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Island Labs

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DATUM/DUAL DATUM FREQUENCY SENSITIVE SWITCHES

GENERAL DESCRIPTION

The FX-301L and FX-401 are two monolithic microcircuits which function as precision frequency sensitive switches. The FX-301L is a single set-point switch intended for HI/LO switching operations, the FX-401 is a dual set-point version designed for sophisticated HI/IN-LIMIT/LO frequency monitoring systems.

Both devices are purpose-designed for 'analogue' frequency monitoring applications, such as Tachometry, Flowrate and Process Control, where switching operations must be performed when a signal frequency reaches pre-determined levels.

These LSI (Large Scale Integration) circuits incorporate all the necessary signal amplifiers, reference generators, logic arrays and output switch drivers forming a fully operational sub-system. The only external components required are a few conventional resistors and capacitors, these allow the user to programme the switch operating frequencies, hysteresis and signal cut-off fail safe delay.

The FX-301L and FX-401 may be used individually, or in combination, to perform almost any required frequency operated switching function, from simple 'No Flow' alarms to complex multi-level precision monitors for high technology control systems. They are the most advanced state-of-art devices for this purpose available today, and set new standards of economy and performance in this important application area.

As an added assistance, two special printed circuit cards are also available. These are supplied ready drilled for the appropriate device and its external components, and allows experimental or prototype circuit arrangements to be rapidly and correctly set up by the engineer.



TYPICAL APPLICATIONS

TACHOMETRY

FLOWRATE

PROCESS MONITORING

FREQUENCY ALARMS

FIG. 1 FX-401 DUAL DATUM SWITCH

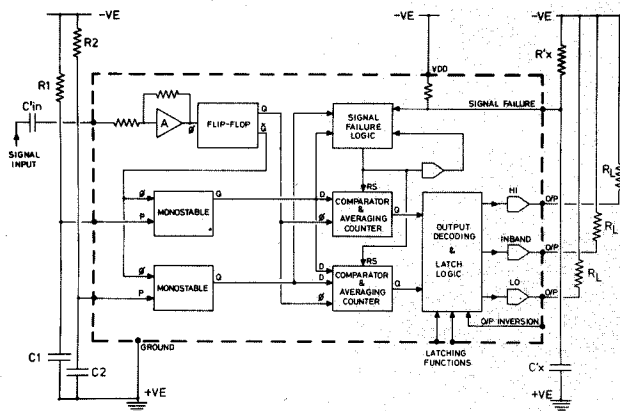
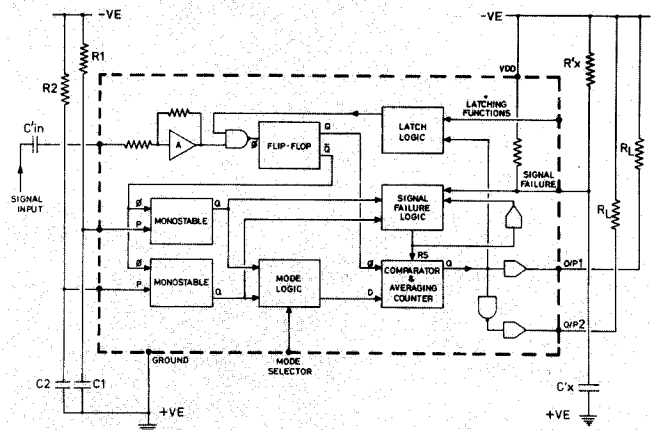


FIG. 2 FX-301L DATUM SWITCH



GENERAL OPERATION

The frequency recognition system employed by the FX-301L and FX-401, is based on a period sampling technique. Input signals are amplified and shaped to provide clock signals to the bistable flip-flop, the output of which is a square wave, having a period equal to the interval between successive input wave form 'zero-crossings'.

The flip-flop output triggers a dual monostable, which generates reference periods corresponding to set-point f1 and set-point f2. These periods are determined by R1/C1 and R2/C2.

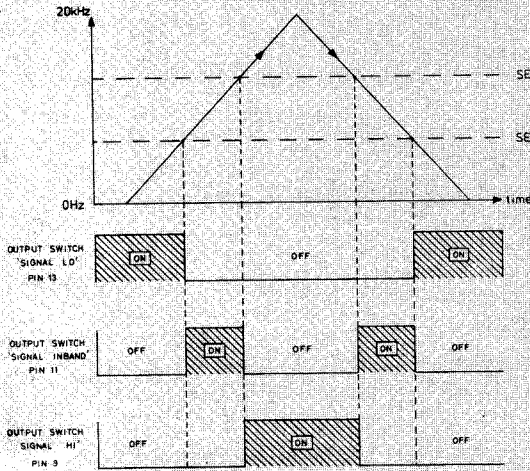
The reference periods are compared against the signal input period in one comparator (FX-301L) or two comparators (FX-401), the output/s of which control a special counter/storage system. This counting system discriminates against random/spurious noise information and delivers an output only when a true input set-point frequency is received. Gating circuits are incorporated which prevent false operation when harmonics of the set-point frequencies are applied.

