

# NIEC's SBD and FRED for Audio

Nihon Inter Electronics Corporation (NIEC) is a major manufacturer of Schottky Barrier Diode (SBD) and Fast Recovery Epitaxial Diode (FRED). Thanks to low dissipation, fast switching, and low noise characteristics, these fast switching diodes are widely used in Switching Mode Power Supply (SMPS) all over the world. Other than such applications, these features are also valuable to *Audio* applications. In fact, our SBD and FRED are adopted to line rectifiers in high-end and medium-class audio equipments in Japan. This paper represents the possibility of SBD and FRED to improve sound quality.

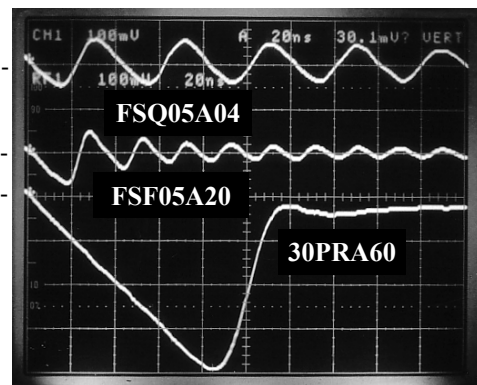
## Reverse recovery vs. Switching noise in SMPS

Firstly, before talking about audio application, let's check the relationship between reverse recovery and switching noise in SMPS. Shown below is an evaluation board of JRC's NJM2367 step down DC-DC converter, where input is 12V, and output is 5V. Three diodes are compared, and major characteristics of these diodes are shown in the following table. The input voltage is 12V, so

P/N		$I_o$	$V_{RRM}$	$V_F$ (max.)
FSQ05A04	SBD	5A	40V	0.55V
FSF05A20	FRED	5A	200V	0.98V
30PRA60	FRD	3A	600V	1.15V

### 3 diodes compared in DC-DC converter

40V of  $V_{RRM}$  is sufficient. As a matter of course, FSQ05A04 is the proper choice here, but the other two are participated to see the effect of higher  $V_F$ , longer trr, and recovery manner. Photo1 indicates reverse recovery of the 3 diodes under same condition,  $I_F=3A$ ,  $-di/dt=50A/\mu s$ ,  $25^\circ C$ . This photo shows that reverse recovery time (trr) of FSQ05A04 (5A, 40V, SBD) is almost same as

