The All Relay PABX

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Introduction

This PABX was designed to prove that it could be done using just 3000 type relays.

The original PABX was donated to a junior school in Wiltshire in the mid 1980's so as they could get youngsters used to using the telephone. It was still working when I last visited the school a couple of years ago.

The design was based on a 32 position standard relayset and the basic specification was that all the required components could be mounted in that space. A separate PSU was built using a transformer with an output of 22V RMS and the ringing supply was derived from a BT PBX Static Ringing Converter.

The tone supply was derived from the bridge rectifier output before the smoothing capacitor and tapped off using a 1µF capacitor and a 200 O resistor. This gave a single tone of 100Hz which was used for Dial Tone, Busy Tone and Ring Tone, only the cadences being different.

Design Details

The relays used in the PABX are all standard 3000 type relays which have in some cases been modified slightly.

The EF, LF and RF relays are all derived from selector "A" relays using the two 200O windings and omitting the 570O winding. The spring piles on these relays sometimes contain an "x" operating contact. This was achieved by adding a spacer into the spring piles either at the bottom or just above the "x" contact and then adjusting the armature travel to suit. I chose the coil for the EF, LF and RF relays on the basis that there were plenty about; the maintenance boys in the Strowger exchange used to change them regularly when the switches failed the routiner tests. Resistors are placed across one winding to provide a "slugging" effect to ensure better core saturation and manage the release lag.

The "EB", "LB", "F" "LA" and "LC" and "EC" relays were pulled from a 4000 type final selector, the LA, LB and LC and EC being the former "A", "B" and "CD" relays respectively.

MF has a 5000O coil. The remaining relays are various and selected by availability, the only special among them being "TGR" which probably came from a CFC relayset, but careful selection of the capacitors will provide the desired output cycle regardless of the coil winding resistance. The only stipulation is that it has a copper cheek to the coil.

All together, there are 30 relays and a transformer that came from an auto-auto with MOJ relayset which occupies two relay-plate spaces. This achieved the design criteria.

The relays associated with the local bridge are:-

LA, LD, LB, LC, LCR and F

With the exchange bridge:-

EA, ED, EB, EC, TA, TB and TC

Common relays are:-

TGR, MF

Relay Layout of original design:

MF	TR1
1RF	
1LF	EA
1EF	ED
2RF	EC
2LF	EB
2EF	TA
3RF	TB
3LF	TC
3EF	TGR
4RF	LB
4LF	LA
4EF	LD
5RF	LC
5LF	LCR
5EF	F

All large resistors and capacitors mounted in rear component box.

Note that there is an electromagnetic screen on the LA relay.

All diodes are 1N4004 or equivalent.

Resistors are 0.5W except R1 which is 5W.

All extension telephones must be rotary dial and fitted with an earth recall button.

Circuit Operation

Relay MF is operated while the power supply is providing an output. If the mains fails, MF releases and connects the exchange line to extension 1 so as calls can still be made to the public exchange.

Extension to Extension Call

Under idle conditions all the extensions are connected to the common call circuit, LB4, nRF2, nEF2, nLF2, extension loop, nlf1, nEF1, nRF1, nLF coil a-b, LB2, TB4 LA coil d-e LB5 to battery.

If an extension goes off hook, the LA relay will operate. The LD (differentially wired) relay coils are shunted to ensure that the nLF relay will fully flux. In the event that two or more extensions go off hook simultaneously, the lowest number extension circuit has priority.

LA operates
- LA1 provides fast hold path for nLF
- LA2 operates LB

LB operates
- LB1 consolidates hold path for nLF
- LB2 & LB3 disconnect nLF operate path
- LB4 removes shunt from relay LD
- LB5 removes shunt from relay LD and provides self-hold path for LB and operate path for TGR
- LB6 prepares EA operate path

Relay TGR is a self-interrupting relay which has a variable operate/release ratio. This is managed by the 270µF and 15µF capacitors. With both capacitors in circuit, the operate/release ratio is approximately 3:1, with only the 15µF capacitor in circuit it is approximately 1:1.

The extension receives dialtone via the LA relay tone coil. An extension can be dialled.

The first dial pulse releases LA

LA releases
- LA1 ineffective
- LA2 operates relay LC from the LB4 earth

LC operates
- LC1 operates 1RF
- LC2 spare
- LC3 disconnects relay F to prevent unwanted ringing of extensions during selection.
- LC4 operates relay LCR

LCR operates

LCR1 provides hold path for nLF relay
LCR2 spare
LCR3 holds itself to LB4 earth
LCR4 disconnects dialtone

LA reoperating
LA1 ineffective
LA2 prepares release path for LC

If further pulses are received, LA will operate in sympathy. The nRF relays will operate sequentially up to 5 digit pulses, any further pulses are ineffective.