This frequency discrimination system yields extremely sharp set-point definition coupled with a fast response time, and a positive 'chatter-free' switch-action.

As the device monitors all input signals applied, care should be taken to ensure that the input does not include noise signals having a frequency lying above the switch set-point levels.

For example, a magnetic pick-off may generate signals arising from vibration effects in addition to the true signal caused by passing gear teeth; if the frequency and amplitude of the vibration signals are high enough they may operate the output switch. Short term spurious noise signals, for example random spikes induced by contactor operation, will have little effect, but may cause the switch response time to be increased if they occur as the input frequency reaches a set-point threshold.

FIG. 3 FX-401 SWITCH STATE vs INPUT FREQUENCY



FX-401 OPERATION

Fig. 3 illustrates the switching functions of the FX-401 Dual Datum Switch, for a constantly varying signal input (as derived from the pick-up in a tachometry application). With no signal, or a signal below f2, the decoding systems incorporated in the device, turn ON the 'Signal LO' output switch (pin 13). When the signal input reaches set-point f2 the internal counters trigger the decoding system and the signal is recognised as an 'inband' frequency, turning ON the 'Signal Inband' switch (pin 11) and simultaneously switching OFF the 'Signal LO' switch. As the input signal progresses through set-point f1 the decoding system turns ON the 'Signal HI' switch (pin 9), simultaneously turning OFF the 'Signal Inband' switch. The three switches are mutually exclusive and only one switch is ON at any one time.

The mode control inputs (pins 14 & 15) allow various latching functions to be performed. These two input pins are logic controlled by either grounding (logic '0') or open-circuiting (logic '1') the pin. With both control pins at '0' the output switches are 'UNLATCHED' and operate at the relevant set-point frequencies, thus reflecting the present value of the signal input frequency. With both control pins at '1', 'LATCH OUT-BAND' mode, the HI or LO output switch will latch if the input signal deviates outside the INBAND zone, i.e. above f1 or below f2. 'LATCH HI' mode is obtained by applying '1' to pin 14 and '0' to pin 15, this latches the output HI switch when the signal input lies above f1. LATCH LO' mode requires '0' on pin 14 and '1' on pin 15, thus latching the signal LO switch when the signal lies below f2. See fig.4 for latching Truth-Tables.

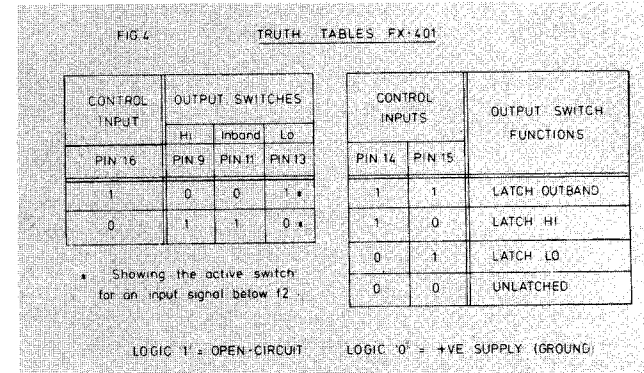
Once latched, a switch remains in the ON condition regardless of further input signal changes. To unlatch, or reset an output switch, the signal input must be returned to a non-latch value and a momentary '0' applied to both control pins.

A 'Signal Failure' recognition facility is incorporated in the circuit which allows a choice of switch actions in the event that the input signals are cut-off instantaneously (see section on Signal Failure).

A further useful facility is the 'Output Inversion' option provided by Pin 16. By applying '0' or '1' level to this pin the 'polarity' of all three output switches are reversed. This allows the user the choice of energising or de-energising an external switch load when the set-point frequency is reached.

Each control input (pins 14, 15 and 16) is provided with an internal pull-up resistor which automatically places a '1' level (-ve) on the pin when the pin is open-circuit.

NOTE: Set-point f1 should always be at a higher frequency than set-point f2. If component values are used which place f2 higher than f1, the INBAND zone disappears and the output switches change directly from LO to HI at the frequency determined by the components used for set-point f1.



FX-301L OPERATION

Fig. 5 illustrates the switching functions that are performed by the FX-301L Datum Switch. Complementary outputs give a single pole change-over switch action when the input frequency reaches a pre-set value. Only switch output 1 (pin 4) is illustrated, output 2 (Pin 5) operates simultaneously but in anti-phase. i.e. Output 1 is OFF for input LO and Output 2 is ON for input LO.

