

M51564P

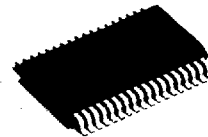
OPTICAL PICKUP SERVO CONTROL

DESCRIPTION

The M51564P is a semiconductor integrated circuit built-in the logic control, servo amplifier and switches required for servo control of CD player pickup.

FEATURES

- The amplifier, switches and logic control, all requirements for optical pickup servo control, are accommodated in a single chip
- Built-in the focus search circuit capable of auto search in both upward and downward directions
- Built-in the serial-parallel data conversion circuit, which alleviates load on the microcomputer
- Is highly applicable to a wide variety of pickup because of variable gain and frequency characteristics accomplished only by changing external parts
- Built-in the $V_{CC}/2$ generation circuit so as to permit the use of either double or single power source



RECOMMENDED OPERATING CONDITIONS

Supply voltage range..... V_{CC} , $V_{EE} = \pm 4.75$ to $\pm 5.25V$
or $V_{CC} = 4.75$ to $5.25V$

Rated supply voltage

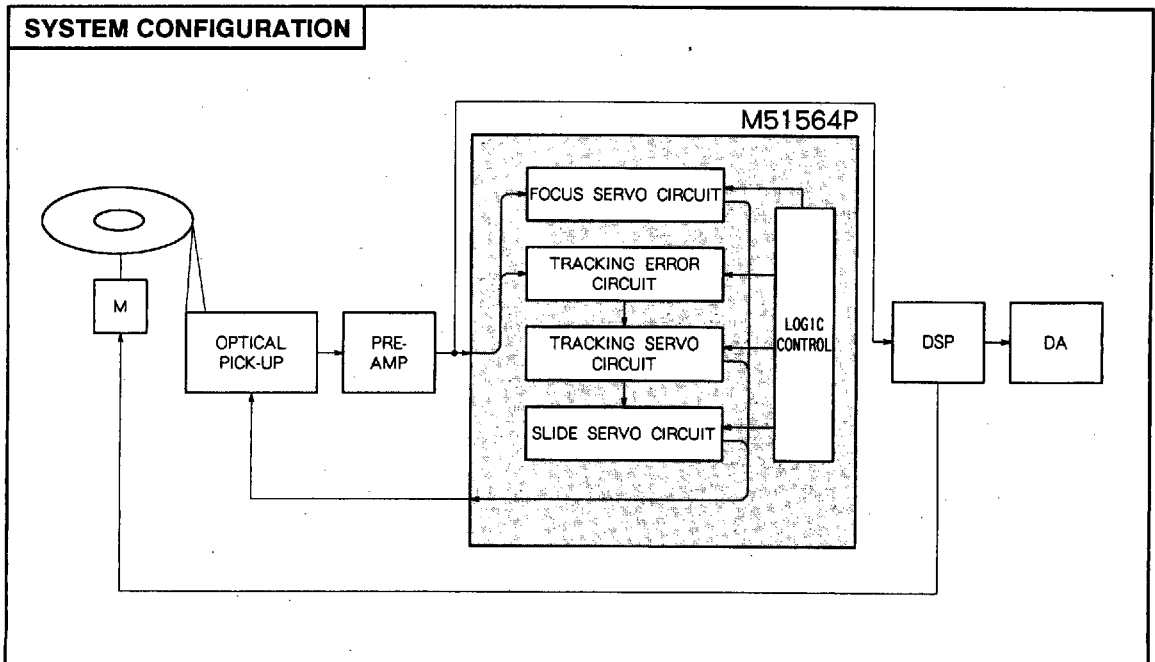
..... V_{CC} , $V_{EE} = \pm 5V$ (double power source)
or $V_{CC} = +5V$ (single power source)

Rated power dissipation 70mW

Outline 36P2R-A

0.8mm pitch 450mil SSOP
(8.4mm $\times$ 15.0mm $\times$ 2.0mm)

SYSTEM CONFIGURATION



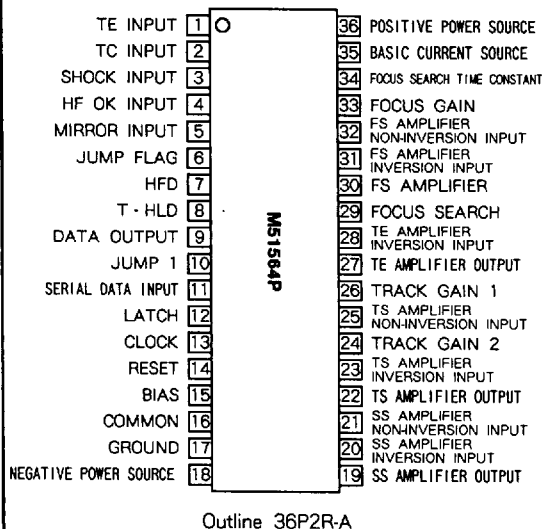
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OPTICAL PICKUP SERVO CONTROL

