FEATURES

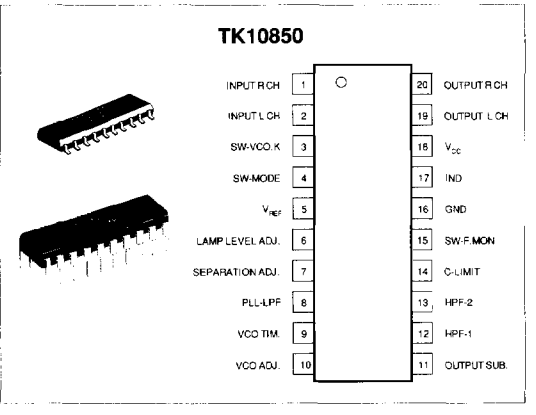
- **Low Voltage Operation**
- **PLL Demodulation**
- **VCO Killer Pin**
- **Multiplex Detection Level Variation Circuit**

APPLICATIONS

- **Portable TVs**
- **Radio/Cassette Players With TV Sound**
- **VCR**

DESCRIPTION

TK10850M and TK10850D are Japanese television multiplex audio signal restorers suited for use in products such as portable TVs and radio/cassette players. They provide a complete decoder system for stereo sound and subchannel decoders based on a PLL detection circuit. The IC has a built in Lamp Driver for a LED multiplex indicator. The TK10850 is designed for low voltage operation (2.7 V) and low operating current (1.5 mA) and is ideal for battery operated equipment. The IC uses a minimum of external components and includes a built in voltage regulator. The TK10850 is available in DIP20 and MFP20 surface mount packages.



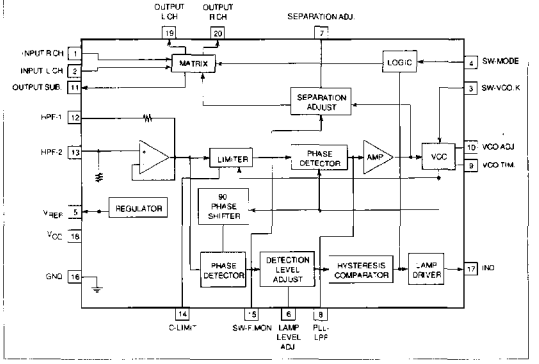
ORDERING INFORMATION

TK10850 □ □ □□

- Tape/Reel Code
- Temp. Range
- Package Code

PACKAGE CODE	TEMP. RANGE	TAPE/REEL CODE
M: Surface Mount	C : -20 to +70 °C	BX: Bulk/Bag
D: Plastic Dip		TX: Paper Tape
		TR: Tape Right
		TL: Tape Left
		MG: Magazine

BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Input Voltage V_{CCMAX} ..... 10 V
Power Dissipation (Note 1) ..... 410 mW
Operating Power Supply Voltage ..... 2.7 to 9.0 V
Junction Temperature ..... 150 °C

Storage Temperature Range ..... -55 to +150 °C
Operating Temperature Range ..... -20 to +70 °C
Lead Soldering Temp. (10 sec.) ..... 300 °C

ELECTRICAL CHARACTERISTICS

Test conditions: V_{CC} = 4.5 V, T_A = 25 °C, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
I_{CCQ}	Supply Current	No signal, stereo mode		3.5		mA
I_{CCK}	Supply Current (VCO Killer Operation)	When VCO Killer is operating, stereo mode		1.5		mA
V_{GMAI}	I/O Gain, Main	Main mode		-0.5		dB
V_{GSTE}	I/O Gain, Stereo	Stereo mode		-0.5		dB
V_{GSUB}	I/O Gain, Sub	Sub mode		-1.5		dB
CB	Channel Balance	Each mode		0		dB
D_{MAI}	Distortion, Main	Main mode		0.07		%
D_{STE}	Distortion, Stereo	Stereo mode		0.15		%
D_{SUB}	Distortion, Sub	Sub mode		0.60		%
SN_{MAI}	Signal to Noise Ratio, Main	Main mode		68		dB
SN_{STE}	Signal to Noise Ratio, Stereo	Stereo mode		63		dB
SN_{SUB}	Signal to Noise Ratio, Sub	Sub mode		63		dB
CS	Channel Separation	Stereo mode		47		dB
$Crss_{SM}$	Crosstalk, Sub →Main	Sub mode		62		dB
$Crss_{MS}$	Crosstalk, Main → Sub	Main mode		64		dB
Crss	Crosstalk	Monophonic mode		68		dB
C_{LSTE}	Carrier Leakage	Stereo mode		28		dB
V_{IN}	Maximum Input Level	Monophonic mode, distortion 3%		-5		dB
H_{LAMP}	Lamp Hysteresis	Stereo mode, modulation ratio 0%		4		dB
Z_{IN}	Input Impedance			50		k
V_{SAT}	Lamp driver saturation voltage	When lamp is drawing 5 mA		60		mV
L_{LEAK}	Lamp driver leakage current	When 4.5 V is applied to the lamp pin		0		µA

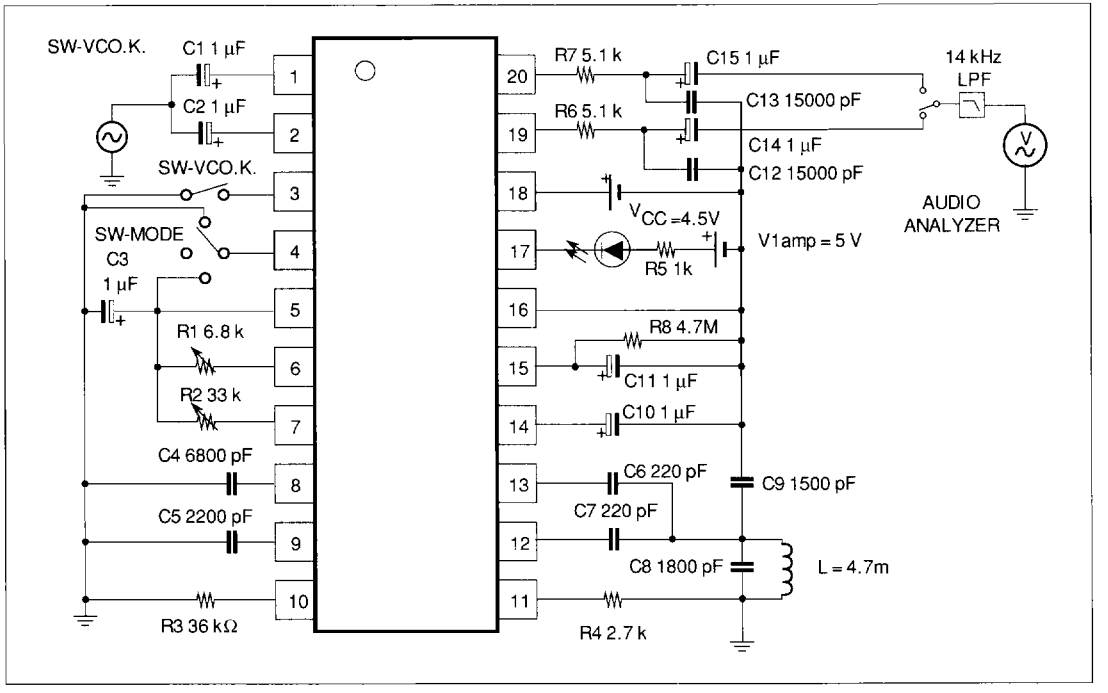
ELECTRICAL CHARACTERISTICS (CONT.)