Pin 9, the mode selector input, controls the internal logic circuits and determines which switching function the FX-301L will perform. Pin 9 is a tri-state input where '1' (open-circuit) '0' (ground) or 'VDD' (-ve supply) are the three input options. (See truth table Fig.6).

With Datum switching at set-point f1, a signal input of increasing frequency will turn output 1 ON when the signal reaches f1 and it will remain ON for frequencies above set-point f1.

With Datum switching at set-point f2, a signal input of increasing frequency will turn output switch 1 ON when the signal reaches set-point f2, and it will remain ON for frequencies above set-point f2.

With either of the above switching modes, the components for the unused ('ghost') set-point must still be fitted to ensure correct operation of the internal logic.

A convenient rule is to make the ghost set-point nominally equal to the operating set-point; tolerances of 10% or so, will not effect operation. Set-point differential is extremely small for both the described switching modes, values of 0.1% of set-point frequency are typical.

Set-point Differentials (hysteresis) may be introduced by use of the third switching mode, where output 1 is turned ON at set-point f1 and remains ON until the signal decreases to set-point f2. The degree of hysteresis is accurately adjustable between 1% and 99%; i.e. f2 may be set anywhere between 99% (max) and 1% (min) of set-point f1.

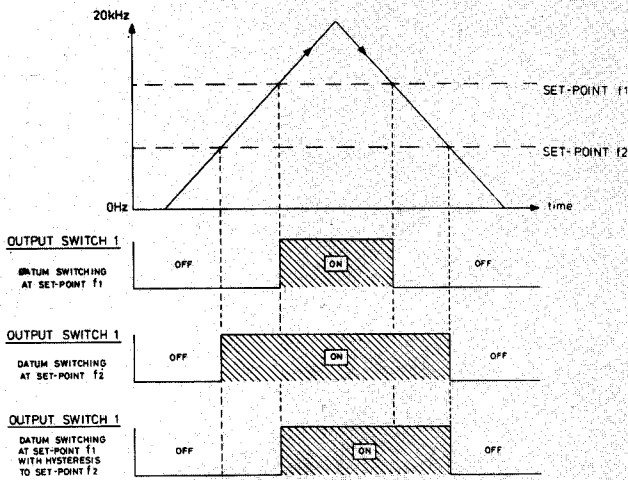
In the Hysteresis switching mode, set-point f1 must always be higher in frequency than set-point f2; if this rule is not observed the output switch will "chatter" ON/OFF when the input signal frequency lies between f1 and f2.

As with the FX-401, the FX-301L has a control input (Pin 2) which offers a choice of switch actions in the event of an instantaneous signal interruption (see section on Signal Failure).

Fig.6 shows the switch latching options available by applying logic levels to Pin 3 or externally linking Pins 4 and 8.

With Control input pin 3 grounded, the output switches are unlatched and operate at the relevant set-point frequencies. The state of the switch

FIG. 5 FX-301L SWITCH STATE vs INPUT FREQUENCY



then reflects the present input frequency relative to the operating set-point/s.

If Pin 3 is open-circuit the output switch latches when the input frequency is LO and remains latched regardless of further input frequency changes. To unlatch the output, the signal must be returned to a non-latch value (HI) and Pin 3 momentarily grounded..

NOTE: When Latch to LO mode is selected and input signals are first applied, no change in switch state can occur until these Reset conditions are met.

To obtain the Latch to HI function, Pin 3 must be grounded (logic 0') and a diode connected between Pins 4 and 8 as shown in Fig.6. If a load is also connected to Pin 4, the load current should be such that the maximum '0' level (switch ON) at Pin 4 is -2V. To reset a Latch HI state, the signal must, first be returned to a LO value, or zero, and the diode link momentarily broken. As an alternative to breaking the link, the diode may be reverse biased momentarily connecting Pin 4 to VDD via a 470 Ω limiting resistor.

FIG. 6 TRUTH TABLES FX-301L

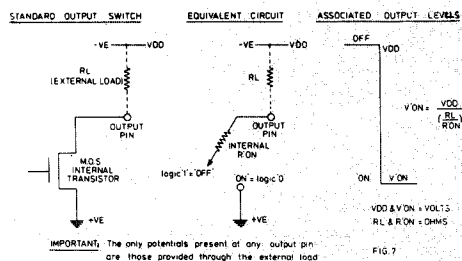
MODE SELECTOR	OUTPUT SWITCHING MODE	CONTROL INPUT	OUTPUT SWITCH FUNCTIONS
PIN 9		PIN 3	
0	DATUM SWITCHING AT SET-POINT F1	0	UNLATCHED
VDD (-VE)	DATUM SWITCHING AT SET-POINT F2	1	LATCH TO LO
1	DATUM SWITCHING WITH HYSTERESIS	0 & link as shown	LATCH TO HI

LOGIC '1' = OPEN CIRCUIT LOGIC '0' = +VE SUPPLY (GROUND)

OUTPUT SWITCH CHARACTERISTICS

The standard output switch used in all devices is a MOS driver transistor connected between the output pin and the ground pin (+ve). No internal load is provided, therefore the only potentials present at the output pins are those provided by the external load. Low current loads may be directly connected between the output pin and -ve supply, high current loads should be operated through a buffer transistor.