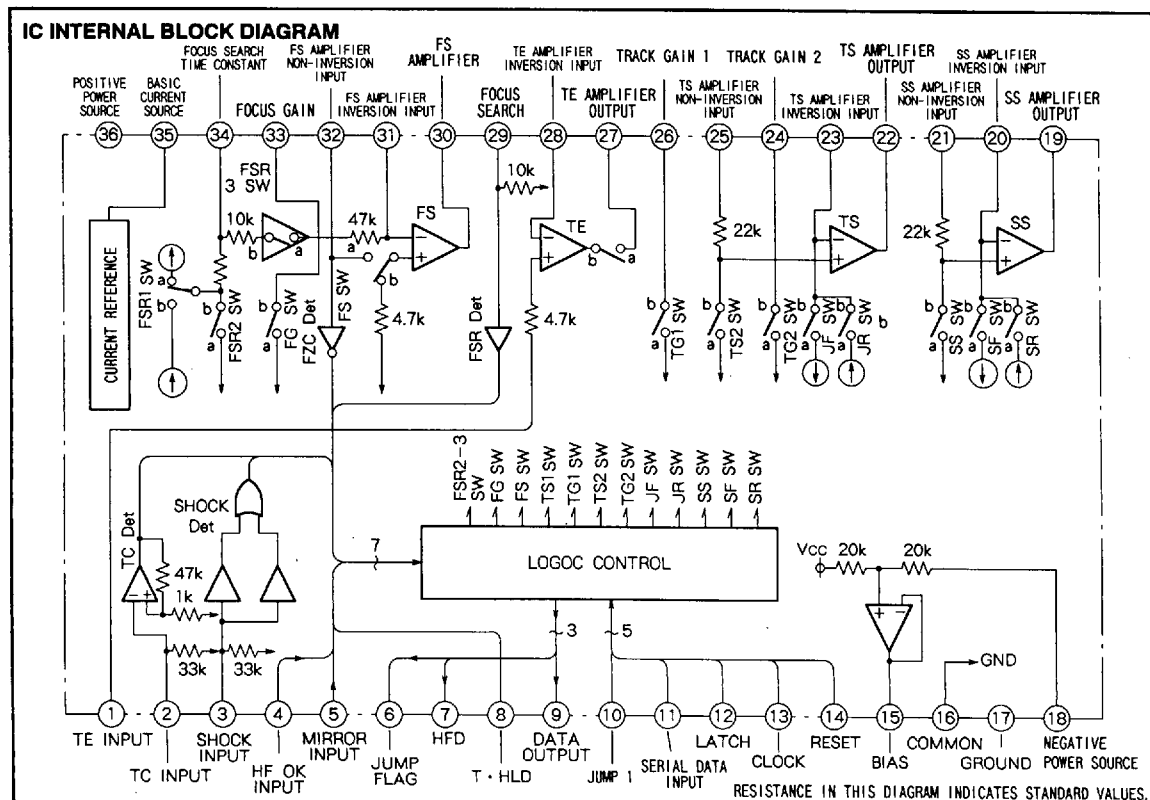
BUILT-IN FUNCTIONS

- Focus servo amplifier : FS (Focus Servo Amp.)
- Tracking error amplifier : TE (Tracking Error Amp.)
- Tracking servo amplifier : TS (Tracking Servo Amp.)
- Slide servo amplifier : SS (Slide Servo Amp.)
- Jump and brake switch circuits :
 - TS1 SW, TS2 SW (Tracking Servo Switches)
 - TG1 SW, TG2 SW (Tracking Gain Switches)
 - JF SW, JR SW (Jump Forward/Reverse Switches)
 - SS SW (Slide Servo Switches)
 - SF SW, SR SW (Slide Forward/Reverse Switches)
- Focus search circuit :
 - Focus search switch (FSR1, FSR2, FSR3, FS, FG)
 - Focus search switch (FZC Det)
 - Focus zero cross detector (FZC Det)
- Track cross detector : TC Det (Track Cross Detector)
- Shock detector : Shock Det (Shock Detector)
- Logic controller :
 - Serial→parallel data conversion circuit
 - Jump, brake and focus search controls
- Vcc/2 generation circuit

PIN CONFIGURATION (TOP VIEW)



IC INTERNAL BLOCK DIAGRAM



OPTICAL PICKUP SERVO CONTROL

PIN DESCRIPTION

Pin No.	Symbol	Block	I/O	Function
①	TE IN	Pre-amplifier input	I	Input terminal for tracking error signals
②	TC IN	↑	I	Input terminals for track cross signals
③	SHOCK IN	↑	I	Input terminals into the shock detection circuit
④	HF OK	↑	I	Input terminals for HF OK signals
⑤	MR	↑	I	Input terminals for disc mirror surface detection signals
⑥	Jump Flag	Output to the pre-amplifier	O	Outputs "H" in jump modes such as TS OFF, JF JR, and BRAKE
⑦	HFD		O	HFD="H" when MR input="H" and when track servo loop is OFF (TS OFF, JF, and JR)
⑧	T·HLD	Track servo	I	Direct control terminal for When T-HLD = "H", TS1SW = "b"; When T-HLD = "L", controller command prevails
⑨	DATA OUT	Microcomputer I/O	O	Interior condition output corresponding to microcomputer commands
⑩	JPT	↑	I	Control signal for track jump brake pulses. Normally "H"
⑪	MSD	↑	I	Microcomputer serial data Transfers serial data from microcomputer to servo IC. LSB first. 8-bit data
⑫	MLA	↑	I	Latches serial data from microcomputer to servo IC. Transfers data when this falls
⑬	MCK	↑	I	Clock for serial data transfer from microcomputer to servo IC. Takes data at the rising edge
⑭	ACLR	↑	I	All cleared. Resets all internal registers and flip-flops with signal "L"
⑮	Bias	Power source	O	When power source is single, this outputs $V_{cc}/2$ bias power
⑯	COM	↑	I	COMMON terminal. Connected to GND when positive and negative power is supplied, and to BIAS when power source is single
⑰	GND	↑	I	GND
⑱	VEE	↑	I	Negative power terminal. Connected to GND when power source is single
⑲	SS OUT	Slide servo	O	Operation amplifier SS output
⑳	SS⊖	↑	I	Operation amplifier SS inversion input
㉑	SS⊕	↑	I	Operation amplifier SS non-inversion input
㉒	TS OUT	Track servo	O	Operation amplifier TS output
㉓	TS⊖	↑	I	Operation amplifier TS non-inversion input
㉔	TG2	↑	-	Output of track/gain selector switch TG2. Made open or takes common level
㉕	TS⊕	↑	I	Operation amplifier TS non-inversion input
㉖	TG1	↑	-	Output of track/gain selector switch TG1. Made open or takes common level
㉗	TE OUT	↑	O	Operation amplifier TE output
㉘	TE⊖	↑	I	Operation amplifier TE inversion output
㉙	FSR IN	Focus servo	I	Input into focus search voltage level detector
㉚	FS OUT	↑	O	Operation amplifier FS output
㉛	FS⊖	↑	I	Operation amplifier FS inversion output
㉜	FS⊕	↑	I	Operation amplifier FS non-inversion output
㉝	FG	↑	-	Output of focus/gain selector switch FG. Made open or takes common level
㉞	C·FSR	↑	-	Connects the capacitor determining the time constant of focus search waveform
㉟	I-ref	Constant-current source	I	Terminal to connect current setting resistors of reference current source
㊱	Vcc	Power source	I	Terminal for positive power source

ABSOLUTE MAXIMUM RATINGS (Ta = 25°C, unless otherwise noted)

Symbol	Parameter	Ratings	Unit
Vcc	Supply voltage	+ 6.5	V
VEE		- 6.5	V
Vi	Input voltage Absolute value	Applied supply voltage + 0.3	V
Vo	Output voltage Absolute value	Applied supply voltage + 0.3	V
Pa	Power dissipation	560	mW
Topr	Operating temperature	-20 to +75	°C
Tstg	Storage temperature	-40 to +125	°C

RECOMMENDED OPERATING CONDITIONS (Ta = 25°C)