Test conditions: V_{CC} = 4.5 V, T_A = 25 °C, unless otherwise specified.

The following conditions apply unless otherwise noted: Multiplex detection level (lamp on) = -30 dB (stereo mode, modulation ratio 0%); measured after channel separation adjustment (stereo mode).

MODE	INPUT SIGNAL					MODE SWITCH
	MAIN CHANNEL SIGNAL		SUB-CHANNEL SIGNAL			
	Level (dBV)	Frequency (kHz)	Level (dBV)	Frequency Variation (kHz)	Modulation Frequency (kHz)	
Monophonic	-24.0	1	-∞	—	—	Open
Main	-24.0	1	-28.4	31.468±0	—	V_{REF}
Stereo	-30.0	1	-25.9	31.468 ±5	1	Open
Sub	-∞	—	-28.4	31.468±10	1	Gnd

TEST CIRCUIT



TYPICAL APPLICATIONS

IC OPERATION

CHANNEL SEPARATION CORRECTION

A channel separation correction circuit has been built into the TK10850 to prevent deterioration of channel separation due to variation of the input signal level. Japanese television audio multiplex uses the FM-FM method, so theoretically the level of the signal input to the audio multiplex signal restorer doesn't vary. In reality, however, the signal level does vary due to factors such as the power supply and temperature dependence of components connected to the audio multiplex signal restorer (such as the FM-IF).

The formula below shows the channel separation in dB of typical audio multiplex signal restorers (i.e., those without channel separation correction circuits). The E term is the input signal level variation in dB.

$$CS = -20\log\frac{1-10^{-\left|\frac{\Delta E}{20}\right|}}{1+10^{-\left|\frac{\Delta E}{20}\right|}}$$

Formula 1

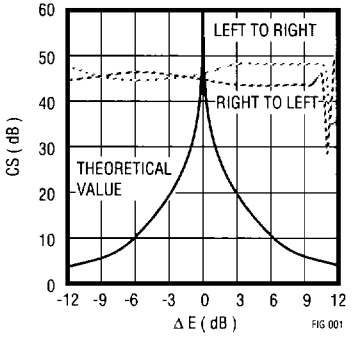


Figure 1: Audio multiplex signal restorer input signal level vs. channel separation

This function is shown in Figure 1 (the solid line). It is clear from Formula 1 and Figure 1 that channel separation deteriorates quickly with a variation in the input signal level. The channel separation correction circuit protects against this deterioration. This circuit controls the level of the signal (the L-R signal and sub-audio signal) that recovered the sub-channel (FM) signal being input. With this circuit, the deterioration of channel separation due to input signal level variation is sharply reduced. The dashed line in Figure 1 shows the improvement.

Furthermore, with typical audio multiplex signal restorers, a discrepancy develops between the main audio and sub-audio levels when the input signal level changes. Figure 2 shows the relationship between the input signal level and output signal level. Figure 3 clearly shows that this problem is solved in the TK10850 with the addition of the correction circuit.

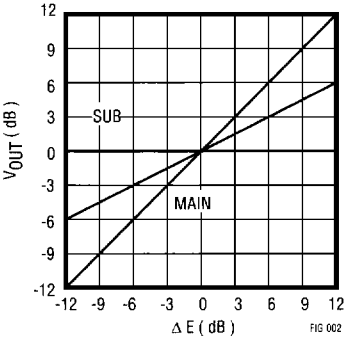


Figure 2: Input signal level vs. output signal level in a typical audio multiplex signal restorer.

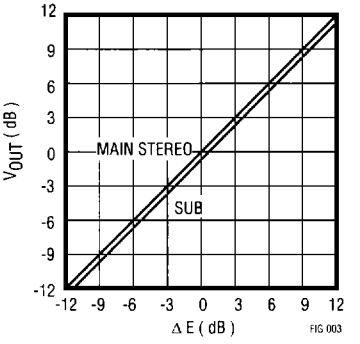


Figure 3: Input signal level vs. output signal level in the TK10850.

TYPICAL APPLICATIONS (CONT.)

IC OPERATION (CONT.)

MONO/MULTIPLEX DETECTION

The TK10850 can automatically determine whether a received signal is a monophonic or multiplex (stereo or bilingual) broadcast. This determination is made based on the input level of the sub-channel signal (with PLL locked). Thus a stereo broadcast is not automatically distinguished from a bilingual broadcast. These broadcasts are distinguished manually using a mode switch. When it is determined that a monophonic broadcast is being received, the matrix circuit converts to monophonic mode and the indicator is turned off. When a multiplex broadcast is being received, the matrix circuit converts to mode set on the mode switch and the indicator is turned on. However, during VCO killer or forced monophonic operation, the IC will operate as if a monophonic signal were received even if the received signal is a multiplex broadcast.

There were errors in mono/multiplex detection in earlier models which used the sub-channel signal level to discriminate between monophonic and multiplex signals. The TK10850 has been equipped with two types of malfunction prevention circuits described below, eliminating these errors.

1. The Lock-Capture Range Two-Level Conversion Circuit

This circuit is used to prevent errors in mono/multiplex discrimination due to the 19 kHz FM stereo pilot signal. The spectrums of the FM stereo composite signal and the Japanese television audio multiplex signal are shown in Figures 1 and 2, respectively.