When the switch is turned ON, it becomes a low resistance path (value = R'on) connecting the output pin to ground, (see Fig.7). When the switch is turned OFF, it exhibits a high resistance (10M Ω minimum), effectively open-circuiting the output pin. The switch has a 'jitter-free' snap action; typical OFF-ON transition times are in the order of 2 micro-seconds.



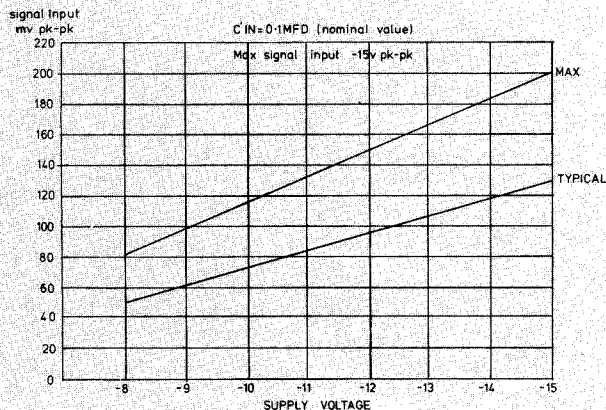
SIGNAL INPUT NOTES

All the devices incorporate a signal input amplifier offering a high input impedance. The amplifier is designed using negative feedback principles and therefore the input is D.C. self-biased. Signals to the input pin should normally be A.C. coupled to avoid disturbing this bias point. High level pulse signals ($\geq -6v$) may be directly coupled. The actual shape of the signal waveform is not important and may be sine, square or pulse in form.

Input impedance is typically 50k Ω at mid-range supply voltages. This value varies with supply voltage and production tolerances, and a total spread of 25k Ω to 200k Ω should be assumed. The minimum value of the input coupling capacitor (C'in) depends on the frequency of set-point F'2 and must be large enough to yield a time constant product $C'in/Z'in (MFD \times M \Omega) \geq \frac{1}{f2 \text{ Hz}}$

Fig. 8 shows the production spread of input sensitivity versus supply voltage. If overvoltages and transients are likely to occur on the signal line, a protective diode clamp should be used to limit input voltages to a safe level.

FIG. 8 SIGNAL SENSITIVITY versus SUPPLY VOLTAGE



RESPONSE TIME

The response time (T_S) of the FX-301L and FX-401 is defined as the interval between the input frequency crossing a set-point threshold and the output switches changing state. Normally, this interval is equal to ten cycles of the input frequency, but this may be increased if the frequency difference between set-points f1 and f2 exceeds 2:1. The response time may also be increased slightly if noise spikes are superimposed on the signal. Excluding noise effects, the response time is expressed:

$$T_S (\text{min}) \approx \frac{10}{f1 (\text{Hz})} \text{ Seconds, where } f1 < 2f2$$

$$T_S (\text{max}) \approx \frac{10}{f2 (\text{Hz})} \text{ Seconds, where } f1 \geq 2f2$$

The frequency of set-point f2 must be considered, regardless of whether it is an operating set-point or a 'ghost' set-point (FX-301L).

The calculations given for T_S apply to continuously increasing or decreasing input frequencies which pass through a set-point.

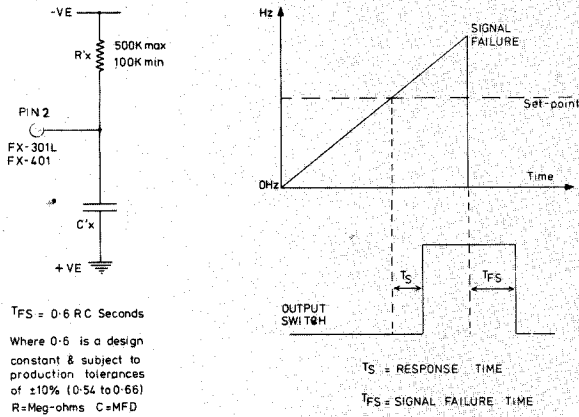
SIGNAL FAILURE RECOGNITION

As the FX-301L and FX-401 are essentially digital devices, the internal circuits come to rest when no input signals are present. If therefore, an instantaneous signal cut-off occurs while the switch is in the HI state, it will remain in this condition until a low frequency input signal is restored. By suitable connection of Pin 2, however, the reaction of the switch to a failure of input signals can be pre-determined according to user requirements.

