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F-MATIC N SERIES (FUJI TRANSISTORIZED DIGITAL CONTROL ELEMENTS)

By Toshio Sakuragi
Tokyo Factory

Takeshi Takemura

Motoshiro Kaneda
Development Dept.

I. INTRODUCTION

Transistor digital control elements possess many advantages in comparison with magnetic relays, and are now indispensable to fulfill such requirments as compactness, wider control function and reliability improvement of various types of control or protective equipment. These elements are now being used more than ever before.

In 1961 Fuji Electric was the forerunner in the industry in developing a standard series of digital control elements employing germanium transistors, and since that time these elements have been put to a wide range of uses. The features of this series were planned for high power electrical control equipment which makes rigorous demands on the transistors as to input surges, changes in the control voltages and ambient temperature, etc.

These features have been confirmed by the excellent operation of the several tens of sets now in actual use in various fields.

Recent technical advances have resulted in a switch to silicon transistors and the widening of the application range has demanded a correspondingly wider range of operating conditions. From the point of standardization, Fuji Electric, with the aid of high level technical know-how from the West German Firm of Siemens, investigated various points concerning counting control and with these results developed the F-MATIC N series of transistorized digital control elements.

The F-MATIC N series consists of two families, the one can be used as standard elements in any digital control system including sequence control etc. and the other as function elements in counting control applications. This series will be introduced in this article.

II. FEATURES OF THE F-MATIC N SERIES

The F-MATIC N series is based on the most up-to-date techniques. It was planned for the wider range of applications expected in the future and developed taking account of following points.

1) The series must be available to any digital control equipment either electrical or electronic.

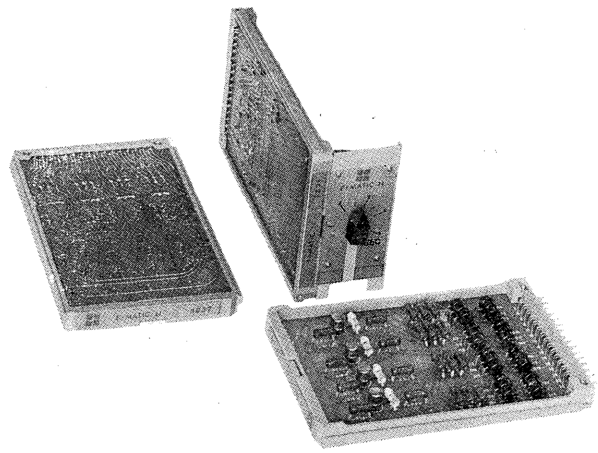


Fig. 1 Element of F-MATIC N

2) It must be highly stable, especially in high power control equipment required severe operating conditions.
3) The control circuits must be easily designed.
4) The series must be economical and very compact.
5) Equal weight must be given to both functions for general application and functions for special applications.

Features derived from the above points are as follows.

1. Introducing NOR Logic System

NOR (OR+NOT) elements are employed as basic logic elements in the F-MATIC N series. In addition, NAND elements are also used to reduce the number of elements to a minimum.

2. Various Types of Elements Available

Besides the logic elements, the standard family includes time elements, memory elements, input/output elements for external signals, and filter elements: there is considerable freedom of choice in any kind of digital control.

In the function family; more than 20 types of elements with such functions as counting, memory, arithmetical operation, synchronization etc. have been prepared so that any type of counting control is possible.

3. Function Elements for Counting Control

Counting control circuits can be constructed by combining and/or modifying various types of peculiar circuits. From this point a function family for counting control has been added along with the standard family to reduce circuit design problems, the number of external wirings and make the equipment more compact. The effect added by these elements are as follows.

1) Improvement of the space factor

In the standard family the number of elements on the printed circuit board is limited by the number of terminals and therefore there is a comparatively large amount of space left over. However, the number of input/outputs to the exterior is smaller when converted to functional elements so that the compactness can be increased and the equipment thus becomes smaller.

The results of studies of 2～3 examples indicated that 50～60% of the number of printed circuit boards were required compared to when the standard family elements are employed.

2) The number of external connections is reduced

Connections between the circuit elements are mainly made by the pattern on the printed circuit board and therefore the number of external wirings is reduced as compared with the standard element constructions. For example, the number of external connections of adder circuits for 4-digit decimal numbers is about 1/6 of that with the standard family.

3) The mental effort required in estimating and designing the equipment is reduced

With the standard drawings, it is unnecessary to make detailed sequence drawings as was done formerly. For this reason, estimation and design works are minimized considerably both as to effort and time required.

4) Reliability is improved because of standardization

Because the standardization of circuit construction, wirings and tests is possible, and the overall reliability of the equipment is improved. The use of printed circuit boards facilitates separation of the equipment into its various functional groups and makes maintenance, inspection, etc. easy.

4. Unified Input/Output Signal Specifications

The connection conditions for the elements, and the input/output signal capacity are clearly indicated by the use of original basic circuits (patent applied for), and input/ output signals are of uniform specifications throughout the entire series. Therefore control circuits can be constructed in any way desired.

5. Supply Voltage May Be Altered Over a Wide Range

The rated voltages are ±24 v for high power equipment and ±12 v for low power equipment, with tolerances between ±11.4 v and ±30 v. Unbalanced voltage changes within the range shown in *Fig. 2* are permissible without any hinderance of element operation.