As shown in Figure 3, a PLL with a wide lock range is required in order to recover the sub-channel signal of television audio multiplex by the PLL method. When the FM stereo pilot signal enters the PLL, there is the possibility that the PLL will lock onto this signal and an error will occur in detection. One method to avoid errors due to the FM pilot signal is to narrow the capture range by narrowing the bandwidth of the PLL's Loop-low pass filter, thus decreasing sensitivity in the 19 kHz region. However, if this method is used, the sub-channel detection output rises dramatically at higher frequencies, as shown in Figure 6. A variety of negative side effects result, so it is impossible to narrow the PLL's Loop-low

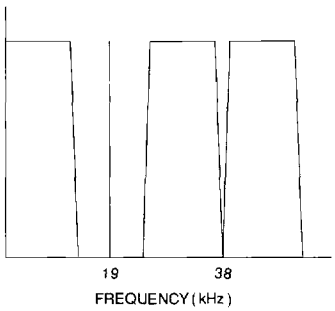


Figure 1: The spectrum of the FM stereo composite signal.

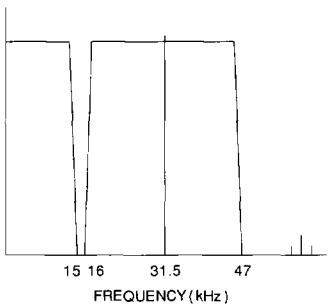


Figure 2: The spectrum of the television audio multiplex signal.

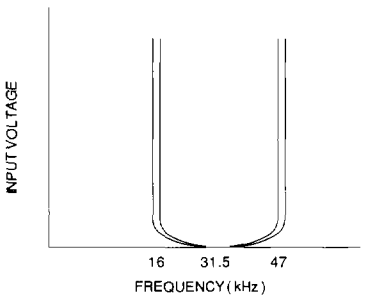


Figure 3: Earlier models' PLL lock and capture range used for the recovery of television audio multiplex signals. (These models locked onto the FM stereo pilot signal.)

TYPICAL APPLICATIONS (CONT.)

IC OPERATION (CONT.)

pass fi lter to the point that the PLL would not lock onto 19 kHz.

The TK10850 has a PLL with selectable capture range that prevents errors in signal discrimination due to the FM pilot signal. This circuit automatically switches between the two capture ranges as shown in Figure 4, depending on the input level of the sub-channel signal. In other words, if the input level of the sub-channel signal is lower than the multiplex detection level, the narrow lock-capture range is used. (The multiplex detection level can vary. See "2. Multiplex Detection Level Variation Circuit.") If it is higher, the wider lock-capture range is used. (The selection of the capture range is synchronized with the on/off switching of the indicator.)

2. Multiplex Detection Level Variation Circuit

This circuit is used to prevent errors in mono/multiplex discrimination due to noise. The type and level of noise can vary a great deal depending on the radio or TV, particularly when the input is weak. Thus, noise can be a cause for errors, too. The TK10850 has been equipped with a multiplex detection level variation circuit that can be set with external resistance to prevent errors due to noise and provide the best multiplex detection level for the particular radio or TV.

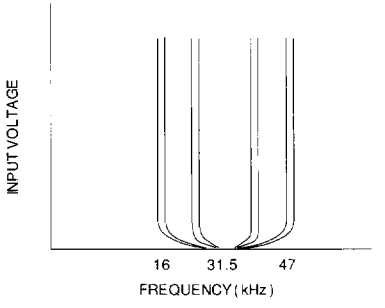


Figure 4: The lock-capture range of the TK10850M, has a PLL with selectable capture range.

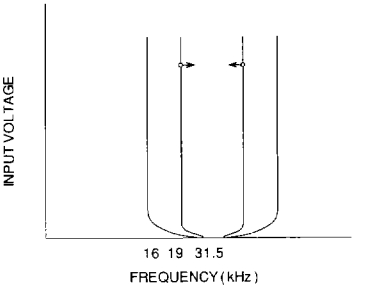


Figure 5: The lock and capture range of the PLL (used in earlier versions for TV audio multiplex sub-channel recovery) when the Loop-bandwidth was narrowed. (The lock and capture range narrowed.)

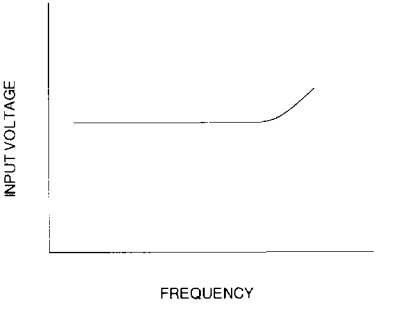


Figure 6: The frequency characteristics of the PLL detector output (used for TV audio multiplex sub-channel recovery) when the Loop-LPF is narrowed. (There is a sudden rise in the higher frequencies.)

Since the TK10850 has a two-level lock-capture range switching circuit as well as a multiplex detection level variation circuit, the lock-capture range observed with the PLL locked/unlocked is different than the lock-capture range observed with the indicator on/off. When observed with the PLL locked/unlocked, Figure 4 shows the wide lock-capture range when the indicator is on, and the narrow lock-capture range when the indicator is off. Figure 7 shows the lock-capture ranges when observed

TYPICAL APPLICATIONS (CONT.)

IC OPERATION (CONT.)

2. Multiplex Detection Level Variation Circuit (Cont.)

with the indicator on/off. That is, the capture range becomes ±0 kHz at the set point of the multiplex detection level. When the multiplex detection level is changed, the lock-capture range is shifted up or down.

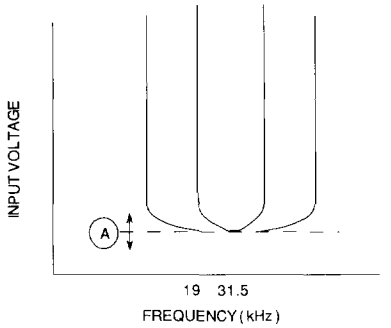


Figure 7: The lock and captures range of the TK10850M when observed with the indicator on and off. "A" shows the up or down shift when the multiplex detection level setting is changed. It does not lock on the 19 kHz signal or noise below the multiplex detection level.

TYPICAL APPLICATIONS (CONT.)