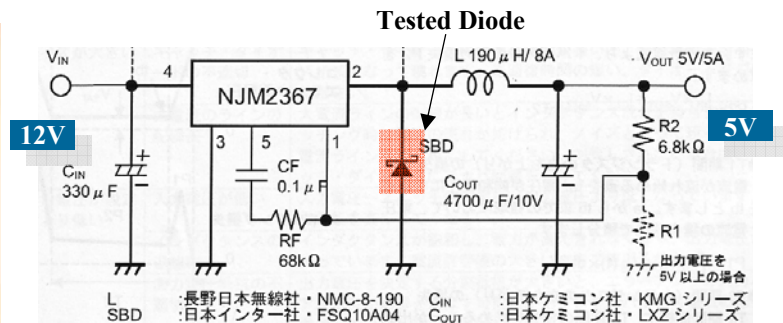


Reverse recovery of 3 diodes

$I_F=3A$ ,  $-di/dt=25A/\mu s$ ,  $25^\circ C$

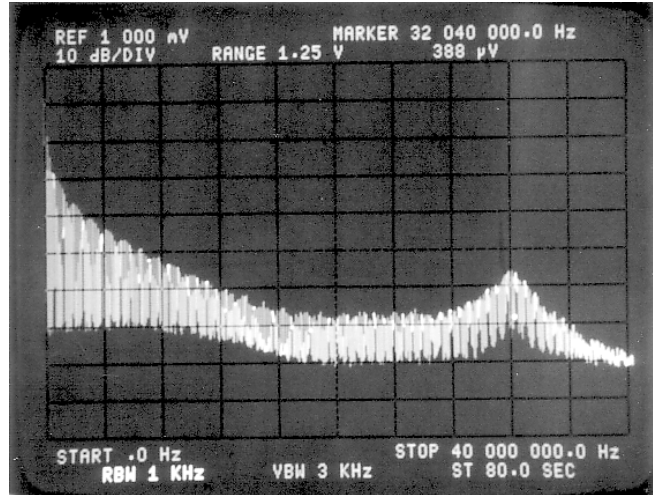
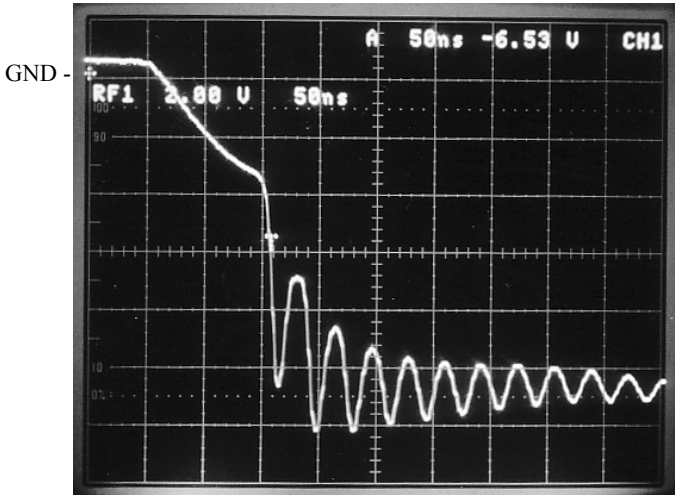
FSF05A20 (5A, 200V, FRED), but we find some difference in voltage ringing. Although two diodes have similar trr at  $25^\circ C$ , as temperature rises, trr of FRED increases but that of 40V SBD remains nearly identical. Among three diodes, 30PRA60 has highest  $V_F$  and longest reverse recovery time (trr), so this diode cannot be a practical choice to this usage.

Photos on next page show operating voltages observed between anode and cathode of each diode. Here we see the effect of reverse recovery

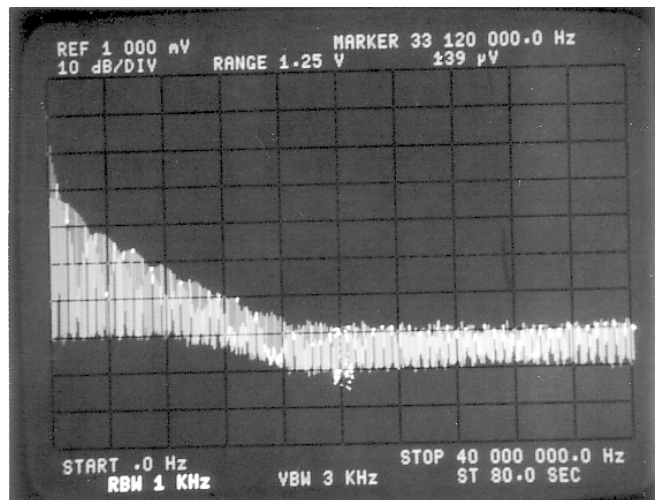
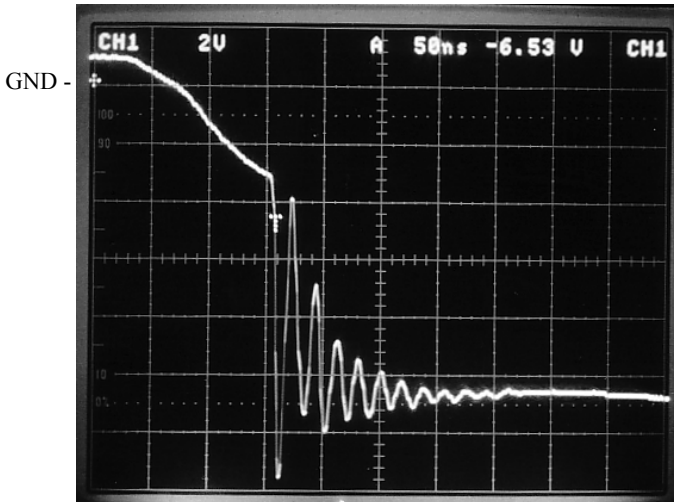