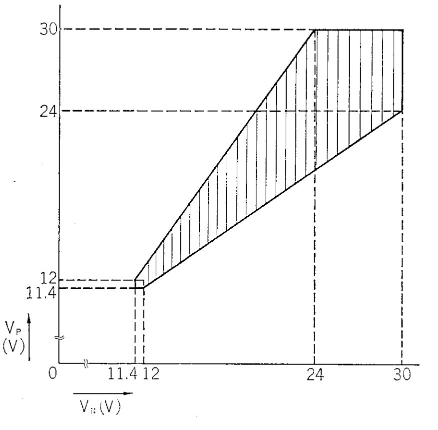


Fig. 2 Tolerance of supply voltage V_P and V_N

6. Ambient Temperature May Change Over a Wide Range

Reliable operation is assured for all elements over an ambient temperature range of −20C° to +65°C.

7. Circuits Are of Noise-Free Construction

To provide reliable operation against input surges, required especially in high power applications, each element consist of an integrated circuit and also has a threshhold value for noise signal in respect to input signal so that the sensitivity is low. For these reasons, the equipment is stable against noise pulses.

8. Wide Design Tolerances

All circuit components are largely derated and the constants of these components, were selected to withstand the worst possible operating conditions so that no troubles would arise during future operation considering all the changes which might be likely to occur over the years.

9. Compact Construction

The printed circuit board for each element contains the maximum number of components so that the spatial efficiency is high. Special connecting plugs and printed board frames have been developed to provide sufficient insulation space.

10. Application of New Element Symbols

The symbols for the elements which make up the control circuits must be such that each function and the various input/output terminals are indicated in an easy-to-read, distinct way. New symbols based on DIN standards are used which were developed as the result of various investigations.

III. BASIC CIRCUIT CONSTRUCTION OF THE F-MATIC N SERIES

The F-MATIC N series basic switching circuit as shown in *Fig. 3* is a diode coupled with common emitter transistor circuit. Switching of this circuit is carries out according to whether the standard zero potential M is applied at the input terminal E (corresponding to a "1" signal) or not (corresponding to a "0" signal). If M is not applied at the input, the base current of transistor T flows via R_b and R_c, T goes into the ON state, output terminal A is then at potential M and the output corresponds to a "1" signal.

On the other hand, if potential M ("1" signal) is applied at the input, the base potential of T becomes negative because of voltage division by R_b and R_a, T goes into the OFF state and the output corresponds to a "0" signal.

The values of constants employed, for all of the transistors and diodes in designing these circuits were obtained by considering the dispersion, temperature changes, and the extent of future changes of each component. In addition a sufficient operating margin was also employed.

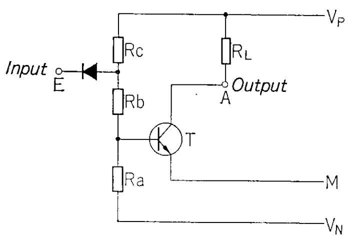


Fig. 3 Basic circuit of F-MATIC N

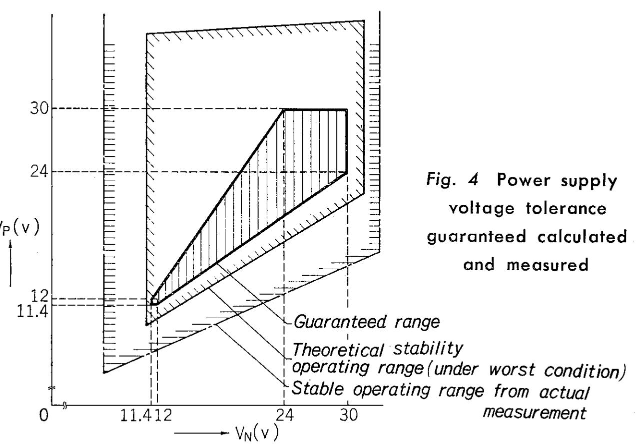


Fig. 4 Power supply voltage tolerance guaranteed calculated and measured

The resistance values are also chosen in consideration of resistance value errors as well as temperature changes and possible future alterations.

IV. COMMON SPECIFICATIONS AND CONSTRUCTION ON THE F-MATIC N SERIES

1. Common Specifications

The main specifications common to the entire F-MATIC N series are as follows:

1) Supply voltage

Two power sources are employed depending upon the positive potential V_P and negative potential V_N in respect to the standard potential M (OV).

Supply voltage tolerance range ± 11.4 to ± 30 v (See *Fig. 2*)

Percentage of pulsation tolerance less than 10% of dc voltage (peak to peak)

2) Sensitive frequency Below 10 kHz

3) Ambient temperature range −20°C to +65°C

4) Conservation temperature range −50°C to +85°C

5) Withstand voltage 2000 vac for 1 minute between element terminal and installation shelf (with the M potential not grounded)

2. Construction

The printed circuit board, installation shelves and cubicles used in the F-MATIC N series are newly developed as Fuji Electric standard,

1) Printed circuit boards

The dimensions of the printed circuit boards are shown in *Fig. 5*. As was described previously, each of the printed boards contains the maximum number of individual elements and the 31 terminal plugs and printed board frames posses sufficient insulation distance between the terminals and ample insulation withstand, especially for high power applications.

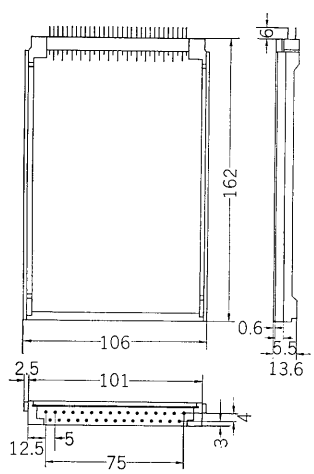


Fig. 5 Dimensions of F-MATIC N element

2) Installation shelves

Fig. 6 shows a shelf of printed circuit boards. These shelves will hold a maximum of 31 printed boards.

