (not shown) is identical to that of RLC B, and which records digit 4.

Further operations of RLY3 in turn operate RLC A; operate RLC B and release RLC A: operate RLC A so that the first three RLC relays are now operated and energize RLC D alone; and so on until all four RLC relays are all operated and the counter is full. A further pulse on RLY3 will release all relays RLC.

If it is designed to count less than the full capacity of the counter, the negation of the number to be counted is set up on the counter by operating a selection of manual switches IA-ID followed by operation of the switch to complete circuit via the operated switches IA-ID to energize the corresponding RLC relays which hold via their hold circuits on the release of SET which is spring-retumed.

In these circumstances, successive operations of RLY3 result in continuing the counting operation from the condition resulting from the above negative setting operation (ones for noughts, and noughts for ones).

As stated, the normally closed contacts RLC A4—D4 are connected in parallel to the signalling leads connected up in place of the multiplier link ML, FIG. 4, in the Controller Unit, so that the circuit across contacts P1, via Q1, RLC A4—D4 in parallel, RLY.1, is opened when the counter is full.

Capacitor CS connected to the front contact of the SET switch is charged when the switch is operated and discharges during return of SET to normal to bridge the change over time before the hold circuits of the operated counter relays are closed. The resistor RS across CS ensures that battery is only available to switches IA-ID while, or soon after, the SET switch is operated. This prevents unintended setting of the counting relays via IA-ID before SET is operated.

It will be seen that RLX, FIG. 4, is normally operated via P1, F2 normal, MR2, MR1, earth on c 1, FIG. 4A. However, the c 1 earth is dependent on the a 1 earth from back contacts RLY.1, FIG. 4. Thus when contacts RLX 1 are operated, earth connections a 1, c 1 disappear. The capacitor C1 is provided in parallel with rectifier MR1 so that when earth on c 1 disappears, an earth connection will be maintained via capacitor C1 and resistor RB1 to relay RLX while C1 is charging. The capacitor C1 will of course discharge when earth reappears on c 1.25

For subtraction, a first number is inserted into the RLB relay set, for instance, by the switches IA-ID with the manual switch F in normal position, and transferred to the RLS relays. By operation of switch P, the number is transferred to the RLA switches.

The manual 'subtract/divide' switch F is now operated and the i switches, in ISW, FIG. 3B, are of a binary subtractor and are operated. Since F3 is reversed, the negation, or mirror image, of the binary number, to the total 1111, is stored in relays RLB: Contacts F1, F2, FIG. 4, of the switch F have been changed over, and a direct earth is applied to one side of the contacts P1, via a, RLX 1 back, F2 front, and a variable battery condition is now connected via terminal d 1, FIG. 3, and front contacts F1 to the other side of P1. Changeover contacts F4 set up a closed loop between the outgoing final Carry lead MSC and the incoming Least Significant Carry Lead LSC.

Any real subtraction giving an answer within the capacity of a 4-stage binary store, will give a Final Carry during addition of the negation of the subtractend: e.g. 2 = 1 is performed as 2 = 1 = 16, of which 15 gives a Carry, which passes around the c 1 loop to enter the least significant first stage, leaving 0001 in the store: 0010 + 1110 1 = 0001.

For this reason, the presence of a Final Carry: that is, battery on MSC, FIG. 3 or 5, is a criterion of a viable subtraction operation.

The absence of a final Carry indicates a negative answer: e.g. 14 15 = 14 + 0 = 14 with which there is no final Carry. As before operation of switch P transfers the results of subtraction to the RLA relays, and a further subtraction takes place on release of P, the result remaining on the RLS relays. Subsequent subtraction can take place as a result of successive operations of switch P until the remainder becomes negative and the potential on MSC is earth, the result of which is to reduce the potential on terminal d 1, FIG. 3, so that further operation of RLY, FIG. 4, is inhibited. The number of subtractions is recorded on counter DEC, FIG. 4. The condition when the remainder is zero is also taken care of. Automatic successive subtractions to a predetermined number, in other words division, takes place under control of switch Q.