NJM2367 Step Down DC-DC Converter Evaluation Board

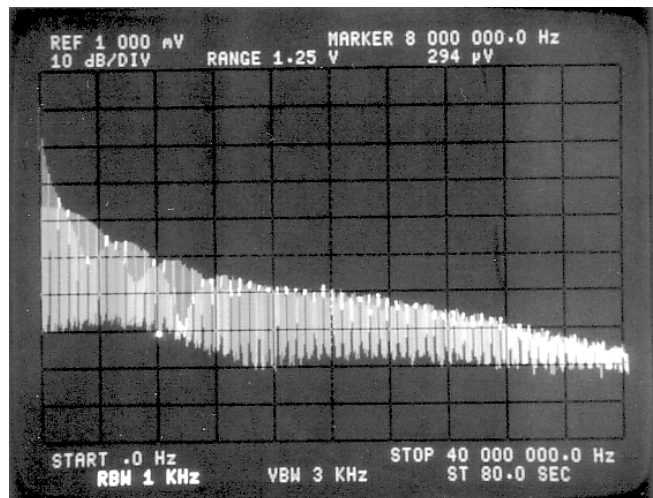
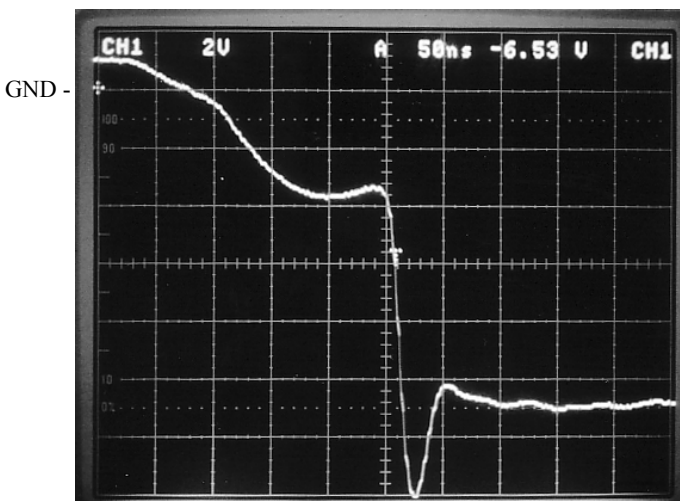
FSQ05A04



FSF05A20



30PRA60



	Input voltage :12V, Output :5.03V/2A		Output ripple voltage		
	Input current	Efficiency	Max.	Min.	RMS
FSQ05A04	1.01A	83.0%	33.6mV	-24.0mV	3.6mV
FSF05A20	1.03A	81.3%	10.4mV	-24.8mV	3.3mV
30PRA60	1.09A	76.9%	56.8mV	-62.4mV	9.1mV

Table 1, Operating Efficiency and Output ripple voltage

on diode operation. In addition, spectrum analyzer also displays frequency domain distributions. It may be very interesting to study these data. Examining frequency distribution of FSQ05A04, we see that voltage ringing results in a peak at specific frequency (32MHz). As expected, FSF05A20 would have similar peak at a frequency higher than 40MHz. Anyway, we would like to emphasize that noises at such high frequency may not have direct influence on audio frequency applications.

Applying three diodes to NJM2367 DC-DC converter, we measured operating efficiency and output noise. Table 1 shows the summary. Naturally, efficiency goes down with increasing forward voltage of diode, and output ripple voltage

increases with increasing trr. However, it is essential that trr is not the direct measure of output noise of SMPS, because other active and passive circuit elements have significant effects on the noise. As for diode, it is generally agreed that shortest trr at actual operating temperature (not at 25°C) and soft recovery can achieve lowest possible output noise.

A point to be stressed here is that reverse recovery is closely related to noise level at MHz through tens of MHz, which is sometimes meaningful in SMPS, but not in audio applications.

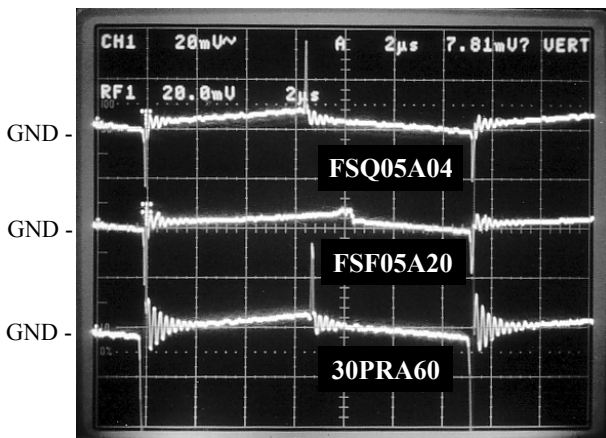
**Line Frequency Rectifier Diode**

Today it becomes common sense that diode used for rectification at line frequency (50/60Hz) influences sound quality. It is true that rectification noise of diode is unexpectedly large. For example, you can hear samples of various noises (including rectification noise) at the following website;