With Pin 2 directly grounded (+ve), the switch ignores signal interruptions and will turn ON or OFF only in response to defined input signal frequencies.

To obtain automatic switch to LO should input signals fail, Pin 2 should be connected to a CR network C'x/R'x (Fig.9). If the output switch is in the HI state and signals fail, the capacitor charges to a preset level and forces the output switch to LO. The capacitor is then automatically discharged.

The Failure Recognition Time T_{FS} (Fig.9) can be adjusted to allow planned signal breaks to be ignored, but ensures that the switch adopts the LO state if a true signal failure occurs.



For general purpose applications a convenient value for T_{FS} is $\frac{10}{f_2}$ (Hz)

seconds, which yields a period T_{FS} approximately equal to the normal response time T_S . Whilst T_{FS} can be set to almost any required longer delay time, it should never be made less than $\frac{2}{f_2}$ (Hz) seconds; if it is

too short, the interval between successive input signal samples may be mistaken for 'LO Signal' and the switch will be held LO permanently.

Pin 2 may also be used as a Direct Reset which switches the outputs to the LO state, over-riding the input signal. If the pin is open-circuited, the internal pull-up resistor applies a reset voltage to the output switch stages. This resets the switch to a LO state in a maximum time $\frac{1}{f_2}$ (Hz) seconds. Note that the output switch will be held permanently LO if Pin 2 is left open-circuit.

FREQUENCY CALCULATIONS F1 & F2

Figs. 3 & 4 illustrate the set-point f_1 and f_2 in relation to the switching characteristics of the FX-401 and FX-301L. Set-point f_1 is always set to the higher frequency and is determined by R_1 and C_1 , set-point f_2 is determined by R_2 and C_2 (see Figs. 1 & 2).

To adjust set-point frequencies, and to allow adjustment for component tolerances, R_1 and R_2 should each consist of a fixed resistor in series with a variable resistor. For maximum stability, the variable section should form only a small fraction of the total resistance.

Set-point Calculations:

$$f_1 = \frac{1}{0.7 R_1 C_1} \text{ (Hz)} \quad f_2 = \frac{1}{0.7 R_2 C_2} \text{ (Hz)}$$

Where 0.7 is a design constant 'K' (subject to production tolerances of $\pm 5\%$), $R = M\Omega$ and $C = \text{MFD}$.

Component Values:

$$R_1/R_2 = 100k\Omega \text{ to } 5M\Omega \quad C_1/C_2 = 470\text{pf to } 5\text{MFD}$$

For maximum set-point stability, capacitor values of 470pf minimum and resistor values of $100k\Omega$ to $500k\Omega$ are recommended. This minimises the effect of humidity and stray wiring capacities of the component assembly. Good quality components should always be used; metal oxide resistors and polystyrene/polycarbonate capacitors are suggested.

PCB C-013L & C-014

The C-013L and C-014 printed circuit cards are designed to assist engineers in rapidly and correctly assembling a fully functional frequency operated switch module. Supplied ready punched and with component positions clearly marked, they are suitable for experimental work or as short run production P.C.B.'s.

Manufactured from 1/16" S.R.B.P. with tinned copper conductors, they each measure 4" (103mm) x 3" (76mm). Card connections are shown by printed letter code. The cards are supplied complete with a set of press-in terminal posts for mounting those components most likely to be changed during experiments, thus minimising possible damage to the metal tracks. Components are not supplied. Connections to the cards may be made by direct wiring or by edge connectors, using a 12 way 0.15" pitch P.C.B. Socket. Normally, the FX device is soldered directly into position, but a 16 way D.I.L. socket (C-014) or a 10 pin TO-100 style socket (C-013L) may be used if required.

CIRCUIT DESCRIPTION C-013L

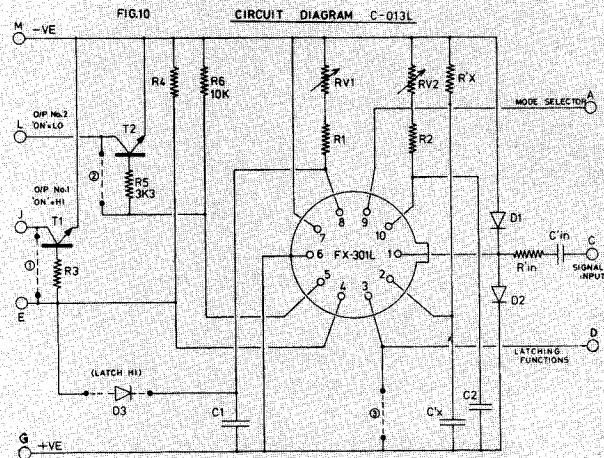
Supplies are connected to terminals M (-ve) and G (+ve). Two output terminals are provided, ON = LO (L) and ON = HI (J). Either or both may be used, directly or via transistor drivers, according to the links/components fitted. Low current loads up to 10mA can be connected directly between the output and M, and links (1) or (2) fitted as appropriate. High current loads up to 200mA are connected between the output and G, in which case T1/2 and R3 through R6 should be fitted and links (1) and (2) removed.