MATRIX CIRCUIT

The block diagram matrix circuit is shown in Figure 1. The truth table of corresponding switches is shown in Table 1.

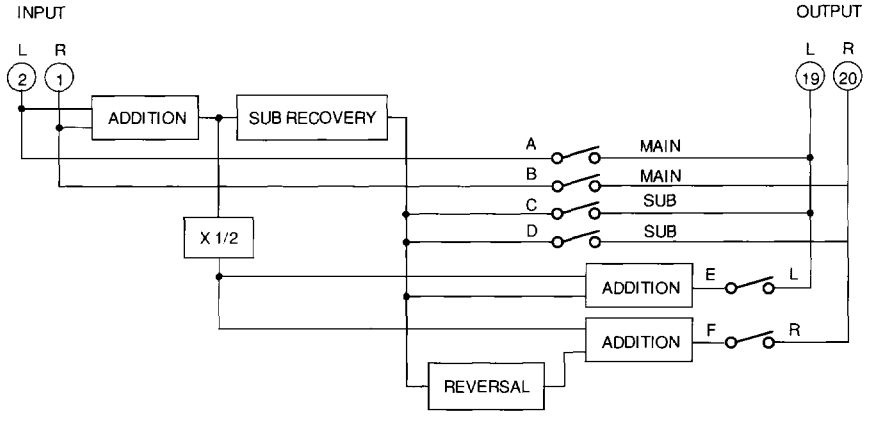


Figure 1: Matrix equivalent circuit

MODE	OUTPUT		MODE SWITCH	INTERNAL MATRIX SWITCH					
	L CH	R CH		a	c	e	b	d	f
Main	Main	Main	V_{REF}	o	x	x	o	x	x
Sub	Sub	Sub	GND	x	o	x	x	o	x
Stereo	L	R	Open	x	x	o	x	x	o

"o" is ON, and "x" is OFF

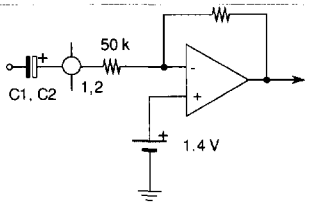
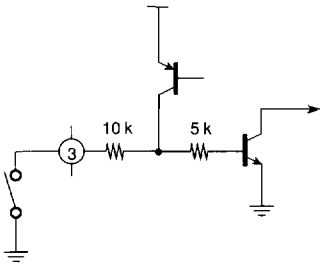
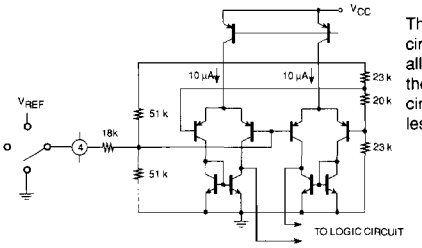
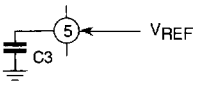
Table 1: Modes and Switch Settings

MODE	BILINGUAL BROADCAST		STEREO BROADCAST	
	L CH	R CH	L CH	R CH
Main	Main	Main	(L + R) /2	(L + R) /2
Sub	Sub	Sub	(L – R) /2	(L – R) /2
Stereo	(Main + Sub) /2	(Main – Sub) /2	L	R

Table 2: Outputs

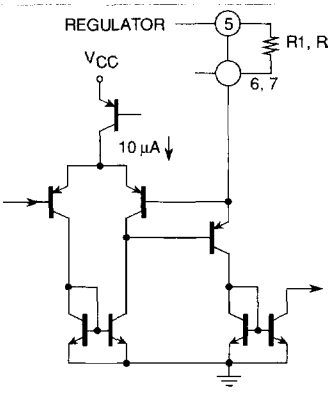
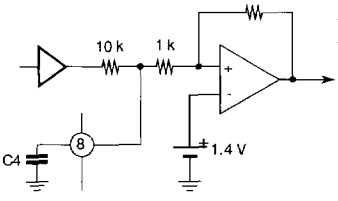
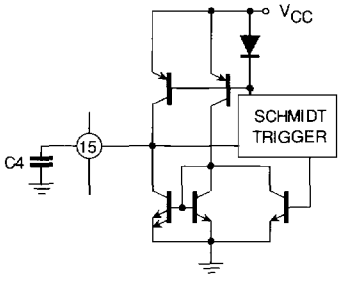
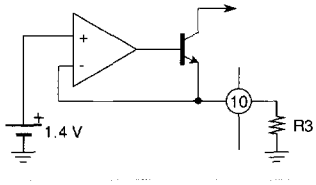
TYPICAL APPLICATIONS (CONT.)

TERMINAL CONNECTIONS

PIN NUMBER	PIN NAME	EQUIVALENT CIRCUIT	FUNCTION	PIN VOLTAGE (VDC)
1 2	Right channel signal input (Input - R CH) Left channel signal input (Input - L CH)		These are signal input pins. The output signal(s) from either the FM restorer or FM stereo restorer is connected to these pins. C1 and C2 are coupling capacitors. The input impedance is 50 kΩ.	1.4
3	VCO killer switch (SW - VCO.K.)		This is the VCO killer pin. Pulling down this pin (0 to 0.4 V) has the following effects: 1. VCO oscillation is stopped. 2. The matrix circuit goes into monophonic mode. 3. The multiplex indicator is turned off. 4. The current consumption becomes 1.5 mA. This pin is used when an AM signal is being received, for example.	0.7
4	Mode switch (SW-Mode)		This is the mode switching pin. The matrix circuit can be switched to any mode manually with the mode switch. However, if any of the following conditions exist, the matrix circuit will be in monophonic mode regardless of the mode switch setting. 1. A monophonic signal is being received. 2. The VCO killer is operating. 3. Monophonic operation is being selected.	0.7
5	Standard voltage output (Reference Voltage)		This is the standard voltage output pin. C3 is a smoothing capacitor.	1.4

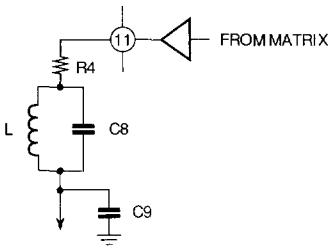
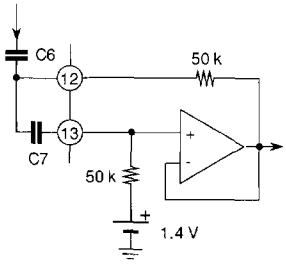
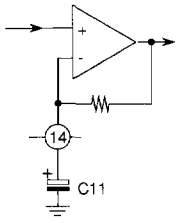
TYPICAL APPLICATIONS (CONT.)

