Title
FILM TAKE-UP SERVO AND CONTROL

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November 14, 1968

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Abstract

An improved film reel take-up unit is designed for Spiral Readers. The requirements were a maximum film speed of 35 ft/sec at an acceleration of 5g. Low cost was also of primary interest.

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Design

The general design of a reel unit consists of: A motor to drive the film spool; an error-sensing element to detect whether the unit should take in or let out film; an amplifier to drive the motor in response to the error signal.

The amplifier is generally the most costly element, because of the dc power supplies and transistors with high current capabilities. Use of a triac with ac line phase control was conceived as the most efficient solution to these problems. Such a Triac drive circuit is shown in Fig. 1.

The circuit consisting of R_1, R_2, R_3, R_4, C_1, D_1, and D_2 forms a square wave at 60 Hz of about 60 volts peak to peak (p-p). The slider of R_4 determines the dc reference level of the square wave. Thus, with the slider in different positions, the wave forms at the slider are as shown

on Fig. 2. R_5 and C_2, then, provide a charging curve that exceeds the diac threshold (28 to 35 V) only if the slider is off center. Positive half-waves fire the Diac and Triac if the slider is in one direction, and negative half-waves if the slider is in the other. The result is a simple bidirectional motor drive with a high current gain. The gain with respect to the arm position $\left(\frac{dv}{ds}\right)$ is controlled by the setting of R_1 and R_5.

By connecting the slider of R_4 to a "flailing arm" ("dancing arm") an error signal may be converted to a motor-drive signal.

RE-2 picks up slowly, preventing sudden current surges when the system is turned on. RE-1 disconnects the error signal when reels are being changed.

R_7, R_8, and C_4 are a frequency-compensation network, in which values were determined in the following manner. A reel system may be roughly thought of as a position-feedback servo. Thus, the error signal (from R_4) goes down at -20 db/decade and is 90 deg lagging in phase. An additional "roll-off" is introduced due to the motor and load response curve. It is difficult to measure the open-loop frequency response due the 60 Hz everywhere in the circuit. But the approximate position of the second roll-off corner frequency may be obtained from closing the loop without frequency compensation and observing the frequency at which the system oscillates.

The phase shift at this oscillating frequency is -180 deg. A phase-lead network may then be placed in series with the open loop to reduce the phase shift (see Fig. 3). To insure stability the -20 db/decade compensation was set to start at a frequency of 1/2 the oscillation frequency.

A restriction on C_1 is that it must introduce little distortion of the 60- Hz square wave from the slider of R_4. A 3-μF capacitor at 60 Hz has an impedance of 1 kΩ, making it sufficiently small to transmit the square wave unaffected. R_7 and C_4 provide a 1.5-Hz roll-off network. R_8 helps maintain a more constant dc resistance to the R_7 C_4 circuit.

Performance on Spiral Reader I

Two prototype reel units were installed on Spiral Reader I (see Figs. 4 and 5). The present capstan drive was operated at its maximum speed and acceleration, but was unable to match the capabilities of the reel units. (This simplified the computer control software operations by eliminating a previously required capstan-velocity ramp subroute). The final version of the control unit is compact—only 4 by 4 by 8 in. (see Fig. 6).

Performance

	Reel unit	Spiral reader capstan
Maximum speed (ft/sec)	30	25
Maximum acceleration (g)	10	5

Motor specification limits

Maximum motor current surge: 80 A (motor rated at 100 A surge)

Average current: 8A (motor rated at 8.6 A average)

Cost of electronic parts

1. Motor (U-16, printed circuit motors)		$ 165
2. Control parts		50
	Total	$ 215

LEGENDS

Fig. 1. Film take-up servo control.

Fig. 2. Wave forms corresponding to different positions of slider.

Fig. 3. A Bode plot, showing method of frequency compensation.

Fig. 4. Prototype control installed on Spiral Reader.

Fig. 5. The film take-up control (prototype) and reel.

Fig. 6. Final version of the control.