LA releasing
LA1 operates 1RF and 2RF in series

This process continues until 5RF is operated.

At the end of dialling with LA reoperated for longer than approx 120mS, relay LC will release.

LC releasing
LC1 Provides hold path for nLF
LC3 applies ringing to the selected extension.

Ringing phase and ringing is sent to line at the cadence generated by relay TGR

TGR interacting
TGR1 self-interrupts itself
TGR2 spare
TGR3 provides ring tone
TGR4 provides interrupted ringing

Stable phase until extension answers.

Extension Answers

F operates
F1 holds itself
F2 disconnects ring tone
F3 disconnects test chain and relay TRG speeds up due to reduced capacitance
F4 disconnects nRF hold path and operates the associated nLF relay via nRF5 contact connecting the called extension to the speech bridge.

The circuit is now in the stable speech phase and remains thus until both parties have cleared or an interruption occurs from the exchange bridge (see below).

Called Extension Busy

The circuit behaves as above until the dialling phase is complete. If the extension dialled is either the same as the calling extension or is engaged on an external call, the

associated nRF6 contact will unbridge the nEF6 or nLF6 contact. This will have the effect of increasing the speed of the TGR relay so that busy tone is extended to the caller at TRG3.

Exchange Call

If the internal bridge is free, then the call proceeds as above until dialtone is received. At this point the calling extension presses the earth button and unbalances the line.

LD operates over coil e-d, a-b being shorted by the extension earth.

- LD1 holds itself to earth at LB4
- LD2 operates relay LCR
- LD3 increases TGR speed
- LD4 releases the calling nLF relay at nLF3

The earth on the extension loop now operates the associated nEF relay through LB6 (operated) to battery at EA coil d-e. This also operates the EA relay.

EA operates

- EA1 operates EB and provides fast hold path to nEF via the associated nEF3 contact
- EA2 provides forward loop to public exchange line

EB operates

- EB1 provides self hold path and full hold path to nEF
- EB2 disconnects the EA operate path to ensure EA doesn't operate prematurely
- EB3 disconnects common bell circuit
- EB4 switches tone path

The extension now receives dialtone from the public exchange and can originate an external call. Relay EA follows the dial pulses and repeats them to line at EA2. Relay EC operates on the first dial pulse.

EC operates

- EC1 has no effect at this point
- EC2 provides clean dialling loop

The call remains in a stable state.

It is now possible for an internal call to be established as above.

If the external call needs to make an enquiry or pass the call to another extension then this is activated by the extension pressing the earth button. With the button pressed, relay ED will operate:

ED operates

- ED1 operates relay TA

TA operating

TA1 provides operate path for relay TB and a self hold path via coil a-b
TA2 provides holding loop for the exchange call
TA3 & TA4 divert the exchange bridge to the LA relay, initially via the 1µF capacitors.
TA5 & TA6 are ineffective at this stage

TB operates
TB1 disconnects TA original operate path
TB2 prepares a tone path to LA
TB3 operates relay TC
TB4 disconnects relay LA operate path

TC operates
TC1 & TC2 short the bridge capacitors and enable LA operate path via the bridge transformer
TC3 provides alternate hold path for itself
TC4 prepares alternative hold path
TC5 prepares alternative hold path
TC6 provides additional holding loop to exchange line to prevent a momentary forward disconnection during reconnection to extension after query

The exchange bridge now operates the LA relay and an internal query call can take place as an extension to extension call above.

If the caller wishes to revert to the exchange call, then the earth button is again pressed operating ED again.

ED operates
ED1 provides hold path for TB and removes hold path for TA which releases

TA releasing
TA1 ineffective
TA2 prepares to remove the holding loop from the exchange line
TA3 & TA4 restore the bridge to the exchange line
TA5 & TA6 restore hold paths

ED releasing when button restores
ED1 removes hold path for TB which releases

TB releasing
TB1 ineffective
TB2 removes tone path to LA
TB3 removes operate path for relay TC
TB4 reconnects relay LA operate path

Relay TC will release when LB4 restores.