3) Cubicles

Fuji Electric has developed a standard cubicle for electronic control equipment and it is possible to

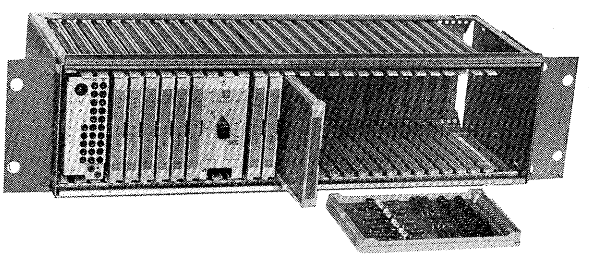


Fig. 6 Shelf of elements

install the F-MATIC N series, analog control elements (TRANSIDYN) thyristors etc. in this cubicle.

An external view of the cubicle is shown in *Fig. 7*.

V. TYPES OF ELEMENTS IN THE STANDARD FAMILY FOR GENERAL USE

The name, type, symbol and functions of each of the elements of the standard family for general use are given in *Table 1*.

VI. OPERATION AND CONSTRUCTION OF THE STANDARD FAMILY ELEMENTS

1. Logic Elements

All logical functions are possible in practice with various combinations of only NOR circuits which are used as standard logic elements in the F-MATIC N series. However, NAND elements are also employed so that the number of elements needed can be kept to a minimum so that the equipment is more economical. Each element has a low sensitivity in respect to noise pulses because of the use of integrated circuits and therefore the entire system is basically stable in respect to noise. AND elements and OR elements are used as fail safe logic components. Other supplemental elements are provided in order to increase the number of inputs for each elements or distribute the signals.

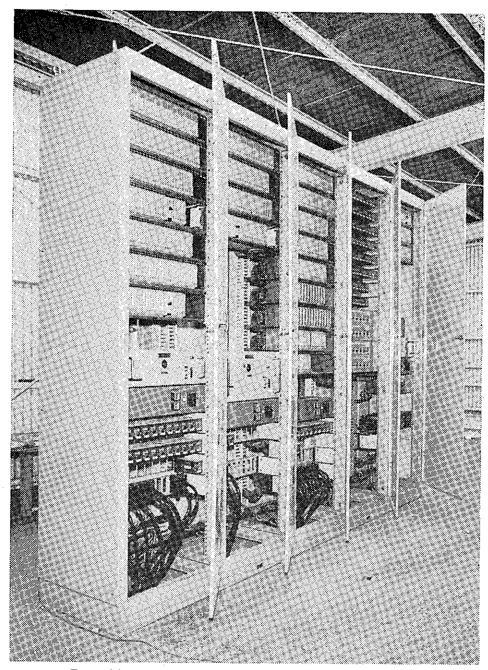


Fig. 7 Outer view of universal cubicle

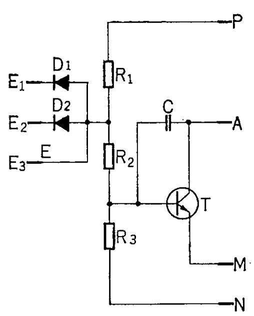
Connection diagram symbol and truth table for the NOR element NR are shown in *Fig. 8*. The slope of the output signal rise is weak because of the integrating operation of the capacitor *C*.

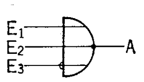
As shown in *Fig. 9*, the NAND elements ND consists of resistors and diodes with AND functions (R_1', D_1, D_2, R_1'', D_3 and D_4) and a signal inverter circuit using transistor *T*.

Table 1. Standard Family for General Use

Classification	Name	Model	Symbol	Number of contained elements (per printed board)	Application and Function	
Logical elements	NOR element	NR 31		9	Logical connection of binary signal ("1", "0")	2 input NOR
		NR 32		7		3 input NOR
		NR 33		4		6 input NOR
	NAND element	ND 31		9		2 input NAND
		ND 32		4		3 input NAND
	OR expander element	OE 31		9	Expanding the number of OR inputs of each element	
	Diode branching element	BR 31		9	Signal branching	
	AND element	AD 31		6	Logical connection of binary signal, especialy when high reliability is required	3 input AND
		AD 32		4		6 input AND
	OR element	OR 31		5		4 input OR
	Dynamic gate element	DG 31		9	Generation of negative pulse voltage for dynamic flip-flop triggering	
		DG 32		9		

Classification	Name	Model	Symbol	Number of contained elements (per printed board)	Application and Function	
Time elements	Time delay element (for short time)	TS 31		1	Delaying of binary signals	10 series, adjustable types, 1 msec～10 sec range
		TS 32		2		11 series, fixed type, 1 msec～2.5 sec range
	Time delay element (for long time)	TL 31		1		7 series, adjustable type, 1 sec～180 sec range
		TL 32		2		8 series fixed type, 2.5～24 sec range
	Monostable element (for short time)	MS 32		2	Temporary holding of binary signals for set time	11 series fixed type, 1 msec～2.5 sec range
	Monostable element (for long time)	ML 32		2		8 series fixed type, 2.5～240 sec range
	Astable element	AS 32		1	Generation of square-waves for clock pulses, flicker signals etc.	13 series fixed type, 1 Hz～10 kHz range
Memory, counter elements	Static flip-flop element	FS 31		4	Binary signal storage	
	Dynamic flip-flop element	FD 31		3	Component for counters, registers etc.	
Input element	Schmitt trigger element	SC 31		4	Signal conversion of contact input, wave shaping and voltage level detection.	
		SC 32		3	Voltage level detection with stabilized bias.	
	Comparator element	CP 31		1	High sensitivity comparsion and detection of voltage magnitude	
	Filter element	FL 31		8	Reduction of noise generated by chattering of contact and noise induced into the lead wires by magnetic or static induction	
Output elements	NOR type power amplifier element	PN 32		6	1. Large output logic element 2. External load (relay, lamp etc.) drive	Max. output current 100 ma
	OR type power amplifier element	PA 32		4	1. Large output logic element 2. External load (relay, lamp etc.) drive	Max. output current 100 ma
		PA 33		4	External load drive	Max. output current 200 ma
Auxiliary elements	Core memory element	MC 31		4	Used in combination with flip-flop circuits to return the circuits to the state they were in prior to the power interruption upon recovery of the control voltage	
	Initial reset element	IR 31		1	Initial setting of flip-flop elements to optional signal condition at supply voltage closing	
		IR 32		1	Same as IR31 (But used in combination with core memory element MC31)	
	Test element	LT 31	—	1	Signal checking of elements under operating conditions	