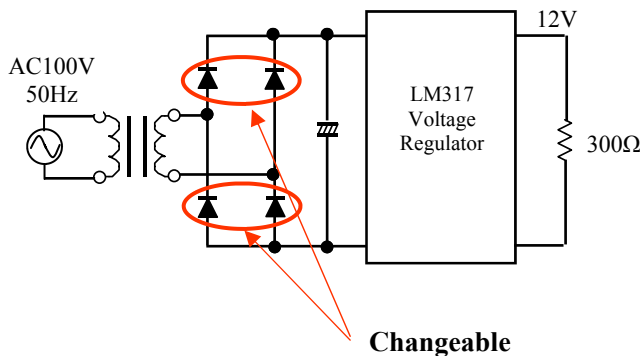
<http://www.ntt-east.co.jp/tasc/gijutu/noise/index.html>

We tried whether change in magnetic flux generated during rectification could be detected. The power supply used was 12V output LM317 linear voltage regulator, where bridge rectifier can be changed with socket. The load resistance is 300 Ω, so the output current is about 40 mA.

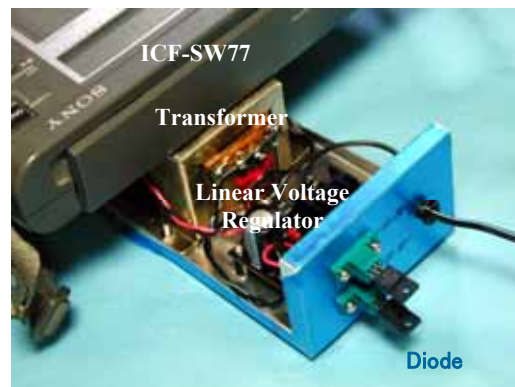
As shown in the photograph below, in order to



Diode dependent Output Noise



Rectification noise comparison circuit



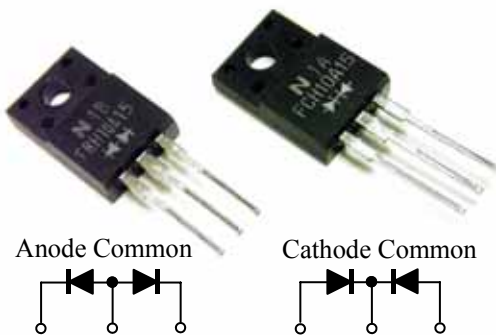
Detection of Rectification Noise

hear the audible noise most loudly, we fixed antenna position of SONY ICF-SW77 (AM receiver tuned at 515kHz) nearest to the transformer as much as possible. We changed diode one by one very carefully so as to maintain the physical position.

The sample diodes were the following three.

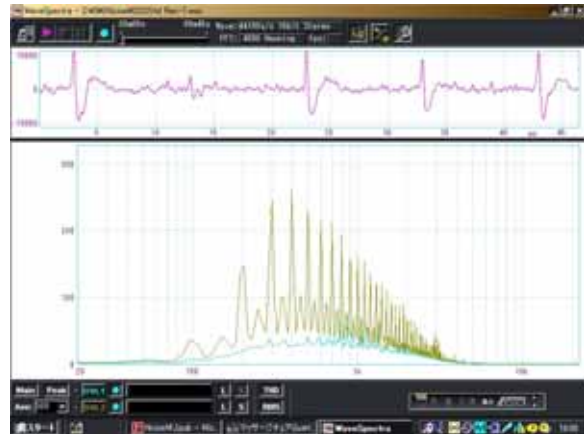
- Rectifier diode DBF10G 1A/600A
- 200V FRED FCF/FRF10A20 5A×2/200V
- 200V SBD FCH/FRH10A20 5A×2/200V

NIEC's FCF10A20/FRF10A20, and FCH10A20/FRH10A20 are TO-220F package twin chip diodes, and we can build-up diode-bridge by combining cathode-common and anode-common.