TERMINAL CONNECTIONS

PIN NUMBER	PIN NAME	EQUIVALENT CIRCUIT	FUNCTION	PIN VOLTAGE (VDC)
6	Mono/multiplex detection level setting (Lamp Level Adjust)		This is the mono/multiplex detection level setting pin. The resistor R1 sets the mono/multiplex detection level. The detection level rises as R1 is increased. (Sensitivity decreases.)	1.4
7	Channel Separation Adjustment		This is the channel separation adjustment pin. The R2 resistance is used to adjust channel separation. The signal that recovered the sub-channel signal increases as R2 is decreased.	0.45
8	PLL low pass filter (PLL-LPF)		This is the PLL loop low pass filter pin. The following effects occur when C4 is increased: 1. The capture range narrows. 2. Carrier rejection becomes higher. 3. The f-characteristic of the signal that recovered the sub-channel signal rises at high frequencies.	1.4
9	VCO timing capacitance		This is the pin for connecting the VCO timing capacitor. The user can monitor the VCO oscillation frequency from this pin. Since this pin has high impedance, either an external buffer or test equipment with high input impedance should be used for measuring the VCO frequency. The following effects occur when C5 is increased: 1. The lock capture range narrows. 2. The level of the signal that recovered the sub-channel signal increases.	–
10	VCO free running frequency setting		This is the VCO free running frequency setting pin. The VCO free-running frequency is set to 31.468 kHz with R3.	1.4

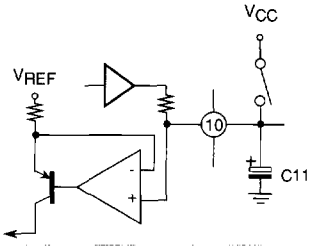
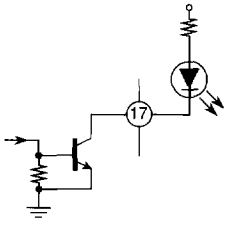
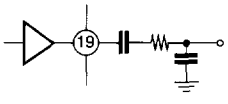
TYPICAL APPLICATIONS (CONT.)

TERMINAL CONNECTIONS

PIN NUMBER	PIN NAME	EQUIVALENT CIRCUIT	FUNCTION	PIN VOLTAGE (VDC)
11	Sub signal output (Output Sub)		This pin is used for sub-channel signal output. The Right Channel input (pin 1) and the Left Channel input (pin 2) are added, and the sum is divided by 2 and made available at the output. It is recommended to insert a filter to remove the control channel signal from this pin's output. If this filter is not included, not functional problems will arise, but with the television audio multiplex method, an audible beat in the audio signal will develop from interaction between the sub-channel signal and control signal channel. The parallel resonance in coil L and capacitor C8 create a filter removing the control channel. Capacitor C9 acts as a low pass filter as well as a phase shift corrector for the sub-channel signal.	1.4
12	Filter 1 (HPF-1)		These pins connect to the active filter for sub-channel signal extraction. A high pass filter is constructed by connecting the C6 and C7 capacitors. The mail channel signal is reduced by the high pass filter and the sub-channel signal is sent on to the recovery circuit and multiplex detection circuit. When C4 = C5 = C, the cutoff frequency f_C of the high pass filter is: $f_C = 1/(2\ CR)$ Hz. The rolloff is 12 dB/Oct.	–
13	Filter 2 (HPF-2)			
14	Decoupling capacitor (C-limit)		This terminal connects to the decoupling capacitor used as a limiter. C10 is the decoupling capacitor.	1.4

TYPICAL APPLICATIONS (CONT.)

TERMINAL CONNECTIONS

PIN NUMBER	PIN NAME	EQUIVALENT CIRCUIT	FUNCTION	PIN VOLTAGE (VDC)
15	Forced monophonic switch (SW-F. Mon.)		This is the PLL loop low pass filter pin. The following effects occur when C10 is large: 1. The capture range becomes narrow. 2. Carrier rejection becomes higher. 3. The f-characteristic of the sub-channel signal's detection output rises at high frequencies.	1.4
16	GND		GND pin.	0
17	Multiplex indicator (Lamp Driver)		This is the multiplex indicator pin. It is an open collector.	–
18	V_{CC}		V_{CC} pin.	4.5
19	Left channel signal output (Output-L CH)		These are the audio signal output pins. The pin bias is 1.4 VDC.	1.4
20	Right channel signal output (Output-R CH)			

TYPICAL APPLICATIONS (CONT.)

THE S-CURVE OF THE FM IF, THE I/O PHASE SHIFT OF THE FM MPX, AND THE TK10850'S OUTPUT

Pin 19 and 20 might correspond to either the left and right or right and left audio signals depending upon whether the S-curve of the FM IF is regular or reversed, and whether the phase shift between the FM MPX's input and output is regular or reversed. Wire as shown in Figure 1 when both the S-curve of the FM IF and the phase shift between the FM MPX's input and output are regular, or both are reversed. The outputs for this case are shown in Table 1. Wire as shown in Figure 2 when one is regular and the other is reversed. The outputs for this case are shown in Table 2.

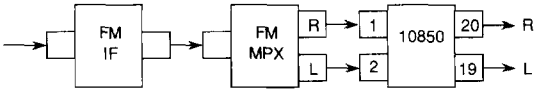


Figure 1: Both regular or both reversed.

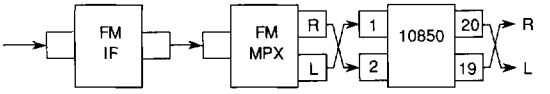


Figure 2: One regular and the other reversed.

		INPUT		OUTPUT		INPUT		OUTPUT	
		Pin 2	Pin 1	Pin 19	Pin 20	Pin 2	Pin 1	Pin 19	Pin 20
	FM stereo	Left audio	Right audio	Left audio	Right audio	V	V	V	V
TV audio	Stereo	TV audio multiplex signal Stereo		Left audio	Right audio			V	V
	Main	TV audio multiplex signal		Main audio	Main audio	V	+f	V	V
	Sub	Bilingual		Sub-audio	Sub-audio			V	V

Table 1: Input and output allocation corresponding to Figure 1.