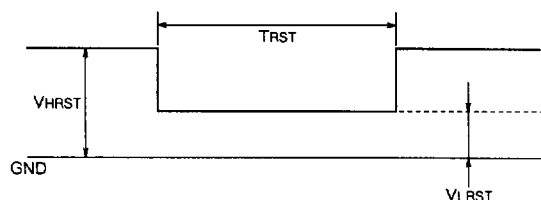
Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
Vcc	Supply voltage	(±) and single power sources	+ 4.75	+ 5.0	+ 5.25	V
VEE		(±) power source	- 5.25	- 5.0	- 4.75	V
VIH	Input voltage ("H" level)		2.5	-	Vcc	V
VIL	Input voltage ("L" level)		0	-	0.4	V

OPTICAL PICKUP SERVO CONTROL

ELECTRICAL CHARACTERISTICS ($V_{CC} = +5V$, $V_{EE} = -5V$, $T_a = 25^\circ C$, unless otherwise noted)

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
I _{CC}	Circuit current	To be reset	-	14	32	mA
I _{EE}	Circuit current	To be reset	-28	-12	-	mA
G _{FS}	FS closed loop voltage gain	f=1kHz, V _i = -10dBm	20	22	24	dB
ATTFS	FS SW attenuation	f=1kHz, V _i = 0dBm	-	-35	-25	dB
R _{ONFG}	FG SW ON resistance	f=1kHz, V _i = 0dBm	-	100	300	Ω
V _{HFS}	FS output voltage H	V _i = 1V, R _L = 220 Ω	2.2	4	-	V
V _{LFS}	FS output voltage L	V _i = -1V, R _L = 220 Ω	-	-4	-2.2	V
V _{FSR+}	FSR reference voltage (+)		0.40	0.45	0.50	V
V _{FSR-}	FSR reference voltage (-)		-0.54	-0.49	-0.44	V
G _{TE}	TE closed loop voltage gain	f=1kHz, V _i = -10dBm	6.8	8.8	10.8	dB
G _{TS}	TS closed loop voltage gain	f=1kHz, V _i = -10dBm	7.8	9.8	11.8	dB
ATTTS1	TS SW attenuation	f=1kHz, V _i = 0dBm	-	-50	-30	dB
ATTTS2			-	-50	-30	dB
R _{ONT1}	TG1SW ON resistance	f=1kHz, V _i = 0dBm	-	50	300	Ω
R _{ONT2}	TG2SW ON resistance	f=1kHz, V _i = 0dBm	-	50	300	Ω
V _{HTS}	TS output voltage H	V _i = 2V, R _L = 220 Ω	2.2	4	-	V
V _{LTS}	TS output voltage L	V _i = -2V, R _L = 220 Ω	-	-4	-2.2	V
G _{SS}	SS closed loop voltage gain	f=1kHz, V _i = -10dBm	11.5	13.5	15.5	dB
ATTSS	SS SW attenuation	f=1kHz, V _i = 0dBm	-	-54	-30	dB
V _{HSS}	SS output voltage H	V _i = 2V, R _L = 220 Ω	2.2	4	-	V
V _{LSS}	SS output voltage L	V _i = -2V, R _L = 220 Ω	-	-4	-2.2	V
V _{SH+}	SHOCK DET reference voltage (+)		0.3	0.4	0.5	V
V _{SH-}	SHOCK DET reference voltage (-)		-0.47	-0.37	-0.27	V
V _{JF}	JF output voltage		1.1	1.4	1.7	V
V _{JR}	JR output voltage		-1.7	-1.4	-1.1	V
V _{SF}	SF output voltage		2.2	2.8	3.4	V
V _{SR}	SR output voltage		-3.4	-2.8	-2.2	V
V _{FCU+}	FZC⊕search reference voltage		0.26	0.29	0.32	V
V _{FCU-}			-0.1	0	0.1	V
V _{FCD+}	FZC⊖search reference voltage		-0.1	0	0.1	V
V _{FCD-}			-0.31	-0.28	-0.25	V
V _{TC+}	TC reference voltage		0	0.1	0.2	V
V _{TC-}			-0.2	-0.1	0	V
V _{HTE}	TE output voltage H	V _i = 2V, R _L = 47k Ω	3.5	4.2	-	V
V _{LTE}	TE output voltage L	V _i = -2V, R _L = 47k Ω	-	-4.2	-3.5	V
V _{OSFS}	FS output offset voltage	Up search	70	130	190	mV
V _{OSTE}	TE output offset voltage		-35	-10	15	mV
V _{OSTS}	TS output offset voltage		-5	20	45	mV
V _{OSSS}	SS output offset voltage		-30	0	30	mV
I _{FSRU}	FSR output current		21	29	37	μA
I _{FSRD}			-32	-25	-8	μA

Note 1. Before taking measurements, whichever of the above, input the reset pulse as shown in the diagram below into terminal④ACL_R after turning power on.



TRST: 1 μs min
VHRST: 2.5V min
VLRST: 0.4V max

OPTICAL PICKUP SERVO CONTROL

FUNCTION DESCRIPTION

Setting the built-in constant-current source current level

Focus search (FSR), tracking servo (TS), and slide motor servo (SS)

The current level of the constant-current source for FSR, TS and SS can be set via resistor Rx connected across terminal ③ to Vcc.

Let the absolute values of the constant-current source current levels for FSR, TS, SS be Ifsr, Its, Iss, respectively. Then

$$I_{FSR} \approx \frac{1}{8} \cdot \frac{V_{CC} - V_{\text{FS}}}{R_x}$$

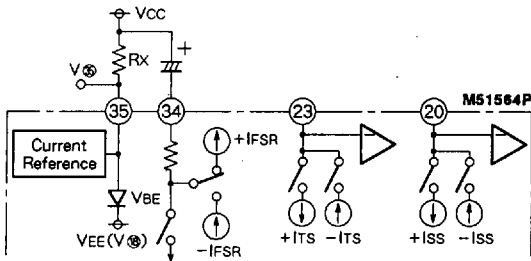
$$I_{TS} \approx \frac{1}{8} \cdot \frac{V_{CC} - V_{\text{FS}}}{R_x}$$

$$I_{SS} \approx \frac{1}{4} \cdot \frac{V_{CC} - V_{\text{FS}}}{R_x}$$

where V_{FS} is voltage at terminal ③. Let voltage at terminal ③ (V_{EE}) be V_{FS}. Then V_{FS} can be obtained

$$V_{\text{FS}} = V_{\text{FS}} + V_{BE} \quad (V_{BE} \approx 0.7V \text{ as standard})$$

Constant-current source block diagram



FSR detector

Current is input from FS OUT (terminal ② output) via resistors or the driver and resistors into FSR IN (terminal ③ input). The following are performed during focus search :