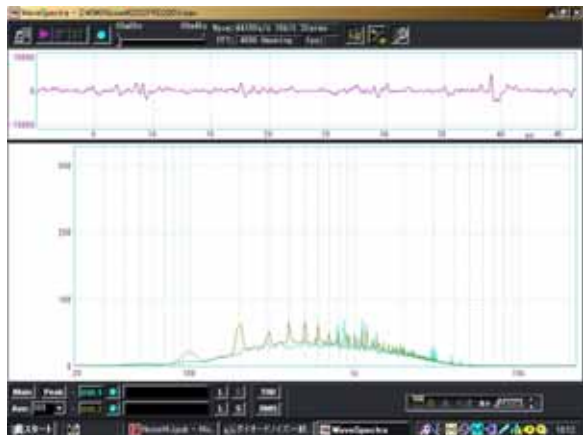


**TO-220F SBD and FRED can be Diode-bridge**

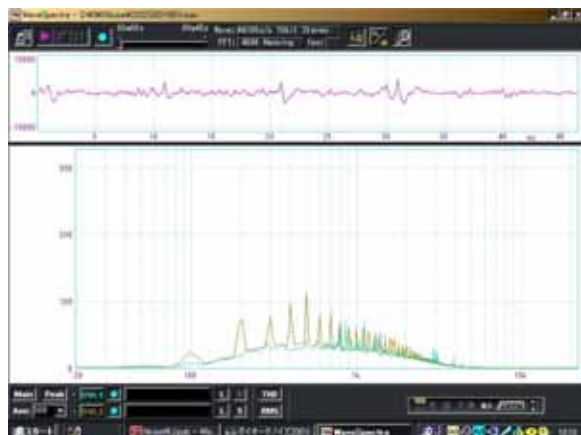
When rectifier diode is used as the bridge rectifier, we hear an amazingly loud noise from the radio, where noise level is significantly higher than FRED and SBD. The graphs on the right show the difference in noise level among rectifier diode, FRED and SBD. Actually, the rectification noise of diode here is not a practical problem at all. This low-cost transformer has inferior magnetic-shield and its coil released noise (change of magnetic field) so much, and sensitive built-in loop antenna in the AM receiver caught the subtle noise. So, if we slightly move the radio apart from transformer, this noise itself has disappeared. Of course, if 1,000pF ceramic-capacitor is added to each rectifier diode in parallel, the noise level could be much lower. However, the ringing of MHz or tens of MHz might possibly increase due to absence in damp control. No doubt, FRED or SBD for low frequency rectification may be clever choice because it has remarkably smaller energy compared with rectifier diode, which is the origin of noise. Using oscilloscope, we measured whether or not rectification noise might modify regulated output voltage. Of course, no difference by adopted diode was observed with oscilloscope.



**Rectification noise caught by AM radio  
Rectifier Diode**



**Rectification noise caught by AM radio  
200V FRED (FCF/FRF10A20)**



**Rectification noise caught by AM radio  
200V SBD (FCH/FRH10A20)**

**SBD and FRED enrich sound**

To check difference in sound depending on Rectifier Diode, SBD, and FRED, we applied the LM318 voltage regulator that was previously used for noise detection. Sound reproduction system was cheap and simple amplifier-built-in speakers



## Hearing check of Diodes

for PC, and memory audio player. The regulated power supply was used in place of original AC adapter.

SBD and FRED as the line frequency rectifiers produce clear and vivid sound, which is undoubtedly distinguished from that of rectifier diode. Everyone who heard the sounds realized this fact.

There are many factors that change sound; electronic components (such as capacitor, resistor, semiconductor), wiring, fuse, AC plug, cable, solder, plating, and so on.

“Change in sound” does not always equal to “improve in sound”. Among various change, sound of SBD and FRED compared with rectifier diode is preferable in every area of music. Please evaluate by yourself. The general requirements when evaluating sound are;

Choose appropriate sound source. Generally, not artificial sound, classical music, and singing voice are suited.

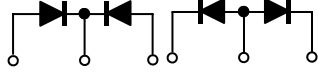
Fix reference source (s).

Maintain sound level constant.