TC releasing
TC1 & TC2 ineffective
TC3 ineffective

TC4 ineffective
TC5 ineffective
TC6 removes holding loop to exchange line

The exchange call now proceeds and the same process can again occur if a further inquiry is necessary.

In the event that an internal call is in progress when an inquiry is attempted, it is possible for the exchange caller to force release of the internal call if required. Initially, warning tone is connected to the internal call from TB2. The TGR relay will be pulsing at busy tone speed and the contact TGR2 will provide a clicking tone in the internal bridge circuit to warn the callers that an enquiry call is being attempted. They can then clear the call in the normal way. If, however, the internal link is held through a fault, the exchange caller can force the release of the internal bridge by dialling a "1".

The circuit state is as above except that relay TC is not operated because its operate path is short circuited by earth from LB4 via TC3 normal. When the caller dials "1" relay EC operates

EC operates
EC1 removes the hold path for the nLF relay(s)

TC operates when LB4 is restored

The call proceeds as above once relay TC is operated.

Call Transfer

If after making an enquiry the extension wishes to pass the call to the called extension, all that is required is for the extension to go on hook. This will release the EA relay.

EA releasing
EA1 starts slow release of EB and releases relay TA
EA2 ineffective since TA2 is operated

EB releasing
EB1prepares operate path for nEF relay
EB2 ineffective
EB3 reconnects common bell circuit
EB4 switches tone path

TA releases
TA1 ineffective
TA2 removes the holding loop from the exchange line
TA3 & TA4 restore the bridge to the exchange line
TA5 restore hold paths
TA6 operates the associated nEF relay of the called extension

All other relays ineffective.

The EA relay will reoperate when the new extension line is connected via the nEF relay operating and will proceed as above.

Internal Bridge Busy, External Bridge Free

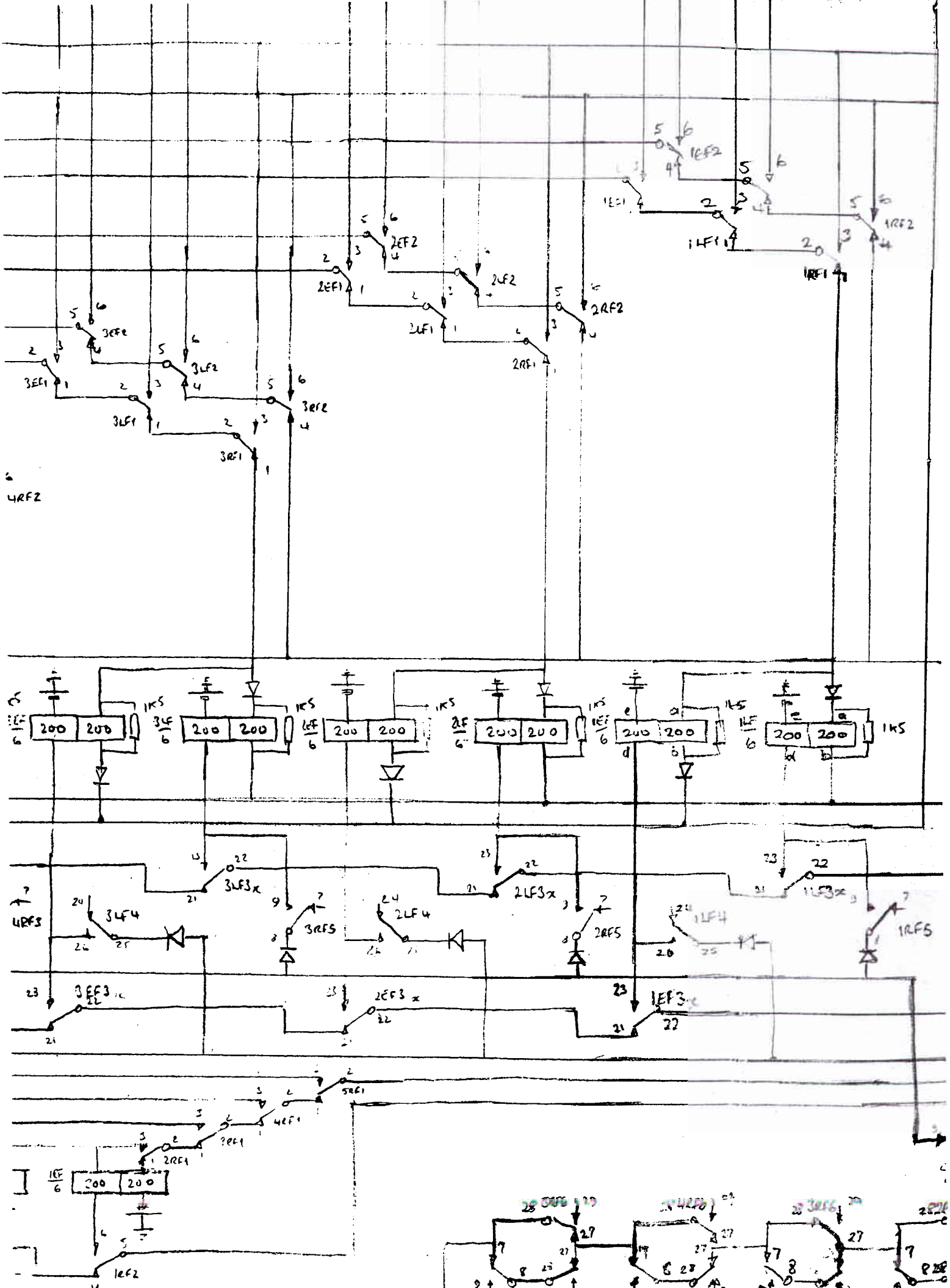
Under these conditions, any extension lifting the receiver will be unable to operate the nLF relay since the operate path is disconnected at LB3. Instead, the extension will hear special clicking tone at busy tone speed from TGR2 pulsing via EB4 (normal) and LB2. The extension can then proceed to an external call by pressing the earth button. The button will earth the calling loop and allow nEF to operate in series with EA vial LB6. The call will proceed as for an exchange call above.