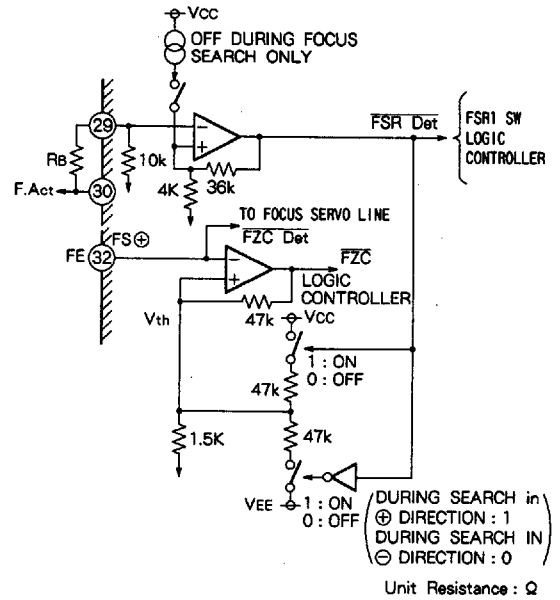
- Automatic switching of focus search direction
- Automatic switching of FZC detection polarity

Focus search always begins from the ⊕ side. The polarity of focus search voltage (⊕ or ⊖) is switched by FSR DET signal via FR1 SW.

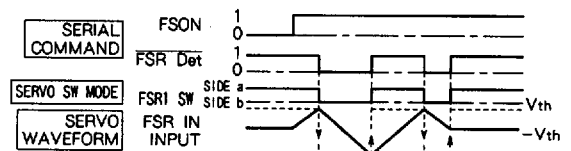
INPUT		OUTPUT	
FSR IN level V _{IN}	FSR Det	FSR1 SW mode	FZC V _{th} level
V _{IN} < V _{th}	0	Side b : ⊖ search voltage developed	Rise 0 - 0.30(V)
V _{IN} > V _{th}	1	Side a : ⊕ search voltage developed	Fall 0.30 0(V)

FZC V_{th} level is the value when the power source is ±5V.

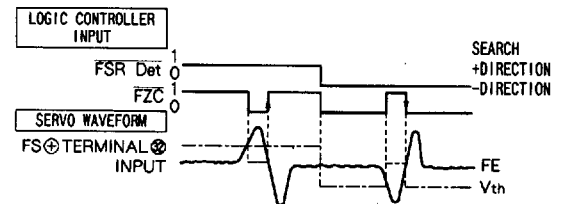
Equivalent circuit



FSR det operation timing chart



FZC Operation timing chart



Setting the focus search voltage and jump pulse and slide feed voltages

(power source : $\pm 5V$; $R_X = 47k\Omega$)

Setting the focus search voltage

Setting the FSR waveform maximum level V_{FS}
(determination of R_B)

$$V_{FS} = \frac{R_A + R_B}{R_A} V_{FSR} \dots \dots \dots (1)$$

$$\therefore R_B = R_A \left(\frac{V_{FS}}{V_{FSR}} - 1 \right)$$

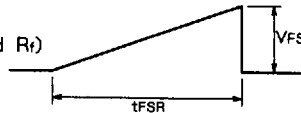
$$= 10 \times 10^3 \left(\frac{V_{FS}}{0.5} - 1 \right) (\Omega)$$

(V_{FSR} : FSR Det threshold value $\pm 0.5V$)
(R_A : FSR IN $\textcircled{2}$ input resistance $10k\Omega$)
(R_B : FSR IN $\textcircled{2}$ external resistance)

Setting FSR time t_{FSR} (determination of C_{FSR} and R_f)

$$t_{FSR} = \frac{C_{FSR}}{I_{FSR}} - \frac{R_s'}{R_f} V_{FS} \dots \dots \dots (2)$$

(R_s : FS $\ominus$ terminal $\textcircled{3}$ internal resistance $47k\Omega$)
(R_f : FS Amp external feedback resistance)
(C_{FSR} : C. FSR terminal $\textcircled{3}$ external capacitor)
(I_{FSR} : focus search current $\pm 25\mu A$)



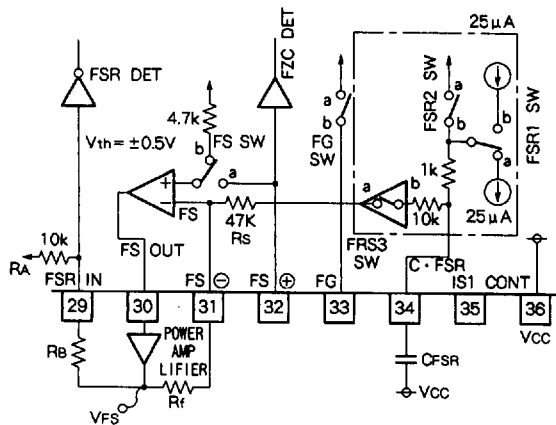
Setting jump pulse and slide feed voltages

- Jump pulse voltage V_{JF}

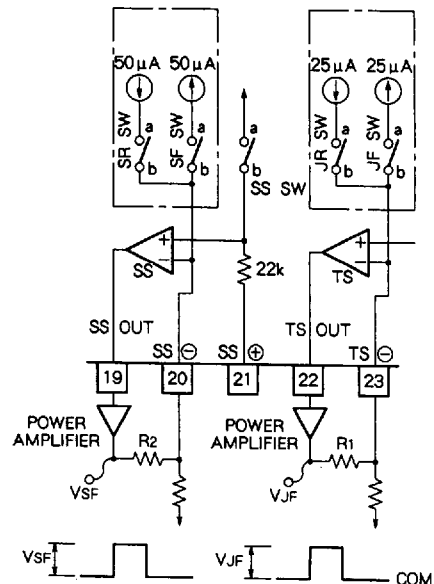
$$V_{JF} = R_1 \times 25\mu A$$

- Slide feed voltage V_{SF}

$$V_{SF} = R_2 \times 50\mu A$$



Note. Resistances in the diagram indicate standard values.
Current and voltage values are those when the power source is $\pm 5V$ and $R_X = 47k\Omega$.



OPTICAL PICKUP SERVO CONTROL

Functions of serial command

The logic controller has in itself a 8-bit shift register, which converts (or decodes) serial data from the microcomputer (input into MSD terminal ⑪) into commands for the servo IC.

Data-IN

The upper four bits (D7 to D4) of 8-bit data can set the

command mode, and the lower four (D3 to D0) the command state.

Commands in the same mode can be used at the same time within a data transfer and remains as set until new data is input. Thus the command state does not change even if other modes are chosen.