Link 3 allows pin 3 to be permanently grounded, giving unlatched operating mode. Alternatively, linking D to G via N/O push-button gives Latch to LO mode, push button to unlatch.

Diode 3 is fitted if Latch to HI is required. To unlatch, momentarily connect E to M using a push-button. Link (3) must be fitted if Latch to HI is used.

Input signals are applied to terminal C. If high voltage spikes can appear on the signal line, protective diodes D1/D2 should be fitted and a $10k\Omega$ resistor used for $R'in$. If no protection is required, $R'in$ may be a wire link.

If $C'x$ is omitted, a wire link must be fitted in its place.



CIRCUIT DESCRIPTION C-014

Supplies are connected to A (-ve) and M (+ve). The three outputs may be connected to the loads directly or via buffer transistors according to the links and driver component fitted. Low current loads connect between output and -ve, high current between output and +ve in the same manner described for C-013L.

Links (5) and (6) are fitted if unlatched mode is required, alternatively, the links are omitted and connections applied to H and J for the optional latch function. Link (4) should be fitted or omitted according to the output 'polarities' required (see Truth Table for FX-401).

Input signals are applied to terminal L, the protective diodes and resistor should be fitted if signal overvoltages can occur. If $C'x$ is not used, a wire link must be fitted in its place.

GENERAL P.C.B. COMPONENT NOTES

- Transistors : BFY 51 or similar NPN type.
- RV1/RV2 : Plessey WMP or similar.
- Diodes : 1N4148 or similar.
- $C'in$: See SIGNAL INPUT NOTES

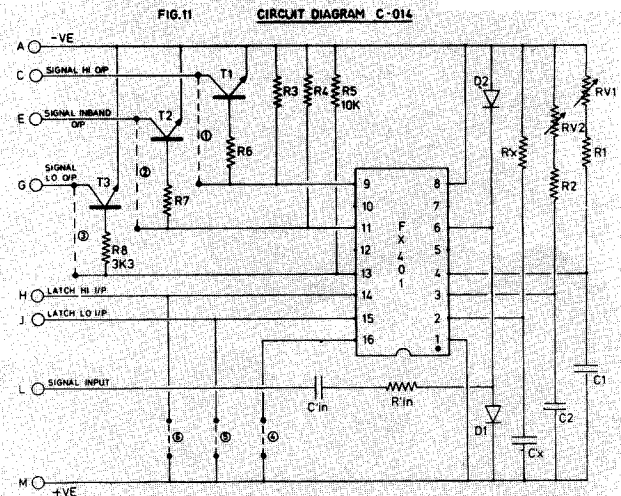


FIG.12 OVERSPEED ALARM WITH LATCHED OUTPUT

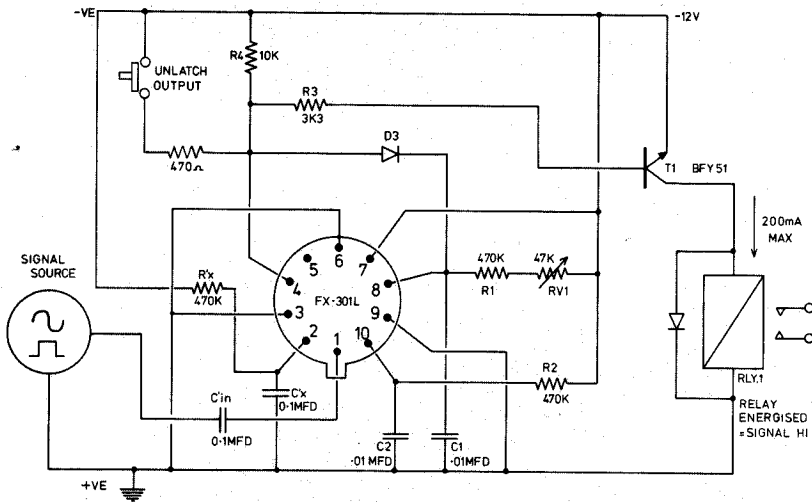


Fig.12 illustrates a typical overspeed alarm circuit using FX-301L. When the input frequency exceeds set-point f1, the relay is latched ON. The relay may be reset, or unlatched, by closing the push-button contacts.