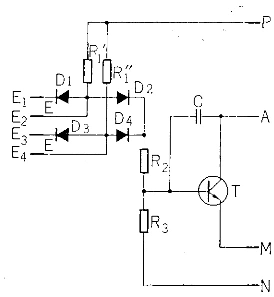


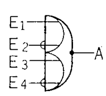


E_1	E_2	A
0	0	1
0	1	0
1	0	0
1	1	0

Note: The input terminal not shown in this table is not connected

Fig. 8 Connection, symbol and truth table of NOR element NR





E_1	E_3	A
0	0	1
0	1	1
1	0	1
1	1	0

Note: The input terminal not shown in this table is not connected

Fig. 9 Connection, symbol and truth table of NAND element ND

2. Time Elements

The F-MATIC N series contain three different types of time elements. 1) time delay operation, 2) monostable operation and 3) astable operation. Circuits are employed which are almost entirely uneffected by any changes in supply voltage. As to the elements of type 1) and 2) repeat operation with short interval is possible due to the quick reset characteristics. There are both short time delay and long time delay elements for both the type 1) and type 2). In addition, the delay time of type 1) is either fixed or adjustable.

The connection diagram of the long time delay element TL is shown in *Fig. 10*. The portion on the left is a time circuit while the part on the right is a Schmitt trigger circuit. A so-called Miller integrator circuit is employed in the time circuit.

When a "1" signal is applied to the input E in *Fig. 10,* causing transistor T_4 to turn off, voltage proportional to negative control voltage V_n derived from voltage dividing resistors R_1 and R_2 is applied to the Miller intergrator input. Resultant output voltage v_A can be found from the following equation.

$$v_A(t)=m\frac{V_N}{CR}t \quad (m: \text{proportional constant}) \quad \cdots\cdots (1)$$

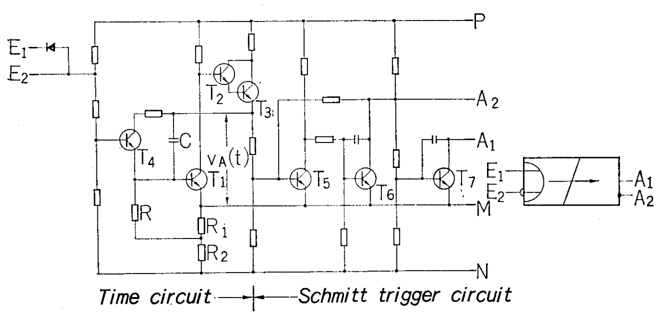


Fig. 10 Connection and symbol of time delay element TL

On the other hand, since the Schmitt trigger circuit operating value V_K is also proportional to V_N as will be described later,

$$V_K=nV_N \quad (n: \text{proportional constant}) \cdots\cdots (2)$$

As operating condition is (1)=(2), delaying time t_s will be

$$t_s=\frac{n}{m}\cdot CR$$

which is theoretically independent to the supply voltage.

The short time delay element TS differs from the above time circuit only in that it employs a passive circuit. The TS is more economical than the TL for time delays below 2～3 sec. The adjustable type of both the TS and TL, the delay time can be adjusted by means of the knob on the front surface of the printed board.

3. Memory Elements

There are two types of memory elements in this series: the static type flip-flop which is triggered by dc signal and the dynamic type which is triggered by signal change.

Formerly flip-flop circuits were sometimes subject to misoperation due to noise pulses and sudden changes in supply voltage, but only reliable circuits with sufficient consideration given to these points are employed in the F-MATIC N series.

The static type flip-flop FS as shown in *Fig. 11* contains two NOR circuits each of which are cross connected so that the output of one is the input of the other. This circuit, assures reliable operation in respect to changes in supply voltage.

The another method to switch the flip-flop circuit from one stable condition to another, is to cut-off the base current of the transistor in conducting state by applying a negative voltage pulse. In the F-MATIC N series, a dynamic gate DG is provided to generate this negative trigger pulse.

Fig. 12 shows the connection diagram of the dynamic type flip-flop element FD along with its trigger circuit. In this element, set or reset are performed by signal rises. In the dynamic gate, no negative pulse develops at the output until the amount of