Serial command function table (X="1" or "0")

Mode	Input into Data IN terminal ⑪								Output from Data OUT terminal ⑩
	Mode selection				Command state setting				
	D7	D6	D5	D4	D3	D2	D1	D0	
FOCUS	0	0	0	0	FS ON	FG	FSR EN	x	FS OK
TRACK1 { A B	0	0	0	1	SHOCK A	BRAKE A	TG2	TG1	SHOCK OUT
			1		SHOCK B	BRAKE B			
TRACK2	0	0	1	0	TRACK		SLIDE		TC
SERVO OFF	0	1	x	x	x	x	x	x	0
STOP	1	1	x	x	x	x	x	x	0

Note 2. TRACK1 modes 1 and 2 are the same. TG2 and TG1 command states can be set in both TRACK1 A and B modes.

TRACK1 mode A or B determines SHOCK and BRAKE mode A or B. When either A or B is set to "1", the other is automatically released to "0".

SHOCK and BRAKE A and B can be released via TRACK1 A and B.

3. The states of command TRACK (D3, D2) and SLIDE (D1, D0) in TRACK2 mode are set in 2 bits each.

4. Output from Data OUT terminal ⑩ is automatically switched when the mode is switched.

5. 1xxxxxxx is used for the command sent to the signal processing LSI, M50422P. During use of this command, the servo IC remains held, or unchanged, retaining the hold condition.

Command function table

Command	Mode	Data		Functions	
FS ON	FOCUS	D3	1 ON	Starts focus search and turns focus on	
			0 OFF		
FG	↑	D2	1 CLOSE	Open/close focus gain selector switch, FG SW	
			0 OPEN		
FSR EN	↑	D1	1 INHIBIT	Prohibits automatic focus re-intake D1 = "1" actuates prohibition	
			0 ENABLE		
SHOCK A	TRACK1 A	D3	1 ON	Inverts TG1 and TG2 SW's via shock detection (Shock OUT = "1")	
			0 OFF		
SHOCK B	TRACK1 B	D3	1 ON	Prohibits TG1 and TG2 SW inversion when SHOCK A function + MR input = 1 (this is provided as remedy for flaws)	
			0 OFF		
BRAKE A	TRACK1 A	D2	1 ON	Provides jump brake (setting) operation Open/closes TS2 SW	
			0 OFF		
BRAKE B	TRACK1 B	D2	1 ON	Provides jump brake (setting) operation Open/closes TS1 SW	
			0 OFF		
TG2	TRACK1	D1	1 OPEN	Controls track gain selector switch, TG2 SW	
			0 CLOSE		
TG1	TRACK1	D0	1 OPEN	Controls track gain selector switch, TG1 SW	
			0 CLOSE		
TRACK	TRACK2	D3 D2		For the states of TS1, TS2, JF and JR SW's, refer to the Track Function Table	
		0 0	TS OFF		
		0 1	TS ON		
		1 0	JF		
		1 1	JR	Reverse jump	

OPTICAL PICKUP SERVO CONTROL

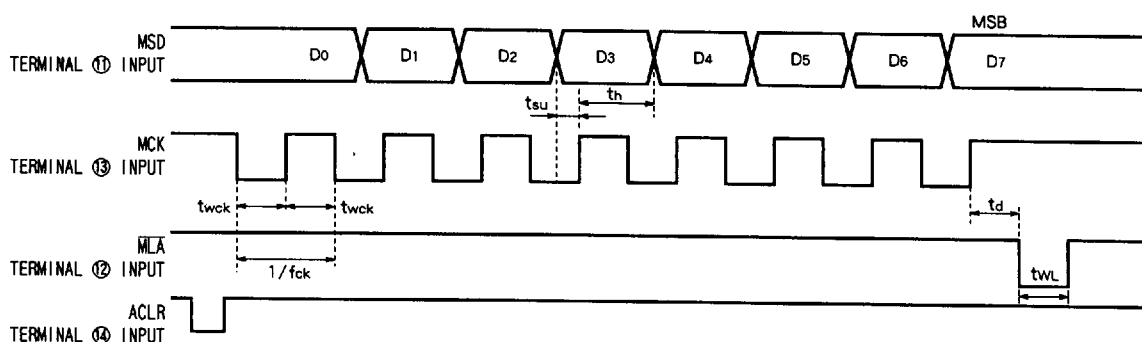
Command function table (Cont.)

Command	Mode	Data	Functions
SLIDE	TRACK2	D ₁ D ₀	
		0 0 SS OFF	Slide servo OFF
		0 1 SS ON	Slide servo ON
		1 0 SF	Forward slide
		1 1 SR	Reverse slide
	SERVOOFF		Resets data D ₀ to D ₃ to "0"
	STOP		Resets data D ₀ to D ₃ to "0" (this command is common to the signal processing LSI, M50422P)

Serial data (MSD) transfer method

With data transferred by "LSD first", sending $\overline{\text{MLA}}$ signal, the command is executed.

Serial data input timing chart



Logic input conditions

Symbol	Parameter	Test conditions	Limits			Unit
			Min	Typ	Max	
fck	Clock frequency		—	50	125	kHz
twck	Clock pulse width		4	20	—	μs
tsu	Set-up time		0.1	0.2	—	μs
th	Hold time		4	20	—	μs
td	Delay time		4	20	—	μs
twL	Latch pulse width		1	5	—	μs

BRAKE's A and B

With BRAKE A or B command set to "1", jump Brake operation begins, improving the jump setting ability after track jump.

Jump brake operation

- When MR = 1 (terminal ⑤ input), $\overline{\text{TC}}$ = "↑ or ↓" (TC Detoutput rise or fall) turns the track servo loop OFF.
- When MR = 0, $\overline{\text{TC}}$ = "↑ or ↓" turns the track servo loop ON.

Jump brake truth table

INPUT	OUTPUT	
MR $\overline{\text{TC}}$	BRAKE A = "1", the state of TS2 SW	BRAKE B = "1", the state of TS1 SW
1	a (track servo OFF)	b (track servo OFF)
0	b (track servo ON)	a (track servo ON)

When JF, JR or TS OFF command is effective, jump brake does not operate.