		INPUT		OUTPUT		INPUT		OUTPUT	
		Pin 2	Pin 1	Pin 19	Pin 20	Pin 2	Pin 1	Pin 19	Pin 20
	FM stereo	Left audio	Right audio	Left audio	Right audio	V	V	V	V
TV audio	Stereo	TV audio multiplex signal Stereo		Left audio	Right audio			V	V
	Main	TV audio multiplex signal		Main audio	Main audio	V	+f	V	V
	Sub	Bilingual		Sub-audio	Sub-audio			V	V

Table 2: Input and output allocation corresponding to Figure 2.

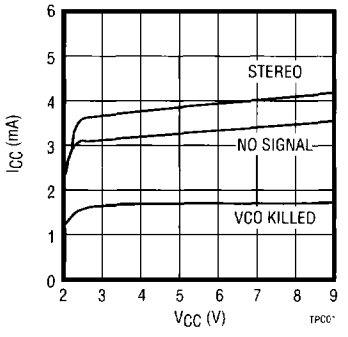
Note: For the diagrams in Tables 1 and 2:

V ⌐‾‾ Horizontal axis = time, vertical axis = DC signal voltage

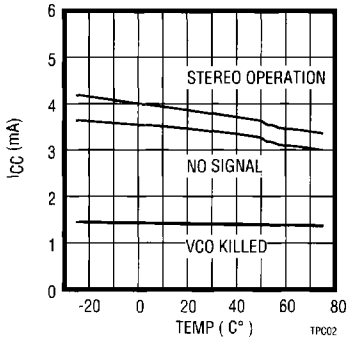
f ⌊‾‾ Horizontal axis = time, vertical axis = frequency

TYPICAL PERFORMANCE CHARACTERISTICS

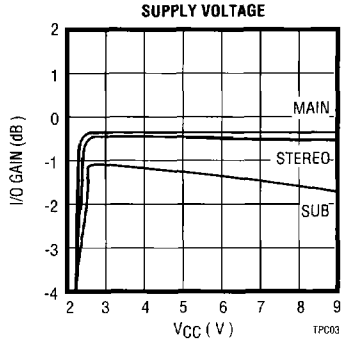
SUPPLY CURRENT vs SUPPLY VOLTAGE



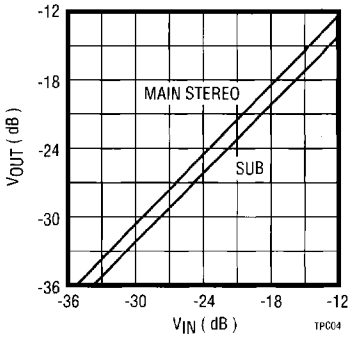
SUPPLY CURRENT vs TEMPERATURE



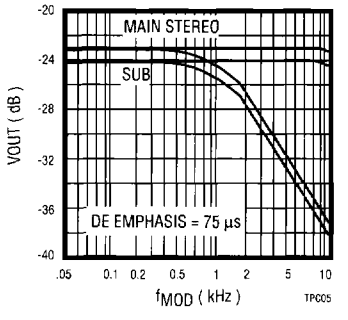
INPUT/OUTPUT GAIN vs SUPPLY VOLTAGE



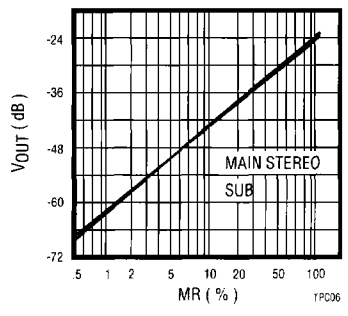
OUTPUT SIGNAL LEVEL vs INPUT SIGNAL LEVEL



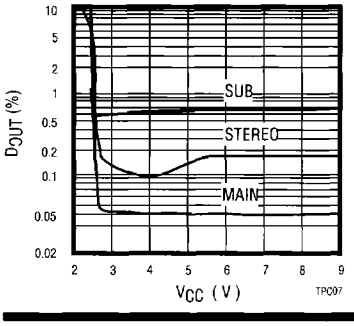
OUTPUT SIGNAL LEVEL vs MODULATION FREQUENCY



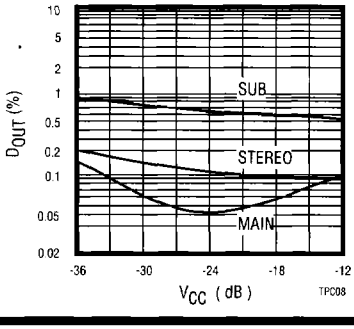
OUTPUT SIGNAL LEVEL vs MODULATION FREQUENCY



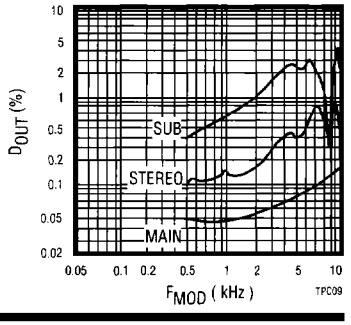
OUTPUT SIGNAL DISTORTION vs SUPPLY VOLTAGE



OUTPUT SIGNAL DISTORTION vs INPUT SIGNAL LEVEL

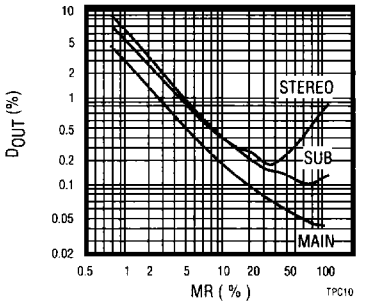


OUTPUT SIGNAL DISTORTION vs MODULATION FREQUENCY

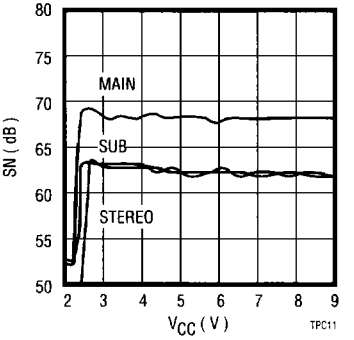


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

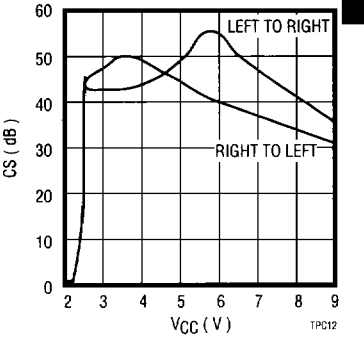
OUTPUT SIGNAL DISTORTION vs MODULATION RATIO