As above, division is stopped when the remainder becomes negative, and further operations of RLX is inhibited. It will be seen that capacitors are connected across relays RLY, RLY, FIG. 4, with the result of slowing down their operation, so that the cycle of operations takes place at a relatively slow speed and can be visually followed.

The binary relay calculator described is for teaching computer fundamentals, by providing an arithmetic unit whose action is both explicable and visible to 12 year-olds.
It is mounted in a box with a transparent plastic top and with a sloping front console.

The power supply is well below 30 volts, with on/off switching and a fuse in the low voltage circuit, so that the machine will be safe to touch.

The over-riding consideration after safety is that it can be made and sold at a price that schools can afford.

The machine is laid out to be useful to a teacher.

The input switches and indicating lamps will be laid out on the console as below.

![image]

There will be no other lamps in view. A switch will be provided to turn off the sum lamps when desired. The other controls will be on the right of the switches and lamps. The relays will be laid out on the floor of the box below the glass top as follows:

<table>
<thead>
<tr>
<th>RLBD</th>
<th>RLC</th>
<th>RLB</th>
<th>RLBA</th>
<th>Input relays.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLAD</td>
<td>RLA</td>
<td>RLA</td>
<td>RLAA</td>
<td>Accumulator relays.</td>
</tr>
<tr>
<td>RLSD</td>
<td>RLSC</td>
<td>RLSB</td>
<td>RLSA</td>
<td>Sum relays.</td>
</tr>
</tbody>
</table>

aligned with the corresponding switches and lamps on the front console.

Pressing the 'single shot' button or switch P will leave the accumulator lamps allight, showing the previous sum now transferred to the accumulator. Releasing the button switch will then show the new sum as well as the accumulator contents, on the sum lamps and accumulator lamps respectively.

The controller is stopped by the presence of negative numbers, or numbers greater than 15, on its sum relays.

Gate transfers during manipulation of the setting switches do not appear.

The machine will operate correctly and reliably, in spite of mains supply voltage fluctuations to be expected on the public supply.

The diode input matrix is built as a separate panel with a plug-in connection to the calculator box. The whole of the matrix is visible on one side of the panel, and the 15 pivoted input light-switches are on the same side, or on one edge, of the panel.

Thus the diodes and switches are on the same side of the board, and the switches are on the right of the panel when in use.

The binary counter FIG. 6, can also be mounted in a separate box with a transparent top if desired and the setting switches are mounted on the top. The connecting plug and cable will provide at least seven separate connections for two power supply connections, three connections from the changeover contacts RLY.3 of relay RLY, and the two terminals of the multiplier link ML, FIG. 4.

I claim:

1. Binary arithmetic equipment which comprises:
   a. three multistage binary digital stores, each stage of each store comprising an electromagnetic contact-making relay and the three relays, one per store, of each stage constituting together with circuits incorporating the relay contacts a binary adder;
   b. number input means to a first one and to a second one of said multistage stores the contents of which are to be added in the third summation multistage store;
   c. carry circuits between the adders; and
   d. an electrical control circuit provided with
      1. a first manual starter for initiating a sequence of operations of the equipment;
      2. and a second manual starter for initiating a succession of operational sequences of the equipment.

2. Equipment as claimed in claim 1 in which each adder also comprises circuit arrangements for the transfer of the contents of said third multistage store after an addition to one of said other stores which acts as an accumulator store in a multiple addition.

3. Equipment as claimed in claim 2 in which each adder also comprises a storage capacitor acting as a transfer store in the transfer of the contents of said third multistage store to said accumulator store.

4. A binary adder which comprises two switches each controlling three changeover contact pile-ups each consisting of a moveable contact between two static contacts, wherein two changeover contact pile-ups of each switch together with a third changeover contact pile-up from the other switch in each case respectively constitute two contact sets, and, wherein in each of said contact sets the static contact of the third changeover contact pile-up are respectively connected to the moveable contacts of the two changeover contact pile-ups belonging to the same switch; which comprises circuit interconnection between contacts of said two contact sets; and which comprises terminal connections for earth, battery, incoming Carry, and outgoing Carry, connected to the remaining contacts of said contact sets.