OPTICAL PICKUP SERVO CONTROL

TRACK function table

INPUT			OUTPUT (SW position)			
Command	Data		TS1 SW	TS2 SW	JF SW	JR SW
	D ₃	D ₂				
TS OFF	0	0	a(servo ON)	a(servo OFF)	b	b
TS ON	0	1	a(servo ON)	b(servo ON)	b	b
JF	1	0	b(servo OFF)	b(servo ON)	a(JF ON)	b
JR	1	1	b(servo OFF)	b(servo ON)	b	a(JR ON)

SLIDE function table

INPUT			OUTPUT (SW position)		
Command	Data		SS SW	SF SW	SR SW
	D ₁	D ₀			
SS OFF	0	0	a(servo OFF)	b	b
SS ON	0	1	b(servo ON)	b	b
SF	1	0	a(servo OFF)	a(SF ON)	b
SR	1	1	a(servo OFF)	b	a(SR ON)

Direct command function

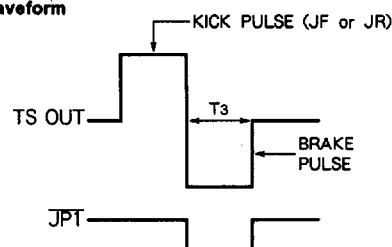
JPT signal

During jump of a track and the like operation, two serial data transfers can be omitted so as to decrease delay in microcomputer processing time.

JPT is normally "1". Switching to JPT = "0" when TC (Data OUT) signal = "↑" causes the logic controller to automatically inverse the Jump polarity (JF→JR and JR→JF).

If JPT is changed from "0" to "1" upon completion of one-track jump (after given time T₃), JF and JR are automatically ended, thus turning TS and SS on.

Jump T. ACT waveform



JPT signal truth table

JPT (INPUT)	TRACK2 Mode (0010·D ₃ D ₂ D ₁ D ₀) (OUTPUT)							
	TRACK (D ₃ D ₂)				SLIDE (D ₁ D ₀)			
	00	01	10	11	00	01	10	11
1	TS OFF	TS ON	JF	JR	SS OFF	SS ON	SF	SR
0	TS OFF	TS ON	JR	JF	SS OFF	SS ON	SF	SR
↑	TS OFF	TS ON	TS ON	TS ON	SS ON	SS ON	SF	SR

Note 6. If JPT = "↑" command is input when TS is OFF (001000XX), TS and SS are not turned on.

7. If TS and SS are turned on when JPT = "↑", TS and SS are kept ON until the subsequent TRACK2 mode command arrives.

T·HLD

Is the direct control terminal of TS1 SW

T·HLD	Function (OUTPUT)
1	TS1 SW = OPEN
0	Logic control command prevails

When BRAKE TS is off, however, the logic command prevails for TS1 SW.

Logic output function

Data out

This is switched by changing the serial command mode (see the Serial Command Function Table).

Data output corresponds to the serial command mode sent last.

Data out output correspondence table

	Data OUT signal name	Serial command mode (INPUT)
(I)	FS ON	FOCUS (0000XXXX)
(II)	TC	TRACK2 (0010XXXX)
(III)	SHOCK	TRACK1 A (0001XXXX) TRACK1 B (0011XXXX)

(I) FS ON

When HF OK terminal ④ input = "1" and when FS SW = "a" (servo ON), this outputs FS OK = "1".

FS OK truth table

INPUT		OUTPUT
HF OK	FS SW position	FS OK
0	b(servo OFF)	0
1	b(servo OFF)	0
0	a(servo ON)	0
1	a(servo ON)	1

While FS OK = "0", the following hold regardless of the command state :

TS2 SW = "a" (servo OFF)

SS SW = "a" (servo OFF)

(II) TC

Outputs TC signals latching MR signals at the edge (rise or fall) of TC Det output TC.

TC = "0" during reset.

(III) SHOCK OUT

Outputs SHOCK Det signals (SHOCK OUT).

TC truth table

INPUT		OUTPUT
MR	TC	TC
1	↑ or ↓	1
0	↑ or ↓	0

HFD

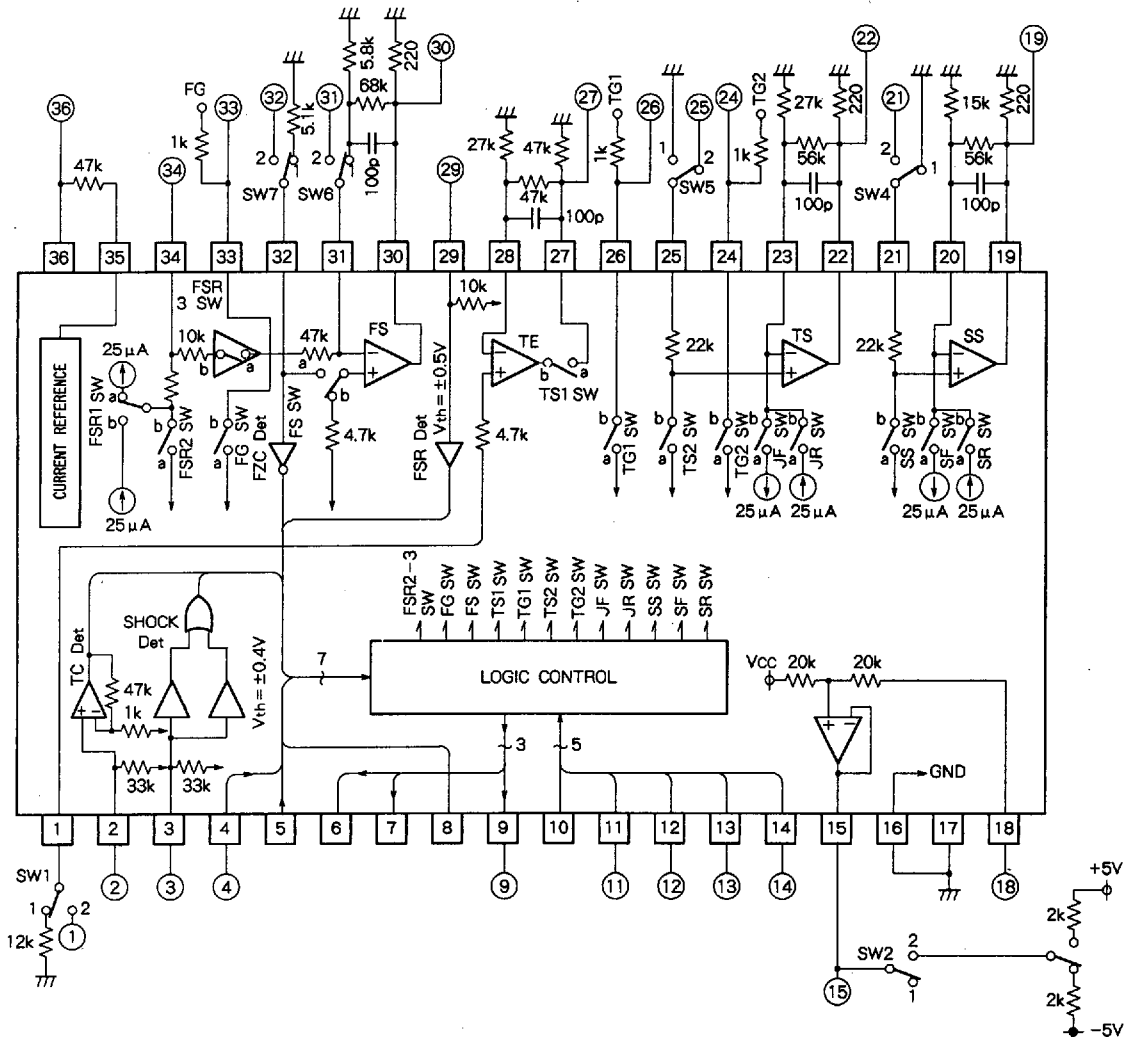
With MR signals (MR = "0" when HF signals are normal) of the pre-amplifiers (M51563P, M51567P, M51599FP) input to MR, this outputs HFD = "1" :