Using the components specified, set-point f1 is at 290Hz and f2 (ghost) at the same nominal value. R'x and C'x are included to allow relay unlatching when no input signals are present. A clamp diode should always be fitted across inductive loads, relay coils etc., to protect the driver transistor. With the interface component values shown (Tr, R3, R4) loads up to 200mA may be driven.

In a number of instances, signals derived from rotating machinery tend to 'hunt', which can lead to switch chatter when the signal has a mean value near the set-point frequency. Fig.13 shows how a precise amount of set-point differential may be introduced to cancel out this effect.

With Pin 9 open circuit, relay 1 turns ON when the input frequency reaches f1 (1400Hz) and remains ON until the input falls below f2 (1000Hz), a differential of 29%. By suitable choice of f1 and f2, any required degree of differential can be obtained.

Two relays are shown, these operate in anti-phase and offer a choice of normally ON or normally OFF failure modes. When using FX-301L with pin 9 o/c, ensure that f1 is always higher in frequency than f2.

FIG.13 HIGH/LOW DATUM SWITCH WITH PRESET HYSTERESIS

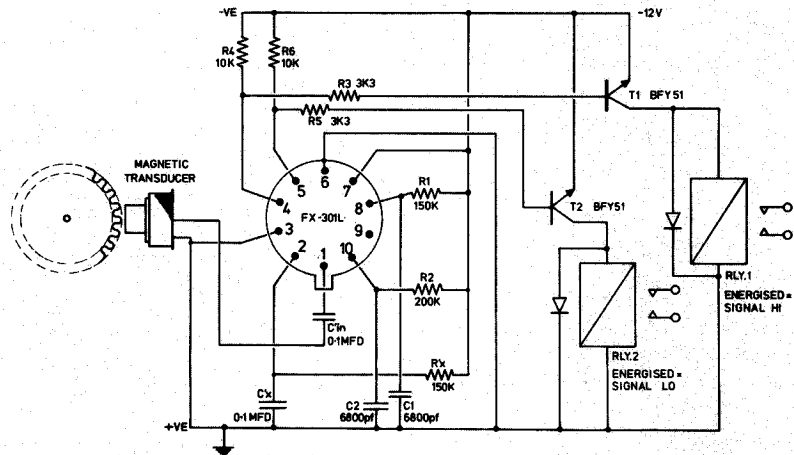


FIG.14 HI/LO/IN-LIMITS FLOWRATE MONITORING

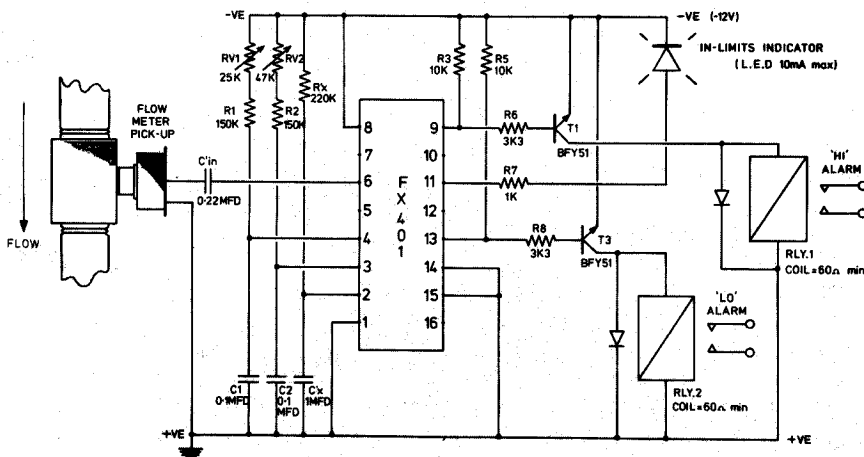


Fig.14 shows how the FX-401 is used to obtain comprehensive monitoring of a flowrate. When signals from the flow transducer lie between f1 and f2 (90Hz and 80Hz), the IN-LIMITS L.E.D. is illuminated. If the signal rises above f1 the HI alarm relay operates, if it falls below f2 the LO relay is turned ON. Only one output is energised at any time and the set-point thresholds are very sharp (0.1% differential typical).

Pins 14 and 15 are shown grounded, which gives non-latching alarm operation; the FX-401 Truth Tables give the Pin connections for latch-alarm functions. If pin 16 is grounded the alarm functions are reversed, i.e. the L.E.D. illuminates for signals 'Outband' and both relays are energised when the signal lies inband.

R'x/C'x ensure that the switches adopt LO state if signals are cut-off.