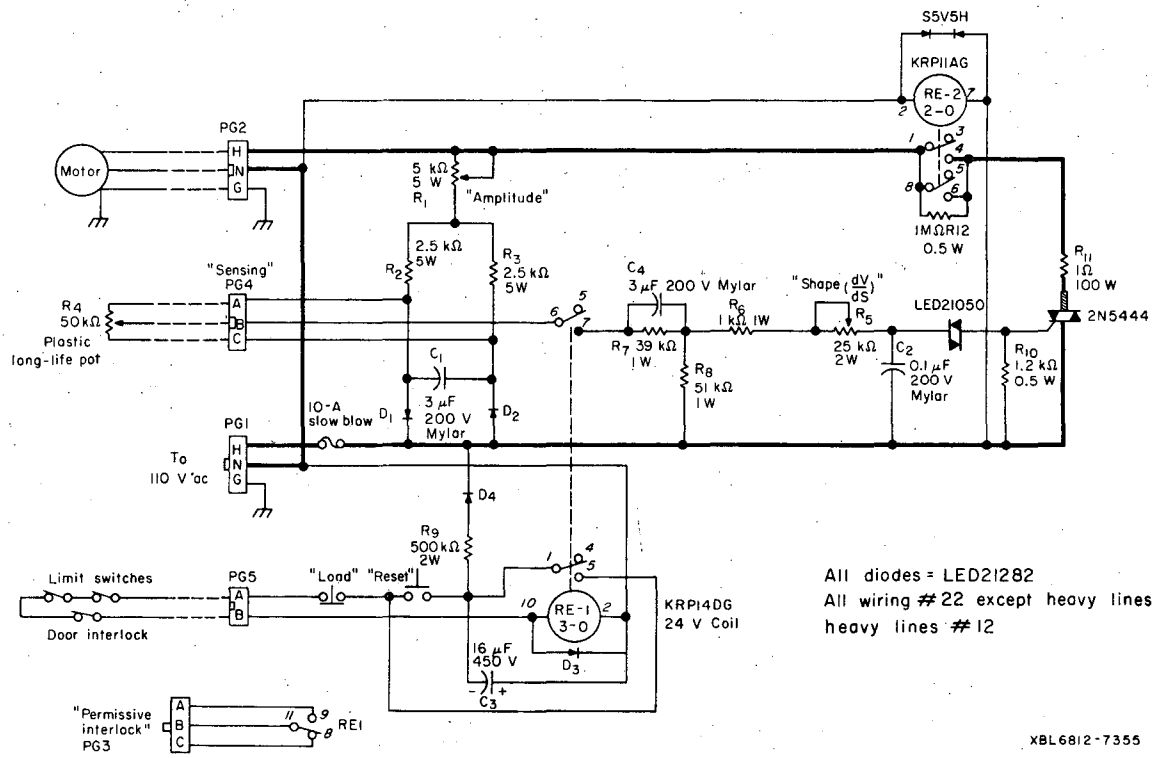
S5V5H
KRPIIAG
RE-2
2-0
PG2
Motor
H
N
G
5 kΩ
5 W
R1
"Amplitude"
1MΩR12
0.5 W
R11
1Ω
100 W
2N5444
"Sensing"
PG4
R4
50kΩ
Plastic
long-life pot
A
B
C
2.5 kΩ
5W
R2
R3
2.5 kΩ
5W
C4
3μF 200 V Mylar
R6
1 kΩ 1W
"Shape (dV/dS)"
R5
LED21050
R7 39 kΩ
1 W
R8
51 kΩ
1 W
25 kΩ
2W
C2
0.1 μF
200 V
Mylar
R10
1.2 kΩ
0.5 W
C1
3 μF
200 V
Mylar
10-A
slow blow
D1
D2
PG1
To
110 V ac
D4
R9
500kΩ
2W
Limit switches
Door interlock
PG5
"Load"
"Reset"
RE-1
3-0
KRPI4DG
24 V Coil
16 μF
450 V
D3
C3
"Permissive
interlock"
PG3
RE1
All diodes = LED21282
All wiring #22 except heavy lines;
heavy lines #12
XBL6812-7355