Change condition very instantly as far as possible.

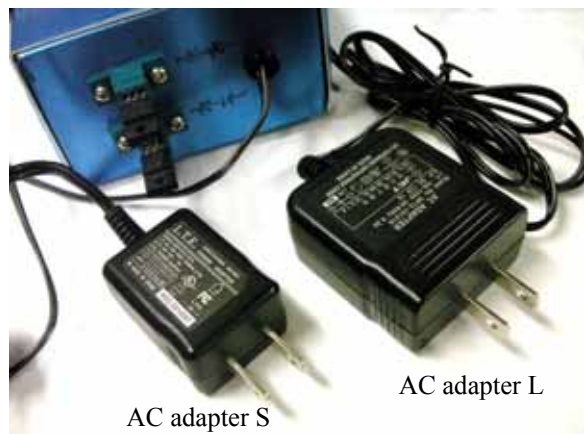
Evaluation should be steady and unchanged, so results obtained today, yesterday, and tomorrow must be same. Establishment of evaluation method and also some training to personnel who ascertain sound might be required.

The table shows our TO-220F package SBD and FRED that can form bridge rectifier. These pairs in TO-220F packages are well suited to low frequency rectification in audio appliances.

$I_o$	$V_{RRM}$			
8A	150V	SBD	FCH08A15	FRH08A15
10A	30V		FCQ10A03L	FRQ10A03L
10A	40V		FCQ10A(U)04	FRQ10A04
10A	40V		FCH10A04	FRH10A04
10A	60V		FCQ10A(U)06	FRQ10A06
10A	100V		FCH10A(U)10	FRH10A10
10A	150V		FCH10A(U)15	FRH10A15
10A	200V		FCH10A(U)20	FRH10A20
20A	60V		FCQ20A(U)06	FRQ20U06
20A	100V		FCH20A(U)10	FRH20A10
20A	150V		FCH20A(U)15	FRH20A15
20A	200V		FCH20A(U)20	FRH20A20
10A	200V	FRED	FCF10A20	FRF10A20
10A	400V		FCF10A(U)40	FRF10A40
20A	300V		FCU20UC30	FRU20UC30

## SMPS for audio applications

Today, even some high-end audio components, such as amplifier, have SMPSs as internal power supplies. Although switching power supply had been not preferred in this area, compact in size and light in weight are market demands. In fact, SMPSs are increasingly popular in medium and high-class audio components. To examine how sound may differ, linear power supply and two SMPSs (12V 1A output) are applied to the PC speakers. Changing these three power supplies of same output voltage, we knew differences in sound. Best sound was obtained by linear power

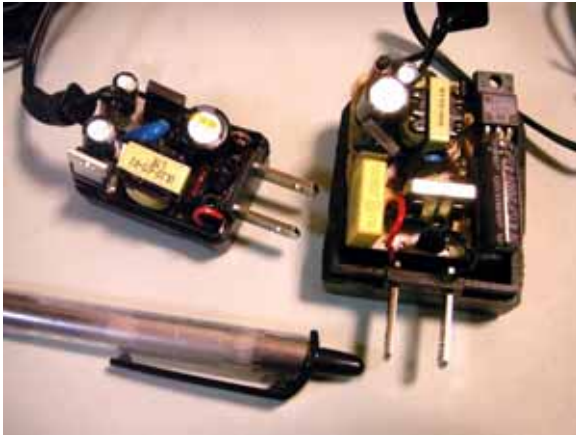


AC adapter S

AC adapter L

Linear Power Supply and two SMPSs

supply, and sound of one SMPS was far better than that of the other SMPS. As a result, we can understand that SMPS can be tuned-up for audio application. Internal photos of the SMPSs are shown below. Smaller SMPS leads to better sound. We don't know the reason why so.