- During track jump
- During HF signal missing part detection
(MR signal : MR = "1").

Jump flag

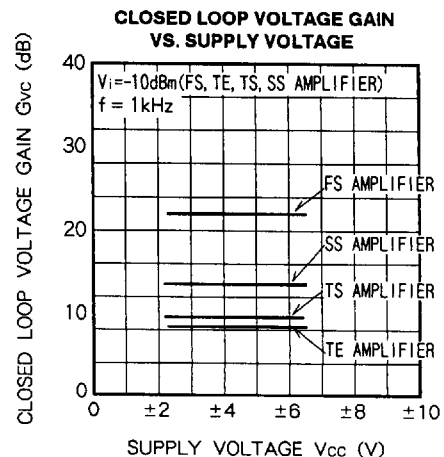
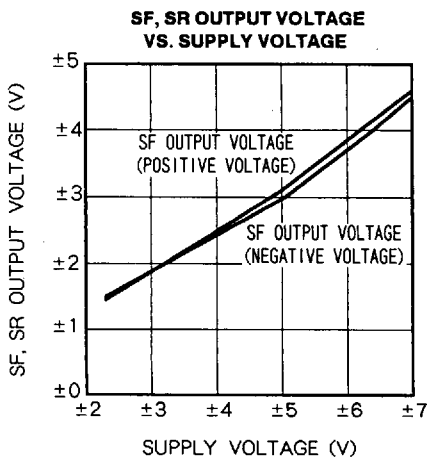
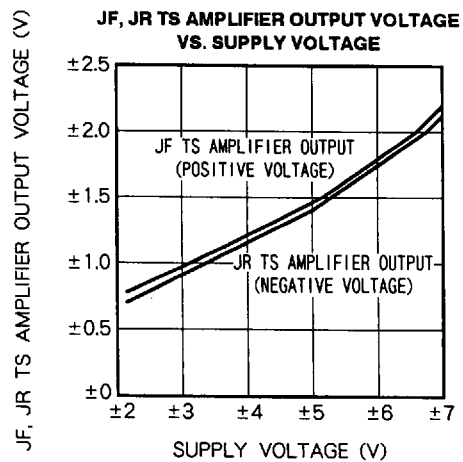
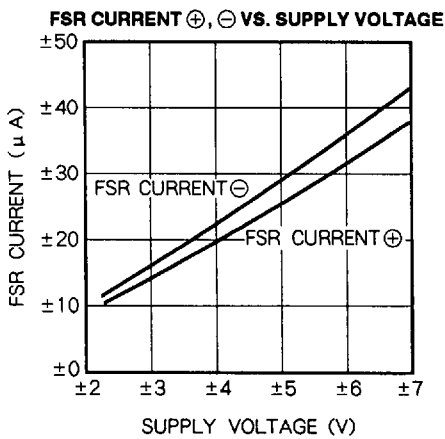
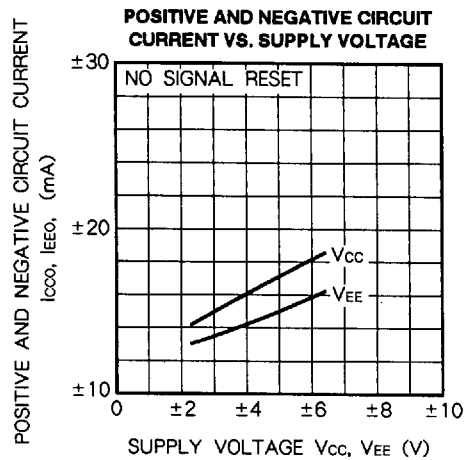
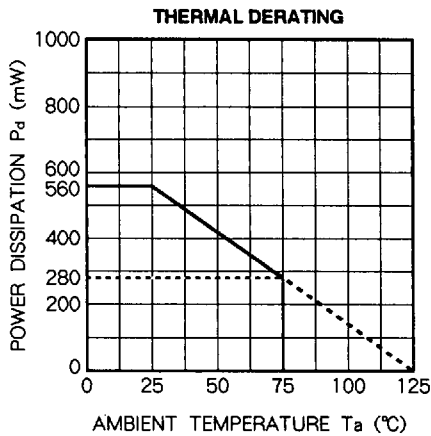
Outputs "1" when the serial command is TS OFF, JF, JR, and BRAKE, and "0" in other conditions.