Fig. 1

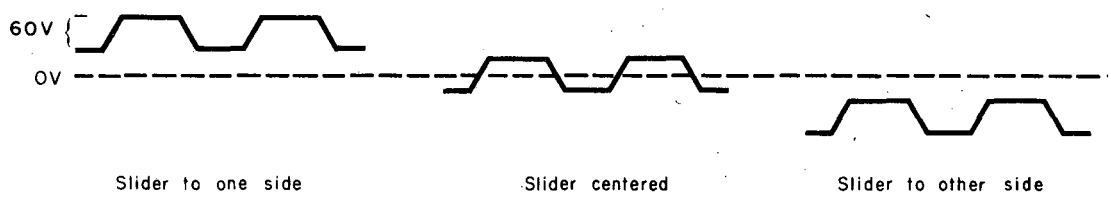

Fig. 2

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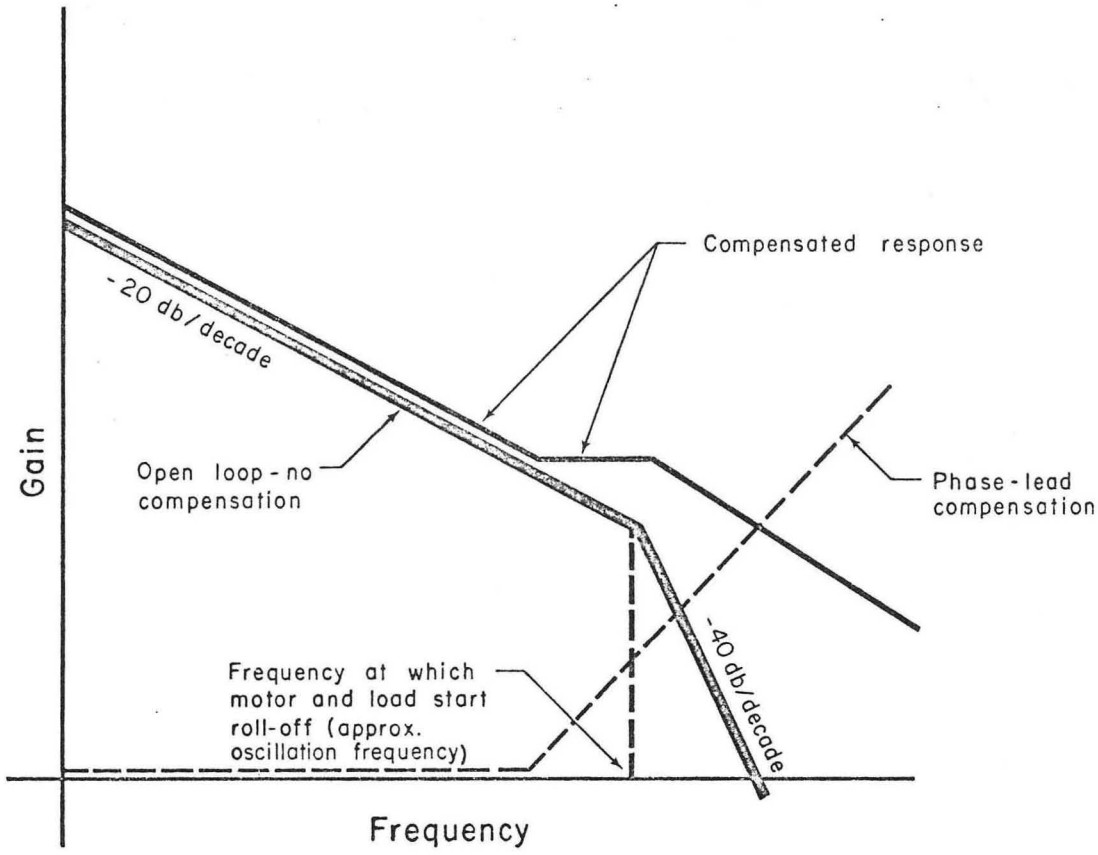