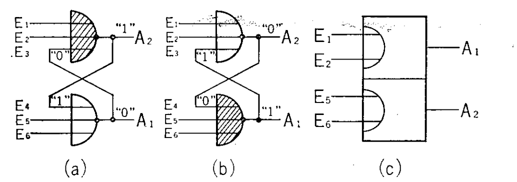


Fig. 11 Flip-flop element FS

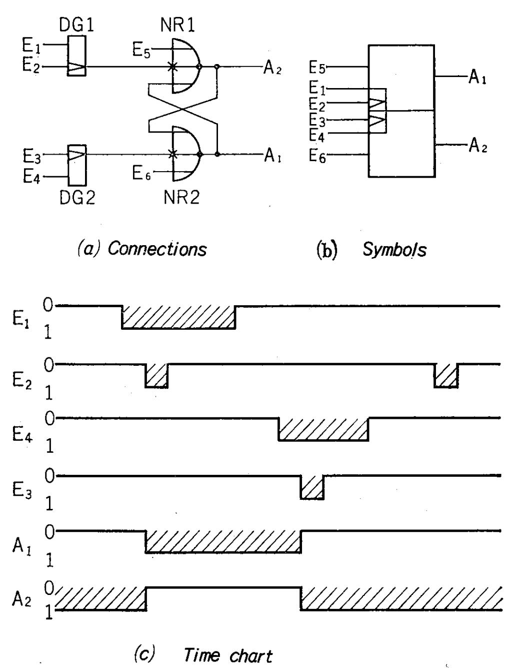


Fig. 12 Basic connection of dynamic flip-flop element FD

potential change at the trigger terminal E_2 reaches the certain threshold value. In other words, this circuit operates differentially in repect to changes in the input signal, but it is extremely stable in repect to noise pulses from the exterior or due to supply voltage changes. The FD is used as the basic element in memory equipment as well as counters, registers etc..

4. Input Elements

Generally when signals are introduced into a control system from exterior sources or some other control system, these signals usually do not meet the requirments of the system in respect to magnitude or rise times. Also in many cases noise signal is superposed because of static and magnetic induction or chattering of contact signal.

The F-MATIC N series has input elements which include Schmitt trigger elements used for voltage level detection, wave shaping, and signal conversion; comparator elements used in high sensitivity comparison of minute voltages; and filter elements for the elimination of noise pulses.

Fig. 13 shows the Schmitt trigger element SC. This element is actually a 2-stage transistor amplifier circuit. This element contains several input terminals which are used for input signal or bias signals to establish the operating value. Operating value can be selected over a wide range by terminal combination. The operating value in respect to the resistance value R_E (R_2 in *Fig. 13*) at the terminal where the input voltage is applied and the resistance value R_N (R_{10} in *Fig 13*) at the input terminal for bias can be expressed as follows:

$$V_K \doteqdot \frac{R_E}{R_N} V_N \qquad (3)$$

Jump characteristics and their hysteresis characteristics can be obtained by applying positive feedback from the output terminal to one input terminal. The hysteresis value $V_K - V_R$ (V_R is the reset voltage) in respect to the resistance R_R (R_8 in *Fig. 13*) at the feedback input terminal can be shown by the following equation:

$$V_K - V_R = \Delta V \doteqdot \frac{R_E}{R_R + R_6} V_P \qquad (4)$$

This value can be selected optionally by any combination of R_E and R_R. As can be seen from Equations (3) and (4), V_K and ΔV tend to change in accordance with the supply voltage. Therefore another element having a stabilized bias source has been prepared to enable voltage detection.

5. Output Elemets

In almost every control system, the output is eventually used to drive the external load (relay, magnetic valve etc.) or to light a lamp for indication. The F-MATIC N series contains power amplifiers as shown below and in addition to external load driving, there are also elements which can be used as logic elements with large output capacity. All of these elements contain circuits to suppress excess voltage which could arise because of switching the inductive loads.

Fig. 14 shows the connection diagram of power amplifier element PN. This element consists of 2 transistors and the first stage transistor T_1 is employed as an emitter follower so as to effectively utilize the current amplification factor. Since this operation is completely the same as a NOR circuit, it can also be used as a NOR element with a large output capacity and it contains a capacitor C_1 to regulate the switching rise time as in other elements. Diode D_3 is used for overvoltage suppress in respect to inductive loads.

Since the power amplifier element PN also possesses NOR function, the input and output signals are of reverse polarity. However a power amplifier PA is provided for cases of the same polarity which can be employed for general use, especially when combined with AND, or OR circuit etc.

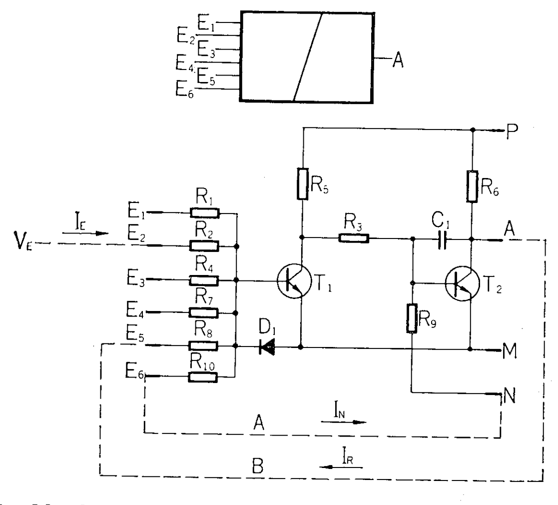


Fig. 13 Connection and symbol of Schmitt trigger element SC

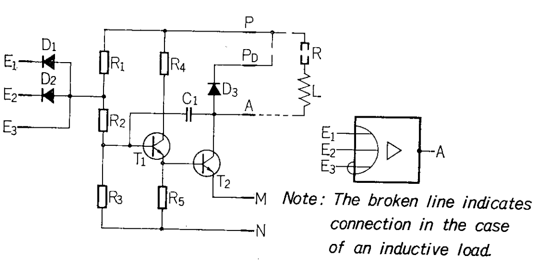


Fig. 14 Connection and symbol of power amplifier element PN

VII. TYPES OF ELEMENTS IN THE FUNCTION FAMILY FOR COUNTING CONTROL

The names, type and functions of all elements in function family for counting control are shown in *Table 2*.