Both External and Internal Bridges Busy

If an extension lifts the receiver when both bridge circuits are occupied the extension receives busy tone from TGR3 pulsing and EB4 operated.

Circuit Diagram

The circuit diagram is provided over 6 pages. It is recommended that they are printed and then assembled into a single sheet.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4RF5
3LF4
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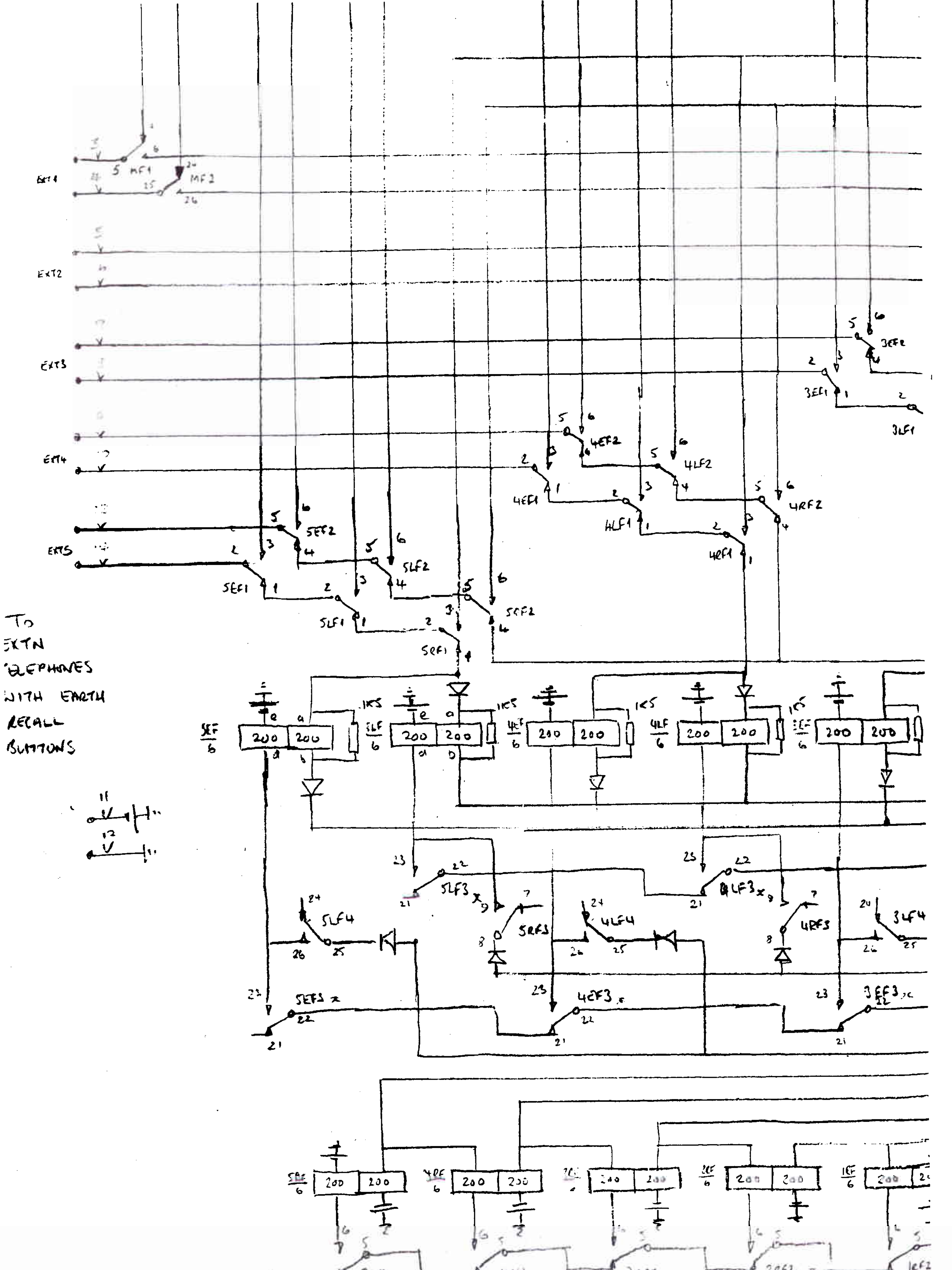
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WITH EARTH
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5LF1