Fig. 3

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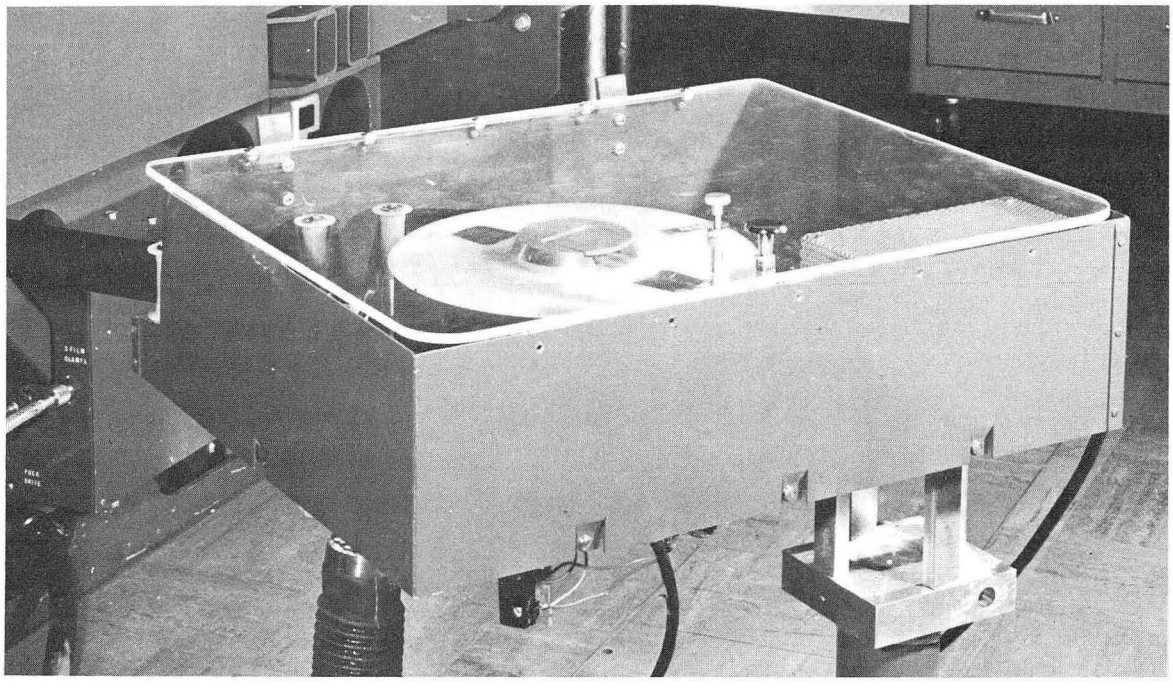