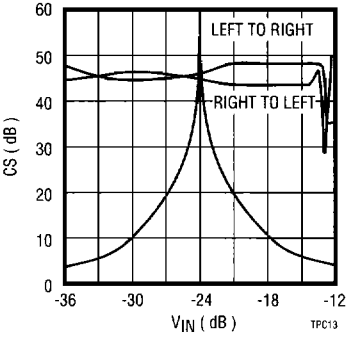
SIGNAL TO NOISE RATIO vs POWER SUPPLY VOLTAGE



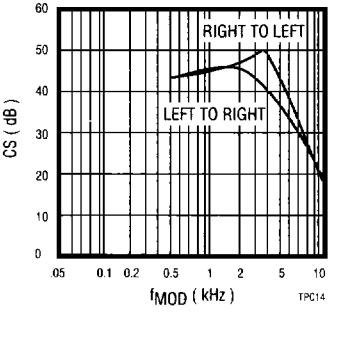
SEPARATION vs POWER SUPPLY VOLTAGE



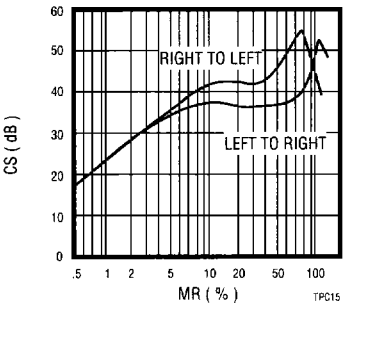
SEPARATION vs INPUT SIGNAL LEVEL



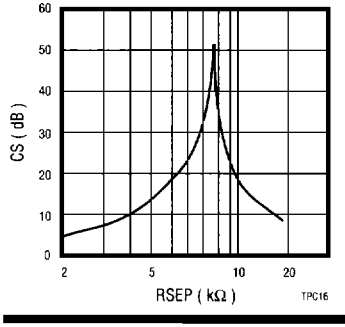
SEPARATION vs MODULATION FREQUENCY



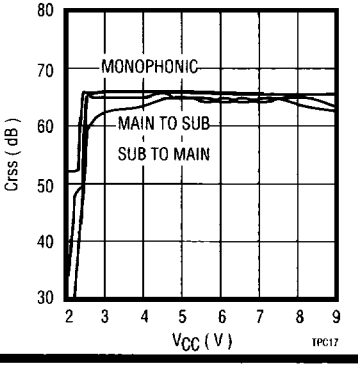
SEPARATION vs MODULATION RATIO



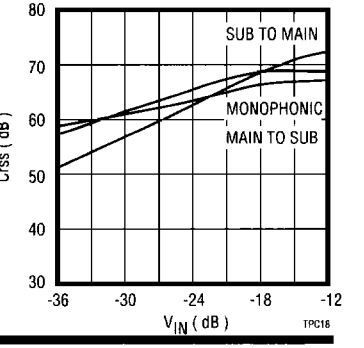
SEPARATION vs SEPARATION ADJUSTMENT RESISTANCE



CROSSTALK vs SUPPLY VOLTAGE

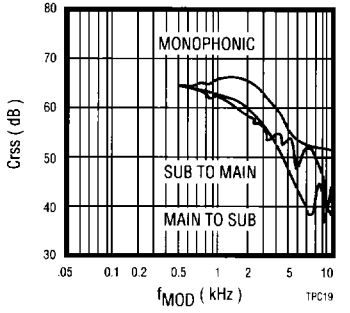


CROSSTALK vs INPUT SIGNAL FREQUENCY

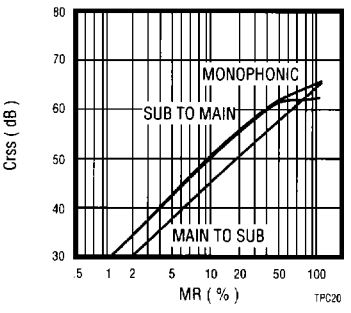


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

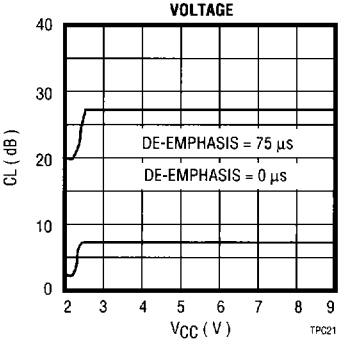
CROSSTALK vs MODULATION FREQUENCY



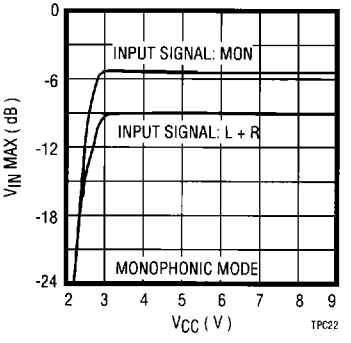
CROSSTALK vs MODULATION RATIO



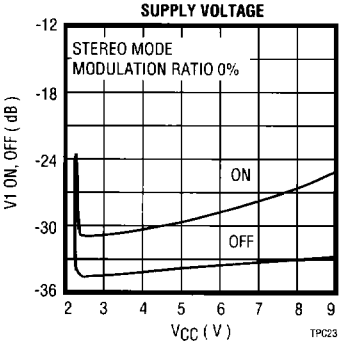
CARRIER LEAKAGE vs SUPPLY VOLTAGE



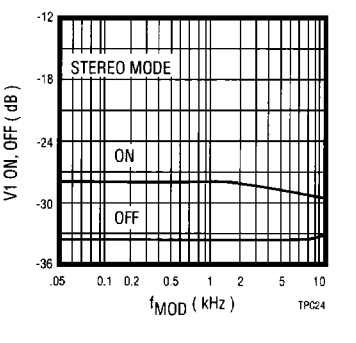
MAXIMUM INPUT SIGNAL LEVEL vs SUPPLY VOLTAGE