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5RF1
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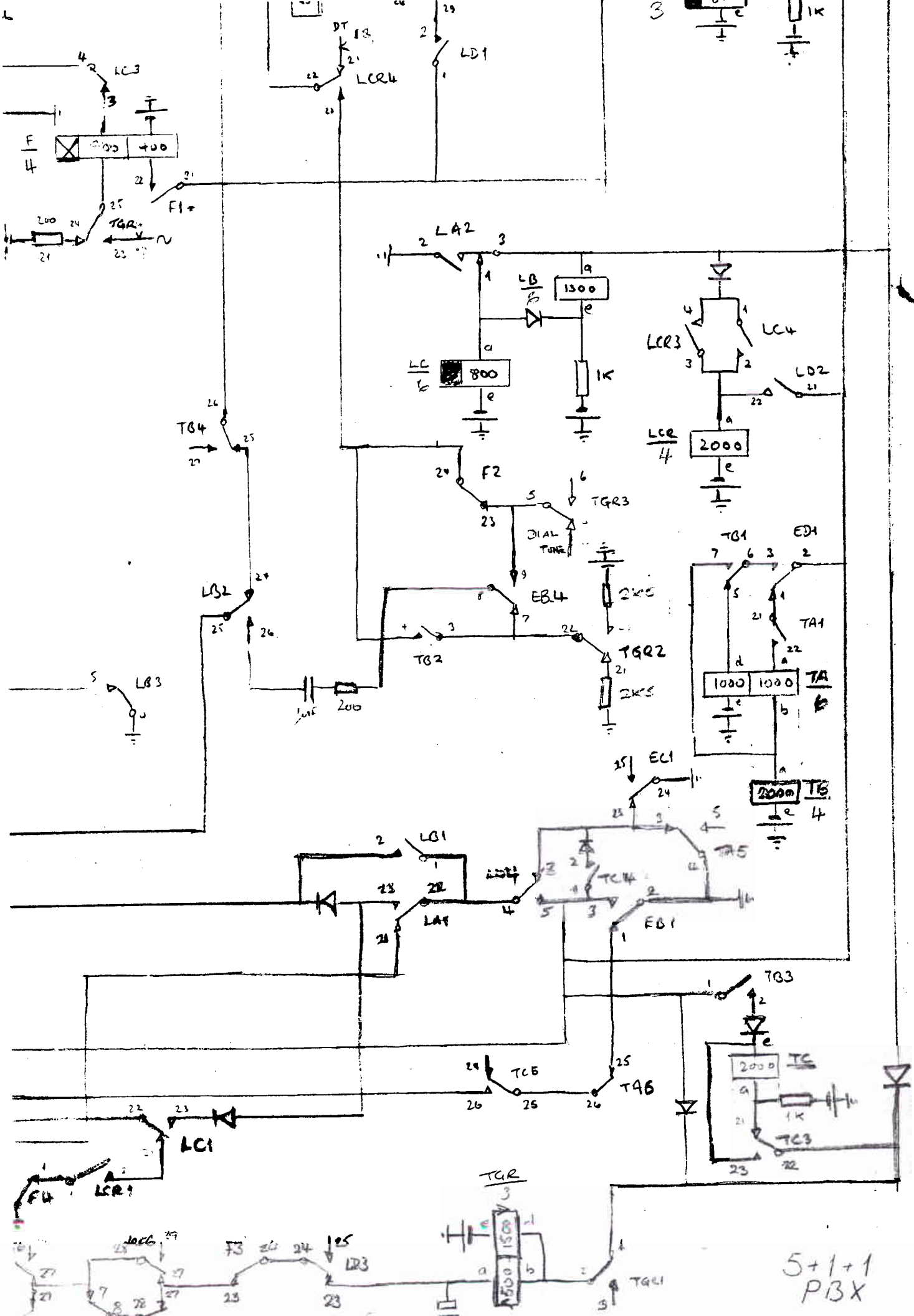
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LCR 4
2000
TB4
F2
TGR3
DIAL TONE
EB4
TB2
TGR2
2KΩ
LB2
LB3
1µF
200