Table 2 **F-MATIC N Function Family for Counting Control**

Classification	Name	Model	Application
Counter Element	Counter element	CT 301	Pulse counting in one direction
	High-speed carry element (for counter)	CT 351	Shortening of carry time
	Reversible counter element	CR 301	Pulse addition and subtraction
	High-speed carry element (for reversible counter)	CR 351	Shortening of carry time
	Direction control element	CR 361	Switching control of the counting direction
	Sign discriminating element	CR 362	Discriminating of sign of counted value
Readin Element	Read-in gate element	ST 301	Signal read-in to counter registor etc.
	Read-in control element	ST 351	Read-in command control
Comparator Element	Coincidence detector element	CN 301	Coincident detection of binary signals
	Large/small comparator element	CN 311	Large/small comparison of binary signals
	Large/small comparator element	CN 312	Large/small comparison of binary signals when No. of bits is large
Register Element	Registor element	RG 301	Register, shift registor, ring counter
	Registor element	RG 302	Register, shift register, ring counter
	Reversible shift registor element	RG 311	Reversible shift register, ring counter
Adder Element	Full adder element	AF 301	Full adder
	Aiken correction element	AF 351	Correction of Aiken prohibited code developed as a result of addition
	Addition control element	AF 361	Switching of complement gate, discrimination sign (+, −) for result of addition
Frequency Divider Element	Frequency divider gate element for Aiken code	FC 301	Read out of counterd value for pulse division
	Frequency divider gate element for Aiken code	FC 302	Read out of counterd value for pulse division
	Frequency divider gate element for pure binary code	FC 303	Read out of counterd value for pulse division
	Frequency divider output element	FC 351	Shaping of divider output pulse
Synchronizer Element	Pulse synchroniger element	SY 301	Synchronizing of pulse series with another pulse
	Synchronized pulse control element	SY 351	Control of addition/subtraction pulse to reversible counter
Code Convertor Element	Aiken/$_{10}C_1$ code converter elemet	CC 301	Conversion from Aiken code to $_{10}C_1$ code
	Aiken/$_{10}C_1$ code converter element	CC 302	Conversion from Aiken code to $_{10}C_1$ code (digital indicator tube drive)
	$_{10}C_1$/Aiken code converter element	CC 303	Conversion from $_{10}C_1$ code to Aiken code
	Aiken/BCD code convertor element	CC 311	Conversion from Aiken code to BCD code
	BCD/Aiken code converter element	CC 312	Conversion from BDC code to Aiken code

VIII. OUTLINE OF THE F-MATIC N COUNTING ELEMENTS

The functions and applications of the elements in function family for counting control are given below.

1. Counter Elements

The basic counter elements are the CT301 and the reversible CR301. In counters where the number of digits is large, carrying digits takes long time and the counting frequency range is thus limited. In order to eliminate this, high speed carrying element CT351 (for counter use) and CR351 (for reversible counter use) are provided. Reversible counters require counting direction control, and a means to discriminate the sign of counted values [POSITIVE] or [NEGATIVE]. For this reason, direction control element CR361 and sign discriminating element CR362 are employed.

Counter element CT301 is a basic element of counters which can perform addition or subtraction in one direction only. Its construction is shown in *Fig. 15*.

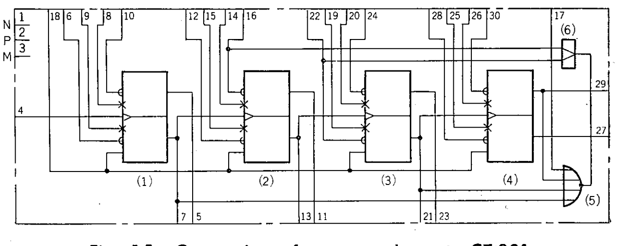


Fig. 15 Connection of counter elements CT 301

Counting of 1 digit (4 bits) is possible in each element and digits can be carried over merely by connecting the required number of digits in cascade. The NOR circuit (5) is a code correction circuit for operating binary four bit counters as decimal counters in accordance with the Aiken code. If the lock terminal 17 of the NOR circuit (5) receives a "1" signal, the Aiken correction is locked and the counter operates as a binary counter.

2. Synchronizer Elements

To add or subtract the number of 2 train of pulse inputs, elements located in front of the counter or reversible counter elements are employed. By combining these elements, counting of more than one train of pulse becomes possible.

The pulse synchronizer element SY301 synchronizes input pulses with another pulses. As is shown in *Fig. 16* (*a*), pulse addition is possible by combining with counter CT301.

The pulse control element SY351 must be used because of trouble which arises in subtracting when both train of pulses are received simultaneously. In such cases, the SY351 controls so that no counting pulse will be applied to the reversible counter. It is used in combination with the SY301 as shown in *Fig. 16* (*b*).

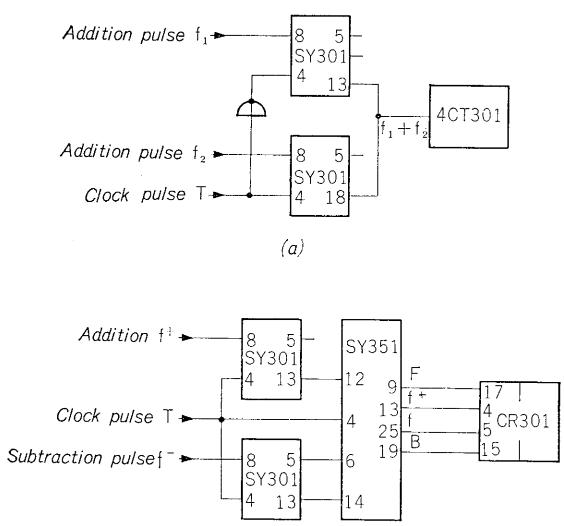


Fig. 16 Addition and subtraction of pulses

3. Read-in Elements

Many cases arise with counters, registers etc. where it is necessary to read-in predetermined signals and read-in elements are used for this purpose.