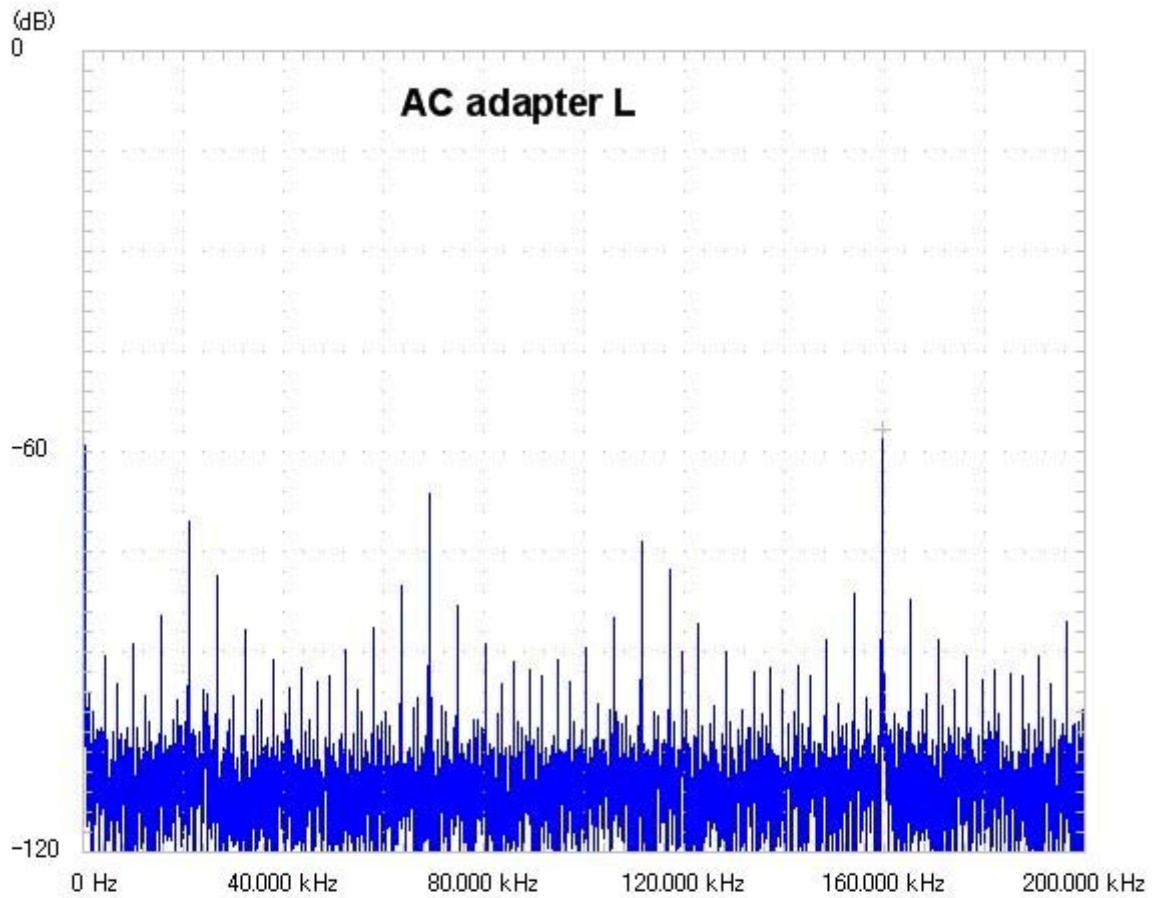
**Inside of SMPS**

**(Output voltage : 6V, same manufacturer)**

### **Nice sound makes us happy!**

Are you suspicious of the fact that, through such a cheap PC speaker system, we can distinguish differences in sound between diodes and SMPSs? It is quite reasonable because the internal amplifier is simple and straight linear amplifier, which has single input, single output and no tone control. In addition, it has JRC 4558 OP amp for voltage amplification. The JRC is audio specialist, and their OP amps, such as 4558, 5532, and 5534, have been applied even to high-end audio. So, it seems that this speaker system was designed not only for low price but also for a better sound.

As mentioned before, there are many factors that alter sound. Out of doubt, the first priority is excellent circuit design and construction. What's more, it is said that power supply and vibration are strongly connected to sound quality. NIEC's products, especially SBD and FRED, are known as their excellent sound in audio applications. It comes from well-balanced chip design, proper assembly, low-noise characteristics, non-magnetic material, and tight quality control. You can enjoy our SBD and FRED products not only in switching applications but also in audio applications.