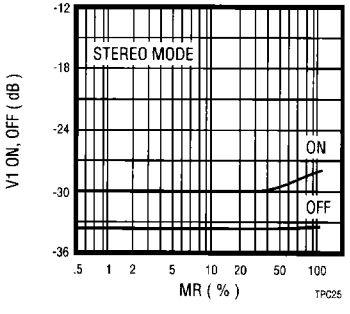
DETECTION LEVEL vs SUPPLY VOLTAGE



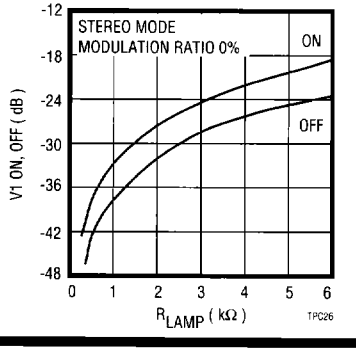
DETECTION LEVEL vs MODULATION FREQUENCY



DETECTION LEVEL vs MODULATION RATIO

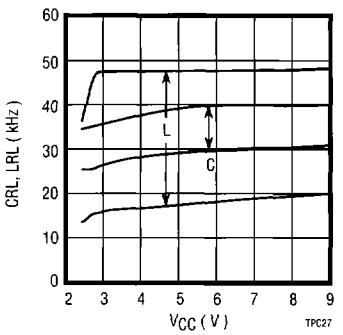


DETECTION LEVEL vs DETECTION LEVEL ADJUSTMENT LEVEL

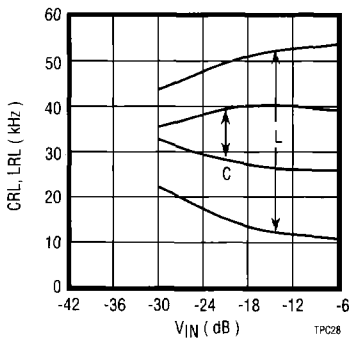


TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

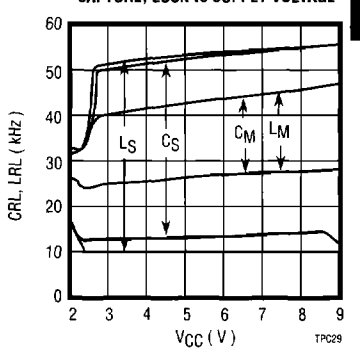
CAPTURE, LOCK vs SUPPLY VOLTAGE



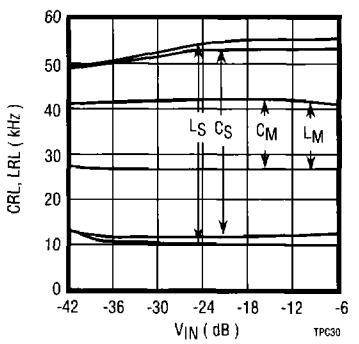
CAPTURE, LOCK vs INPUT SIGNAL LEVEL



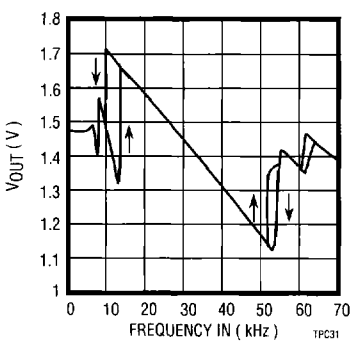
CAPTURE, LOCK vs SUPPLY VOLTAGE



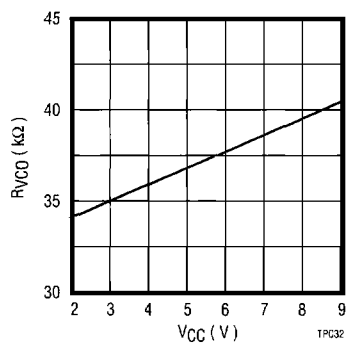
CAPTURE, LOCK vs INPUT SIGNAL LEVEL



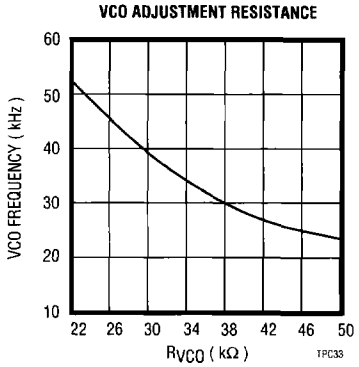
DC OUTPUT SIGNAL VOLTAGE vs INPUT SIGNAL FREQUENCY



VCO ADJUSTMENT RESISTANCE vs SUPPLY VOLTAGE



VCO FREE-RUNNING FREQUENCY vs VCO ADJUSTMENT RESISTANCE



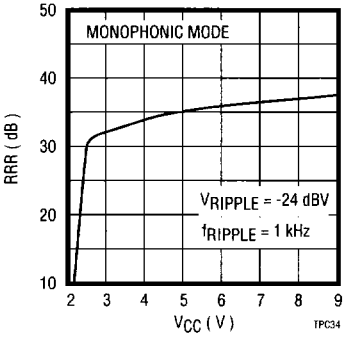
Notes: Measurements in graphs 1 to 4 of this section were taken in stereo mode. Measurements in graphs 1 and 2 were observed according to whether the lamp (multiplex indicator) was on or off. "L" indicates the lock range and "C" the capture range. Measurements in graphs 3 and 4 of this section were observed according to whether the VCO frequency was locked onto the input signal or not.

"L_S" and "C_S" are the lock range and capture range during forced monophonic operation.

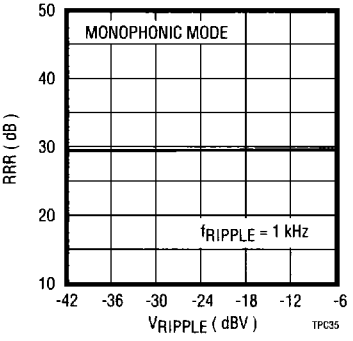
In graph 6, the VCO adjustment resistance is set so that the VCO free-running frequency is 31.5 kHz.

TYPICAL PERFORMANCE CHARACTERISTICS (CONT.)

RIPPLE REMOVAL RATIO vs POWER SUPPLY VOLTAGE



RIPPLE REMOVAL RATIO vs RIPPLE LEVEL



RIPPLE REMOVAL RATIO vs RIPPLE FREQUENCY