SPECIFICATION

MAX RATINGS

Max. Voltage between any pin and positive supply pin.	-20v & +0.3v
Operating Temperature Range	-30°C to +85°C
Storage Temperature Range	-55°C to +125°C
Max. Output Switch load current	-10mA each switch
Max. Device Dissipation at 20°C T'amb)	400mW



CHARACTERISTICS

(T'amb = 20°C, V_{DD} = -12V ±2V, Set-point frequencies 1Hz to 3kHz unless specified)

Symb.	Parameter	Conditions & Notes	Min	Typ	Max	Units
V _{DD}	SUPPLY VOLTAGE	Operating Range	-8	-12	-15	V
I _{DD}	SUPPLY CURRENT	Total, excluding switch load current		2.5		mA
				3.5		
V'in	SIGNAL AMPLITUDE RANGE	Sine or pulse input signals, OHZ to 100kHz, A.C. Coupled. Input impedance typically 50kΩ		0.1	15	V pk-pk
f1 / f2	ADJUSTMENT LIMITS FREQUENCY RATIO	Max & Min Set-Point frequencies	1Hz		20kHz	
		Permitted ratio adjustment, (f2 percentage below f1)	1		99	%
	SET-POINT DEFINITION	Individual set-point on/off differential as % of nominal set-point frequency.		0.1		%
Δf	SET-POINT STABILITY	Set-point deviation versus supply volts & T'amb. External components coeff. excluded	Supply	0.05	0.08	%/%
			T'amb	0.005	0.02	%/°C
T _S	RESPONSE TIME	Overall switching time following receipt of 'switch' value frequency.	@ 3kHz	3.3		mS
			@500Hz	20		
R'on	SWITCH 'ON' RESISTANCE	Internal resistance between output pin and ground, switch 'ON' (Switch 'OFF' resistance ≥ 10MΩ)		0.3	1	KΩ
'1'	LOGIC HIGH	External logic levels to control inputs. (Internal 300kΩ pull-up resistors give logic '1' when pin O/C)	'1'	-6	-15	V
'0'	LOGIC LOW		'0'	0	-1.5	V

SUPPLY NOTES

References to ground, logic '0' and logic '1' in this data sheet are based on the use of a grounded positive supply, i.e. HT (V_{DD}) is negative. A logic '1' level is therefore near V_{DD} (-ve) and a logic '0' level near ground (+ve) There is, however, no objection to operation with the -ve supply grounded, but reference to logic polarities remain unchanged, i.e. a logic '1' is *always* -ve with respect to a logic '0'.

Example: a) V_{DD} = -12V +ve = ground
logic '1' = -12V and logic '0' = ground.

b) V_{DD} = 0v +ve = +12V
logic '1' = 0v and logic '0' = +12V.

Note also that the case is internally connected to the +ve pin and will therefore be above ground potential if V_{DD} = 0v. It is also important to ensure that no pin receives a potential which is positive with respect to the +ve supply pin. Failure to observe this rule may result in damage to the device.

PIN DATA FX-401

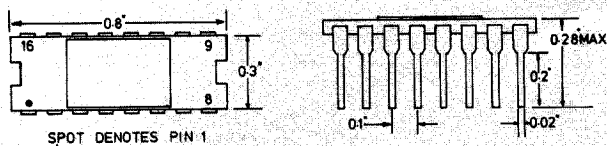
- | | |
|----------------------------------|--------------------------|
| 1. +VE Supply (Ground) | 9. Output Switch HI. |
| 2. Signal Failure | 10. No Connection |
| 3. Set-point f2 | 11. Output Switch Inband |
| 4. Set-point f1 | 12. No Connection |
| 5. No Connection | 13. Output Switch LO |
| 6. Signal Input | 14. Latch HI |
| 7. No Connection | 15. Latch LO |
| 8. -VE Supply (V _{DD}) | 16. Output Inversion |

PIN DATA FX-301L

- | | |
|--------------------|----------------------------------|
| 1. Signal Input | 6. +VE Supply (Ground) |
| 2. Signal Failure | 7. -VE Supply (V _{DD}) |
| 3. Latch Functions | 8. Set-point f1 |
| 4. Outout Switch 1 | 9. Mode Selector |
| 5. Output Switch 2 | 10. Set-point f2 |

FIG15 PACKAGE DETAIL

16 LEAD CERAMIC DUAL-IN-LINE



PACKAGE DETAIL

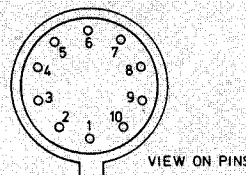


FIG.16

TO-100 STYLE PACKAGE

10 LEADS 0.016" TO 0.019" DIAM.
BY 0.5" LONG
EQUISPACED ON 0.23" PCD