Read-in gate element ST301, if a read-in command is applied, this element sends the signal to the counters or registers connected to it.

Read-in element ST351 transmits the read-in command to ST301 and also serves to lock the Aiken correction circuit during read-in as well as to reset the counters to "0" preceding read-in process.

4. Frequency Divider Elements

Such a pulse frequency division as $f_A = f/n$ (n: interger, f: frequecy)can be carried out easily by means of counters. However, in actual practice, there are many cases when it is convenient to perform divisions of the type $f_A = K \cdot f$ ($K<1$). Frequency divider elements are used in combination with counters especially for this latter type of division, and consist of frequency divider gate elements FC301, FC302 and FC303 as well as frequency divider output element FC351. These elements possess one more big advantage in that the coefficient K can be set optionally by either the Aiken code or binary code signals, so that they can be employed for all type of digital ratio control.

The frequency divider gate elements FC301, FC302 and FC303 are basically the same, and pick up certain numerical values in accordance with the dividing ratio from counted values of the counter with which each is combined.

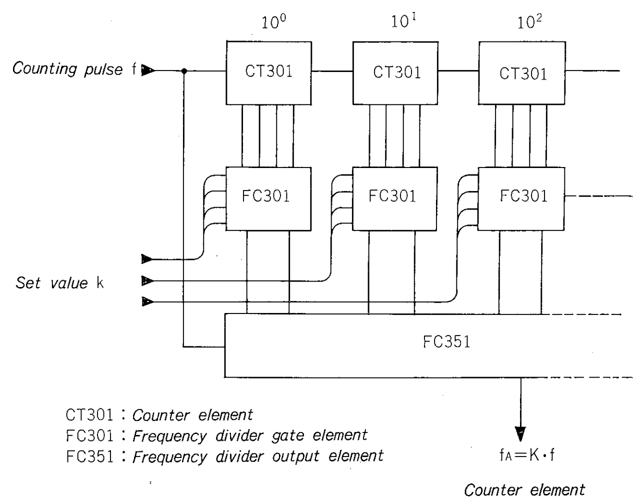
Each gate element consists of four gates, and one is used for one digit.

For example, each gate of FC301 read out one, two, four, or two counted values (total of nine) without duplication from ten values (0–9) obtained from the counter.

The number of each readout value is in accord-

Table 3 **Combinations of Numbers Read-Out by Frequency Divider Gate Element FC301**

Type	Gate terminal applied "1" signal	a	b	c	d
FC 301	Readout counted value	5	2, 7	1, 3, 6, 8	4, 9
	Number of readout counted value	1	2	4	2



CT 301 : Counter element FC 301 : Frequency divider gate element
FC 351 : Frequency divider output element

Fig. 17 Frequency divider circuit

ance with the weighting of aech bit of the Aiken code. Each gate has a gate terminal, and therefore if the "1" signal combination given at these terminals is according to the Aiken code, the total number of the read out value from each gate becomes a number which agrees with that Aiken code. If the divider ratio is small, the number of counter digits should be increased, for example, if the minimum unit is 1/1000, 3 decimal digits are required.

The frequency divider output element FC351 can transmit divided output pulses which is synchronized to the input pulses when numbers are readout from the counter through the FC301, (or FC302, or FC303.)

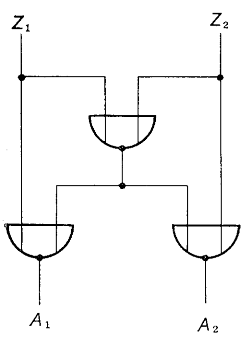
Fig. 17 shows the construction of a divider circuit combined with a decimal counter in Aiken code.

Generally, the divider ratio K is given by k/k_0 where k is the set value of the gate terminal of the divider gate element and k_0 is the counter capacity.

5. Comparator Elements

Comparator elements are provided to decide whether both numbers [coincident] or whether one is [large] or one is [small] etc. when comparing two numbers. Coincidence detection is made with comparator element CN301 while decisions as to large/small are made with elements CN311 and CN312. The former can also be used in code converter circuits, parity circuits, and complement gates.

Fig. 18 shows the basic circuit of a comparator element. With this element, it can be decided which of two 1-bit numbers Z_1 and Z_2 is the larger or smaller and also coincidence can be detected, Comparator element CN301 is a so-called EXCLUSIVE OR circuit with A_1 and A_2 connected in common as shown in *Fig. 18*. In addition to coincident detection of two numbers, it can also be used as an complement gate, as a circuit which converts between the Gray code and binary code ; or as a parity circuit.



Large/small between Z_1, Z_2	Input Z_1	Input Z_2	Output A_1	Output A_2
$Z_1 > Z_2$	1	0	0	1
$Z_1 < Z_2$	0	1	1	0
$Z_1 = Z_2$	1	1	0	0
	0	0	0	0

(a) Basic circuit
(b) Truth table

Fig. 18 Basic circuit of comparator element CN

6. Adder Elements

The basic function of this elements is to add two 1-bit numbers, X and Y. Relationships of X and Y, the sum S and carry C_A can be expressed by the following equations.

$$S = X \cdot \overline{Y} + \overline{X} \cdot Y \quad (5)$$

$$C_A = X \cdot Y \quad (6)$$

This can be made into a logic cuicuit known as a half adder as shown in *Fig. 19*. When two numbers consisting of more than one bit are to be added, another adding functions required since the carry signal C_E is given from the low order bit to the high. This can be accomplished by using two half adder units together, forming what is known as a full adder.