TB1
ED1
TA1
1000
TA 6
2000
TB 4
EC1
LC1
LA1
LD4
TC4
TA5
EB1
TB3
TC6
TA6
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F4
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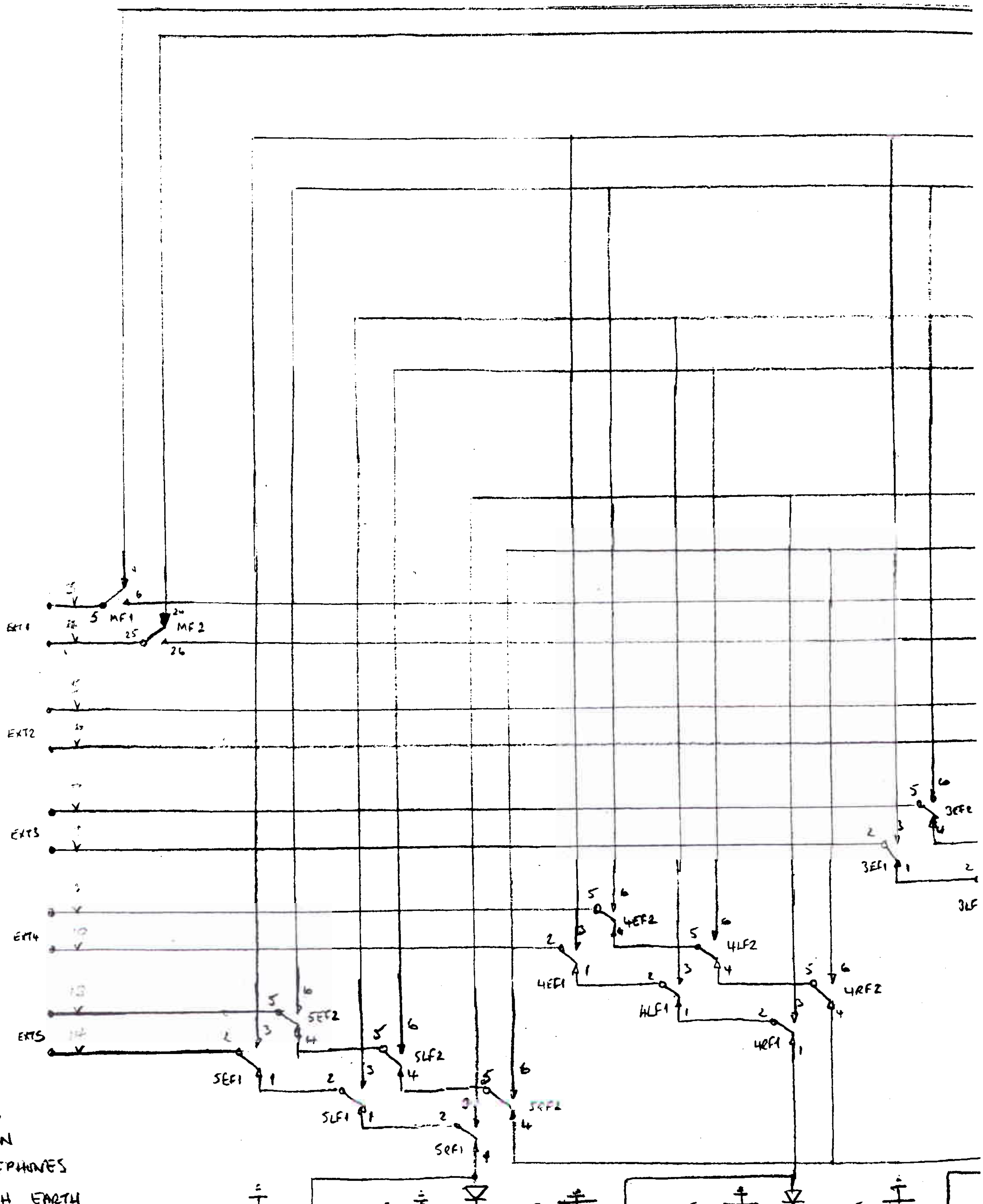
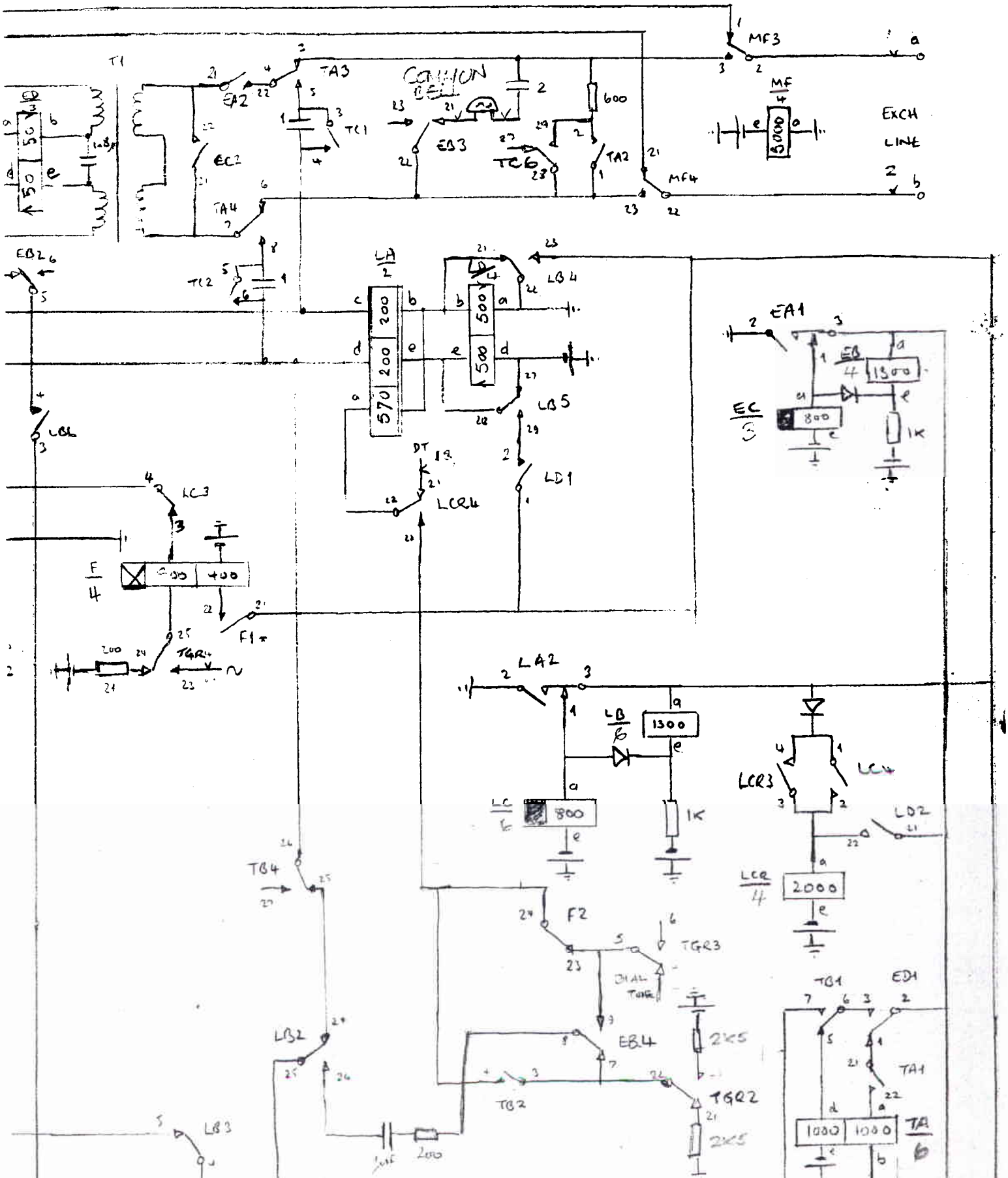
TGR 3
F3
LD3
TGR1
5+1+1 PBX