5. A binary adder stage which comprises a first switch controlling four changeover contact pile-ups and a second switch controlling two changeover contact pile-ups, each pile-up consisting of a moveable contact between two static contacts, wherein pairs of pile-ups of said first switch each with one pile-up of said second switch respectively constitute two contact sets, and wherein in each of said contact sets the static contacts of the pile-up of said second switch are respectively connected to the moveable contacts of the two pile-ups of said first switch, and which comprises terminal connections for earth, battery, incoming Carry, and outgoing Carry, connected to the remaining contacts of said contact sets.

6. Equipment as claimed in claim 1 wherein the relays of said first and second multistage stores included in each binary adder are provided with a total of six mechanical changeover contacts arranged in two interconnected sets, each set comprising two changeovers of one relay and one changeover of the other relay, with the static contacts of the one changeover of each set respectively connected to the moveable contacts of the two changeovers of the respective set.

7. Equipment as claimed in claim 6 wherein the relays of said first and second multistage stores each comprise three changeover contacts, of which two constitute the pair of changeovers of one set and the other constitutes the single changeover of the other set.

8. Equipment as claimed in claim 6 wherein the relays of said first multistage store each comprise four changeovers constituting the two pairs of changeovers of the two sets, and the relays of said multistage store each comprise two changeovers constituting the single changeovers of the two sets.

9. Equipment as claimed in claim 6 wherein the remaining contacts of a first one of said sets of changeovers are connected as follows:
   A1. the front static contact of a first changeover of the pair of changeovers of said first set is connected to the back static contact of the second changeover of the pair and to incoming Carry;
   A2. the back static contact of the first changeover of the said pair is connected to the front static contact of the second changeover of the said pair and to the back contact of the single changeover of the second set;
   A3. the movable contact of the single changeover is connected to outgoing Carry, and wherein the remaining contacts of the second set of changeovers are connected as follows:
   B1. the back contact of a first changeover of the pair of changeovers of the second set, of which the movable contact is connected to the front contact of the single changeover of the second set, is connected to the front contact of the second changeover and to a battery terminal;
B2. the front and back contacts not specified in B1. of the pair of changeovers are connected together and to an earth terminal;

B3. the movable contact of the single changeover is connected via indicator means to the Incoming Carry.

10. Equipment as claimed in claim 2 which comprises condition indicator means associated respectively with the accumulator relay and the summation relay for each adder.

11. Equipment as claimed in claim 1 in which said relays are electromechanical contact-making light-current relays, and in which each stage comprises two digit storage relays one of which also acts as an accumulator relay, a summation relay and capacitor for use in transferring the setting of said summation relay to said accumulator relay.

12. Equipment as claimed in claim 1 wherein one of said number input means comprises a set of binary input switches for inserting a binary number into the relays of one digital store and an input control switch arranged to control the insertion of a setup number itself when the control switch is in one position, and the binary mirror image of the setup number when the control switch is in its other position so that the equipment can also perform subtraction.

13. Equipment as claimed in claim 3 which comprises circuit interconnections between said summation relay, said storage capacitor, and said accumulator relay at each stage, and wherein the sequence of operations resulting from actuation of said second manual starter includes:

A. the charging of the respective capacitors from the operated summation relays;
B. the discharge of the charge capacitors into the respective accumulator relays; and
C. the resetting of the summation relays under control of the other two relays of each adder.

14. Equipment as claimed in claim 1 wherein said control circuit comprises an operation counter arranged to count the number of individual addition/subtraction operations carried out under control of said second manual starter, and automatic detection and control means for detecting when the summation relay store is full and for thereupon automatically inhibiting further operations.

15. Equipment as claimed in 14, and wherein said control circuit also comprises manual presetting means for presetting said counter so that it will be counted out by a predetermined number of operations.

16. Equipment as claimed in claim 13 mounted in a box with a transparent top and a front console, the relay sets being mounted on the floor of the box in parallel lateral lines, while lamp sets for the accumulator and summation relays are mounted across the console with respective lamps in line (front to back) with relays of the same stage.

17. Equipment as claimed in claim 15 and comprising a jack mounted on the box to receive a connecting plug on a control panel containing the operation counter claimed in claim 12 or 13.