Table 4 **Truth Table of Half Adder**

Input	X	0	1	0	1
	Y	0	0	1	1
Output	S	0	1	1	0
	C_A	0	0	0	1

In the F-MATIC N series, full adder element AF301 is used in the adder circuit. When adding two numbers in the Aiken code, prohibited codes are resulted so that Aiken correction element AF351 is employed to change those prohibited codes into the correct ones. When adding two numbers with opposite signs, a complement gate is required, and comparator element CN301 can perform this function.

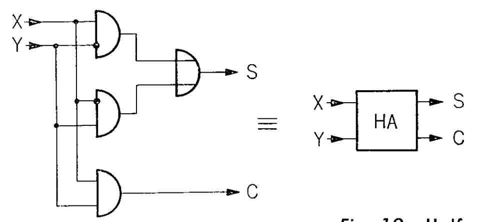


Fig. 19 Half adder

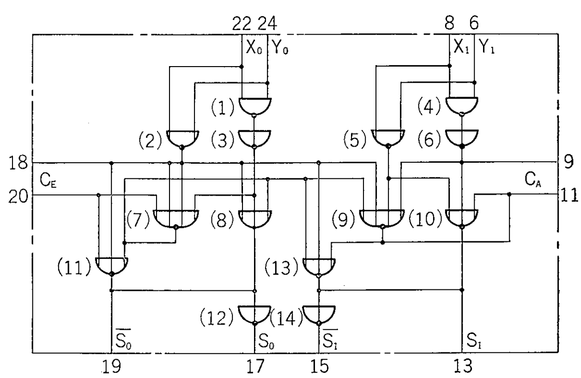


Fig. 20 Full adder element AF 301

For addition of two numbers in various combinations of signs, complement gate, +1 correction of the added result and a decision as to whether the sum is positiive or negative are all required. For these purposes the addition control element AF361 is employed.

Full adder element AF301 consists of 2 units of complete full adders as shown in *Fig. 20*. Complete addition of 2-bits is possible with each element. Addition of the carry signal C_E from the lower digit and the two numbers $X(X_0, X_1)$ and $Y(Y_0, Y_1)$ is carried out, and the sum $S(S_0, S_2)$ as well as the carry signal C_A to the higher digit form the output.

7. Register Elements

Register elements RG301 and RG302 are employed in a ring counter construction which is used for frequency division, signal scanning etc, or as shift registers or resisters for signal storage. Shift register element RG311 is also provided to perform shifting in both the positive and reverse directions.

Register element RG301 as shown in *Fig. 21* consists of 4 dynamic type flip-flop circuits and can store 4 bit signals. When operating as a shift register, the two points in the chain line as shown in *Fig. 21* are connected and at every change of the input signal from "1" to "1" the signal conditions are shifted by one stage to the next in flip-flop circuit. Ring counter operation is possible by connecting the broken lines as shown in *Fig. 21.*

Table 5 Code Converter Elements

	Type	Function	Application
For Aiken code⇄ $10C_1$ code conversion	CC 301	Aiken→$_{10}C_1$	For logical connection
	CC 302	Aiken→$_{10}C_1$	For drive of digital indicator tube
	CC 303	$_{10}C_1$→Aiken	For logical connection
For BCD code⇄ Aiken code conversion	CC 311	Aiken→BCD	For logical connection
	CC 312	BCD→Aiken	For logical connection

8. Code Converter Elements

The code converter elements employed in this series are as shown in *Table 5.* The conversion of a signal from an external BCD code is also considered.

IX. CONCLUSION

An outline of the newly developed F-MATIC N series of transistorized digital control element has been given above. The F-MATIC N series was developed on the basis of Fuji Electric's long years of experience and superior techniques in the manufacture of contactless control elements for high power control. As was described in this article, the equipment possesses many advantages and can be utilized in every type of digital control equipment. F-MATIC N series has been widely used since the autumn of 1967 for such things as valve control in chemical plants, digital control in the iron and steel industry, etc., and in all cases test results and actual operation performance have proven that the series lives up to the original intentions of the manufacturer. Fuji Electric is confident that F-MATIC N series employed as a standard component in digital control equipment will amply satisfy requirement in respect to utility, reliability and stability.

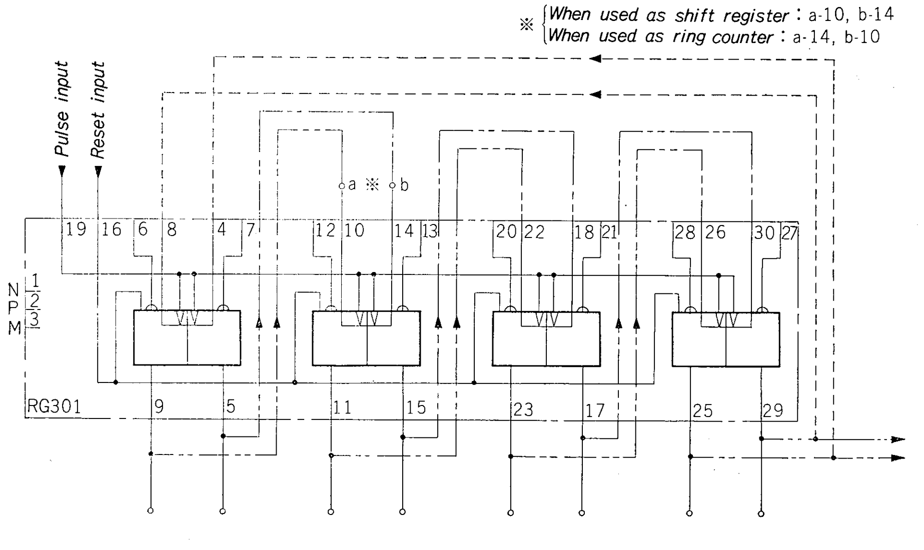


Fig. 21 Connection of register element RG 301