5+1+1 PBX



To
EXTN
TELEPHONES
WITH EARTH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TC1
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TC6
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LB5
LB1
LC3
LCR4
DT
EA1
EB 4
EC 5
LA2
LB 6
LC 6
LCR3
LC4
LD2
LCR 4
TB4
F2
TGR3
TGR2
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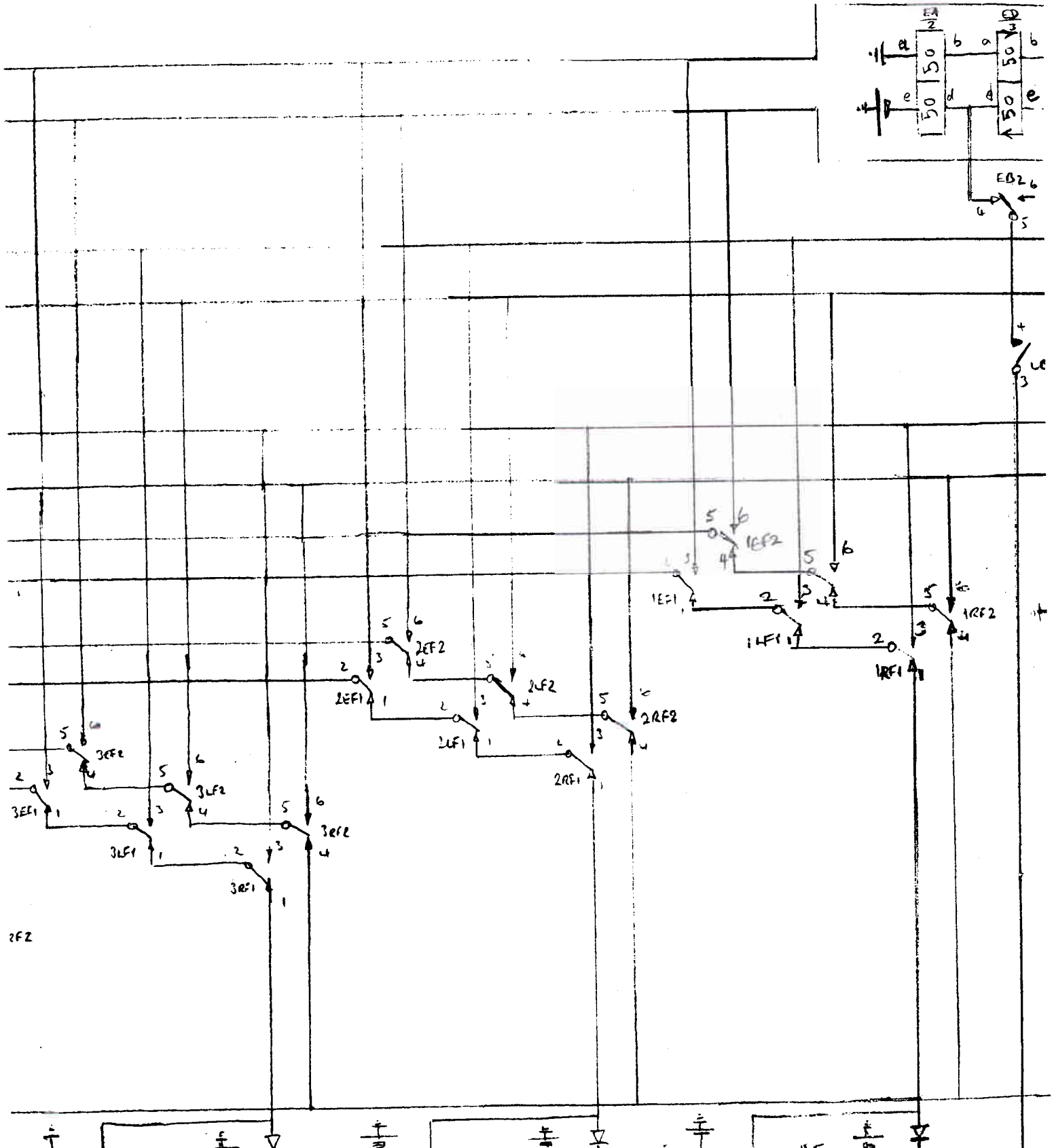
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