Channel : 1 Window Type : Rectangular Window Size : 8192

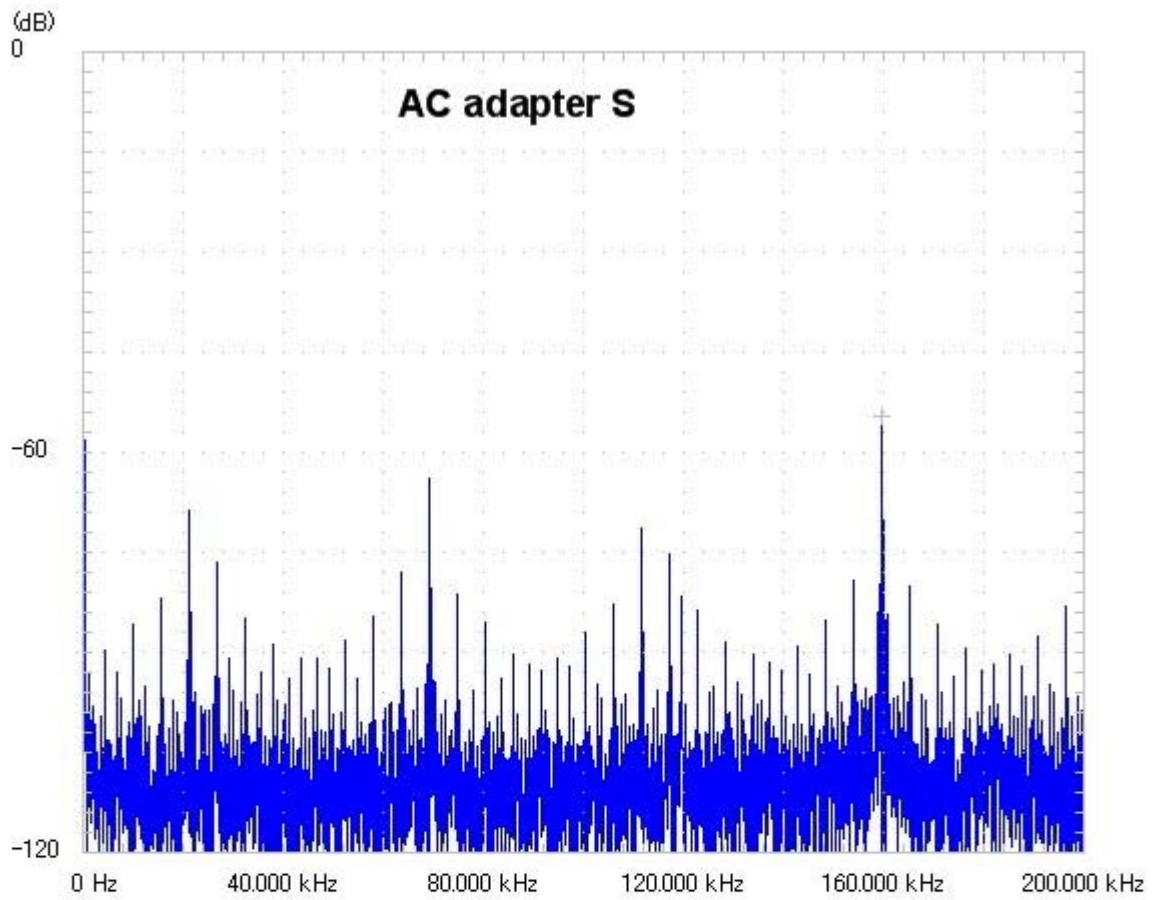
Cursor Information : Cursor off

Harmonic Information :

1st : 159.599 kHz -56.740 dB	2nd : -- --
3rd : -- --	4th : -- --
5th : -- --	6th : -- --

FFT Measurement Information :

SNR : 5.500 dB	THD : 0.000 dB
ENOB : 0.621 bits	SFDR : 9.251 dB
SINAD : 6.460 dB	TotalPower : -55.743 dB



Channel : 1                      Window Type : Rectangular                      Window Size : 8192  
Cursor Information : Cursor off  
Harmonic Information :  
    1st : 159.599 kHz    -54.704 dB                      2nd : -- --  
    3rd : -- --                      4th : -- --  
    5th : -- --                      6th : -- --  
FFT Measurement Information :  
    SNR : 6.356 dB                      THD : 0.000 dB  
    ENOB : 0.763 bits                      SFDR : 9.338 dB  
    SINAD : 7.522 dB                      TotalPower : -53.403 dB