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Fig. 4

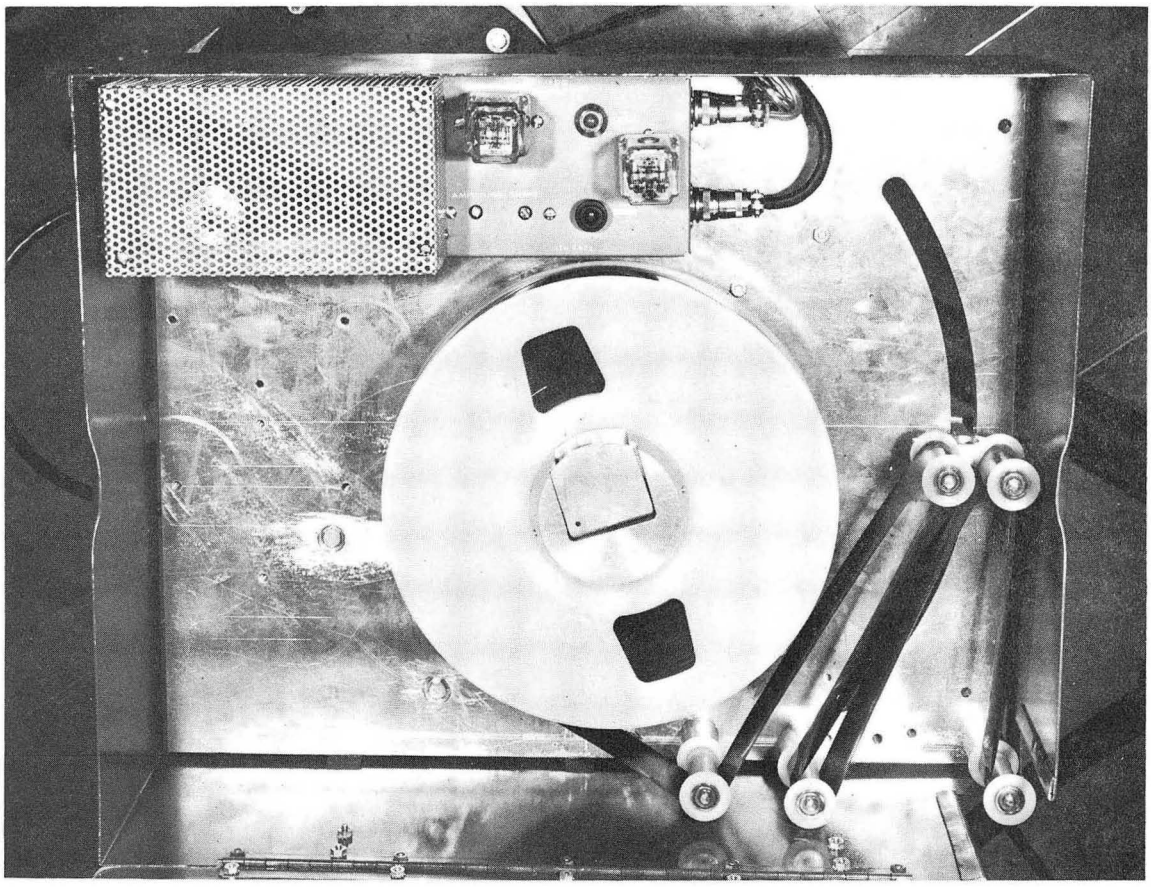

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Fig. 5

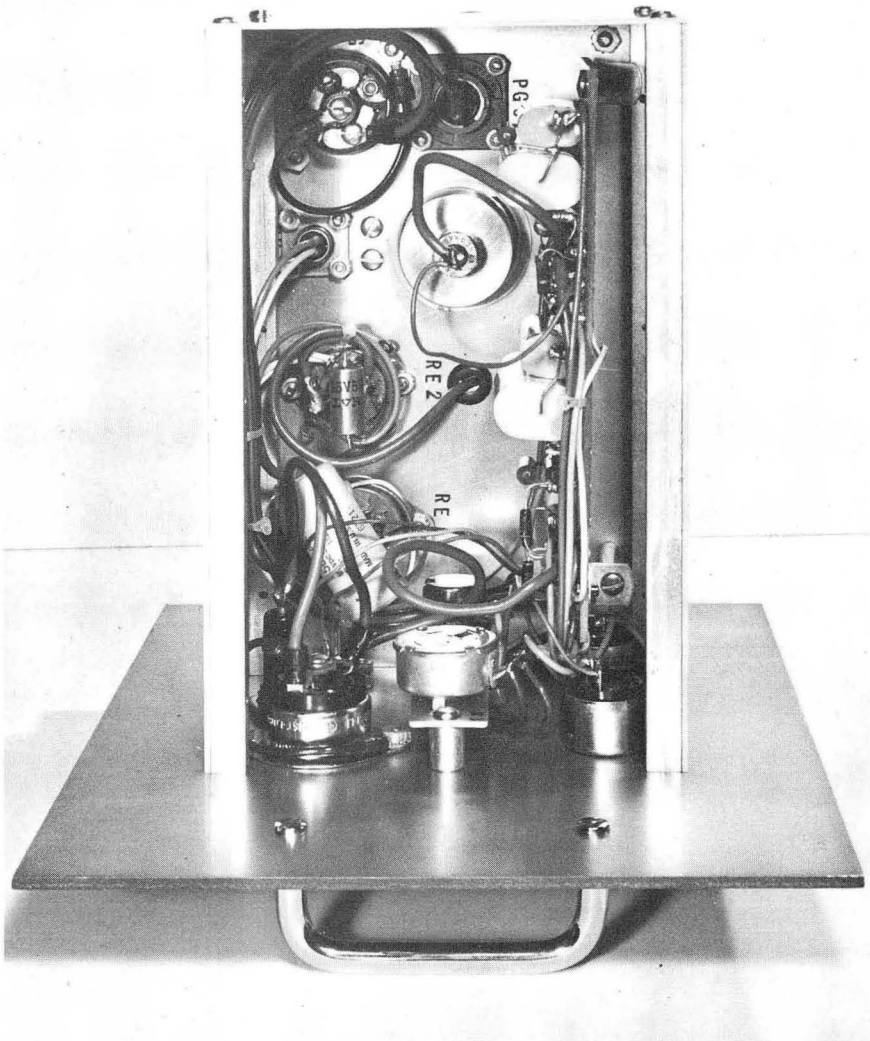

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Fig. 6

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