TEST CIRCUIT

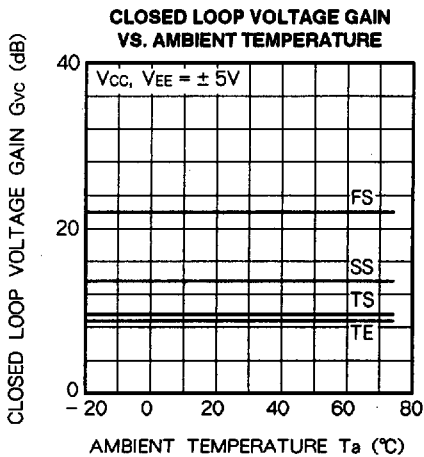
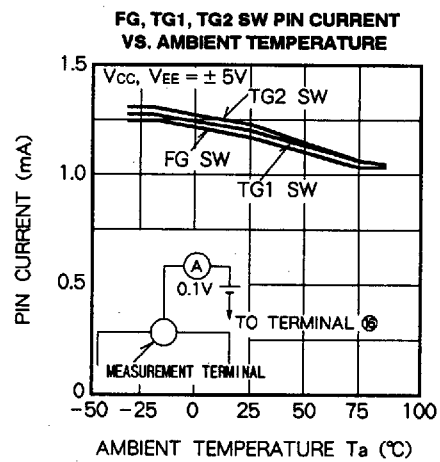
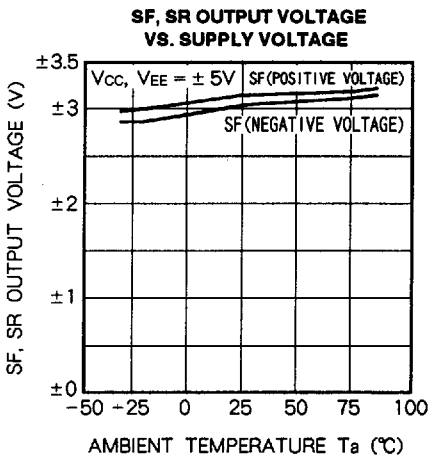
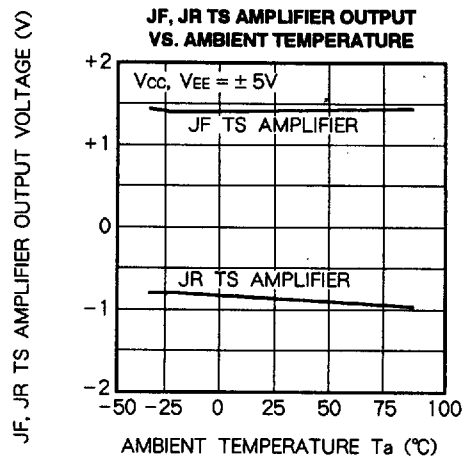
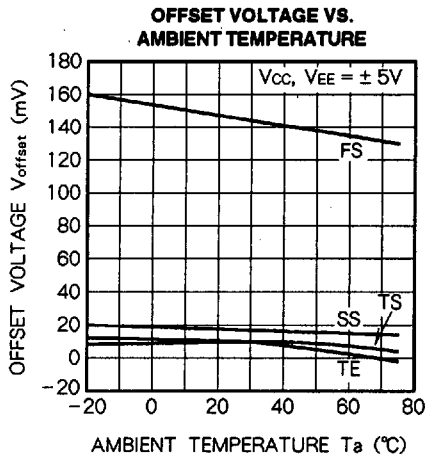


Units Resistance : Ω
Capacitance : F

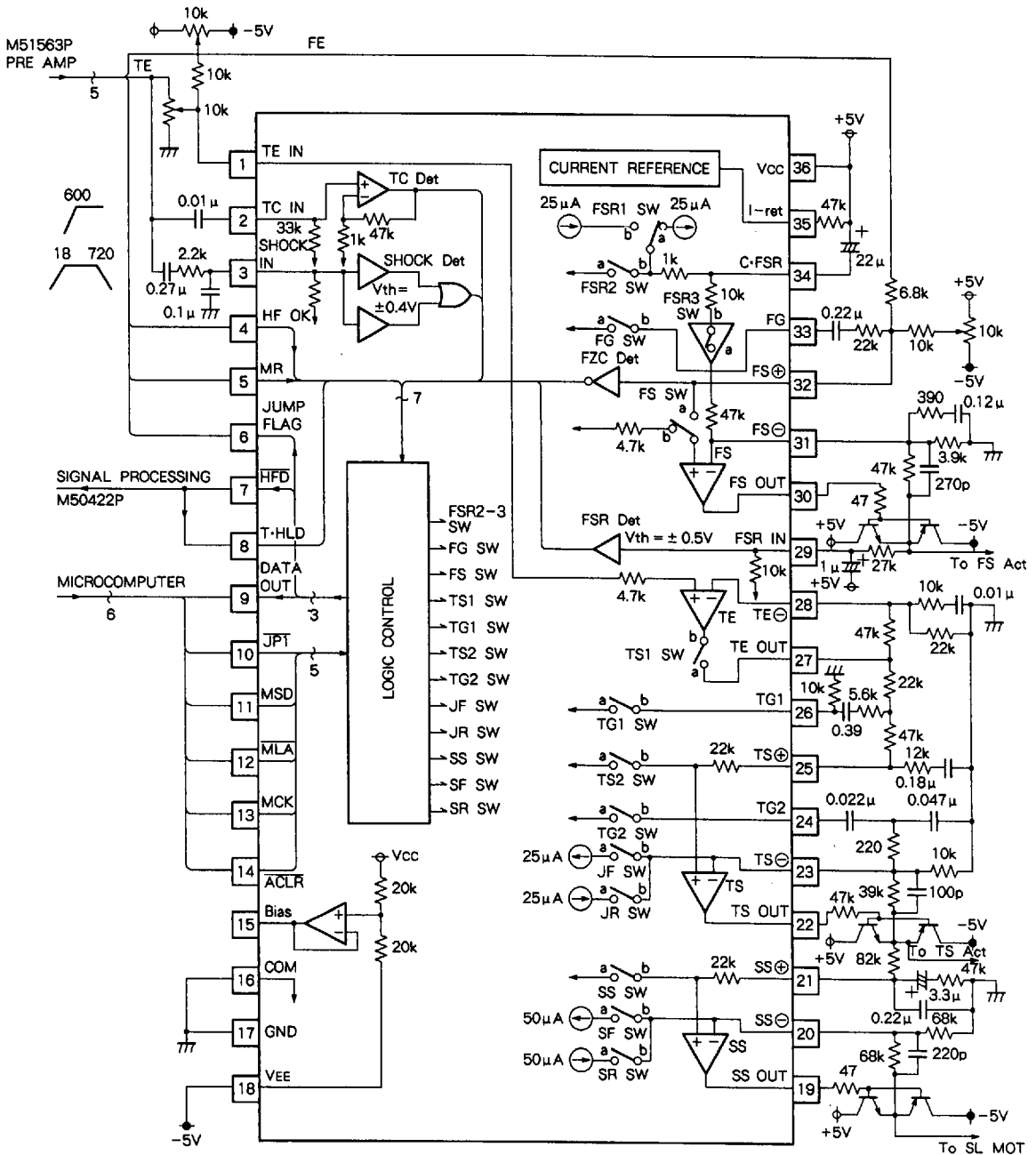
TYPICAL CHARACTERISTICS



OPTICAL PICKUP SERVO CONTROL



APPLICATION EXAMPLE ($V_{CC} = \pm 5V$, $V_{EE} = -5V$)



Units Resistance: Ω
Capacitance: F

Note 8. V_{th} and current values are those when the power source is $\pm 5V$.
 V_{th} with the single $-5V$ power source is used is about half that with $\pm 5V$ power source.