APPLICATION NOTE

Vertical power booster
TDA4863AJ/TDA4863J

AN00040

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Summary

This report describes the application of the TDA4863AJ / TDA4863J vertical power boosters in a monitor chassis. These boosters can be used for frame frequencies up to 200 Hz. The TDA4863J uses a separate flyback supply voltage, the TDA4863AJ has a supply voltage doubler.
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1. INTRODUCTION

The TDA4863J / TDA4863AJ are successors of TDA4861 vertical booster for use in vertical deflection systems for frame frequencies up to 200 Hz. The TDA4863J needs a separate flyback supply voltage with the advantage that the supply voltages are independently adjustable to optimise power consumption and flyback time. For the TDA4863AJ the flyback supply voltage will be generated internally by doubling the supply voltage and therefore a separate flyback supply voltage is not needed. Both circuits provide differential input stages and fit well with the TDA485X / TDA484X monitor deflection controller family.

1.1 Features

- Power amplifier with differential voltage inputs,
- Powerless vertical shift (DC coupling),
- Output current up to 3 A (peak-to-peak value),
- Output stage with thermal and SOAR protection,
- Deflection frequency up to 200 Hz,
- Excellent linearity,
- Smaller package,
- Reduced pin count.
2. GENERAL DESCRIPTION

Block diagram

<table>
<thead>
<tr>
<th>symbol</th>
<th>pin</th>
<th>TDA4863J</th>
<th>TDA4863AJ</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{P1}$</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Positive supply voltage</td>
</tr>
<tr>
<td>$V_{FB}$</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>Flyback supply voltage</td>
</tr>
<tr>
<td>$V_{P3}$</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>Flyback generator output</td>
</tr>
<tr>
<td>$V_{P2}$</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>Supply voltage for vertical output</td>
</tr>
<tr>
<td>Substrate $V_N$</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>Substrate / negative supply voltage</td>
</tr>
<tr>
<td>V-OUT</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>Vertical output</td>
</tr>
<tr>
<td>INN</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>Inverting input of differential input stage</td>
</tr>
<tr>
<td>INP</td>
<td>7</td>
<td>7</td>
<td>-</td>
<td>Non-inverting input of differential input stage</td>
</tr>
</tbody>
</table>

Diagram showing pinning and block diagram of TDA4863(A)J.
2.2 Quick reference data

Measurements referenced to substrate Vn (pin 4).

<table>
<thead>
<tr>
<th>symbol</th>
<th>parameter</th>
<th>conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vp1</td>
<td>Supply voltage (pin 1)</td>
<td>9</td>
<td>-</td>
<td>30</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vp2</td>
<td>Supply voltage (pin 3)</td>
<td>Vp1-1</td>
<td>-</td>
<td>60</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vfb</td>
<td>Flyback supply voltage (pin 2)</td>
<td>TDA4863J</td>
<td>Vp1-1</td>
<td>-</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>Vp3</td>
<td>Flyback generator output voltage (pin 2)</td>
<td>TDA4863AJ;</td>
<td>0</td>
<td>-</td>
<td>Vp1+2.2</td>
<td>V</td>
</tr>
<tr>
<td>Ip1</td>
<td>Supply current (pin 1)</td>
<td>During scan</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Ip2</td>
<td>Quiescent supply current (pin 3)</td>
<td>No load; no signal</td>
<td>-</td>
<td>9</td>
<td>-</td>
<td>mA</td>
</tr>
<tr>
<td>Vinp</td>
<td>Input voltage (pin 7)</td>
<td>1.6</td>
<td>-</td>
<td>Vp1-0.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Vinn</td>
<td>Input voltage (pin 6)</td>
<td>1.6</td>
<td>-</td>
<td>Vp1-0.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Is(p-p)</td>
<td>Deflection output current (pin 5)</td>
<td>(peak-to-peak value)</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>A</td>
</tr>
<tr>
<td>Tamb</td>
<td>Operating ambient temperature</td>
<td>-20</td>
<td>-</td>
<td>+75</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

2.3 General device description

The following blocks are explained in this chapter:
- the vertical amplifier,
- the protection circuits,
- the flyback generator,
- the damping resistor.

2.3.1 Vertical amplifier

The input signal (e.g. coming from the deflection controller family TDA485X / TDA484X) is connected to the voltage inputs of the TDA4863(A)J. In the case of current outputs the current to voltage conversion has to be done by external resistors (Rs1 and Rs2). The output current is fed back to the inverting input pin 6 (see Figure 2-1).
When a single-ended voltage sawtooth generator is used, the application is as in Figure 2-2.
The minimum input voltage on pins 6 and 7 is 1.6 V, while the maximum input voltage is Vp1-0.5 V (both referenced to substrate Vn (pin 4)).

The vertical output stage is a quasi-complementary class-B amplifier (half bridge concept) with a high linearity.
The maximum peak output current is 1.5 A, the gain of the amplifier can be adjusted with Rs1, Rs2 and R1.
2.3.2 Protection circuits
The output stage contains SOAR and thermal protection. The thermal protection will be active if the
junction temperature \( T_j \) exceeds 160 \(^\circ\)C. The output current on pin 5 will be until \( T_j \) has reached the
thermal protection switch-off temperature (<150 \(^\circ\)C).
The SOAR limits the maximum power dissipation in the output transistors and protects for excessive
output currents.

2.3.3 Flyback generator
The flyback generator supplies the output stage during flyback. The TDA4863J is used with a
separate flyback supply to achieve a short flyback time with minimised power dissipation. The
TDA4863AJ needs a capacitor \( C_F \) between pins 2 and 3 which is charged to \( V_{P1} - V_{N} \) during scan,
using the external diode \( D_1 \) and the resistor \( R_5 \) (see Figure 3-3). The positive electrode of the
capacitor \( C_F \) is connected to the positive supply during flyback, so the supply voltage of the output
stage is then \( V_{P1} + V_{P1} - V_{N} \).

2.3.4 Damping resistor
In parallel with the deflection coil a damping resistor is needed. This resistor has to be tuned, so that
no under- or overshoot will occur after flyback. The tuning of this resistor will be treated in more detail
in paragraph 3.4.
3. APPLICATION INFORMATION

3.1 Simplified pinning description

<table>
<thead>
<tr>
<th>INP</th>
<th>INN</th>
<th>V-OUT</th>
<th>VN</th>
<th>VP2</th>
<th>VP3</th>
<th>VP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

![Diagram of TDA4863AJ](image1)

Figure 3-1: internal circuit configuration of TDA4863AJ

<table>
<thead>
<tr>
<th>INP</th>
<th>INN</th>
<th>V-OUT</th>
<th>VN</th>
<th>VP2</th>
<th>VFB</th>
<th>VP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

![Diagram of TDA4863J](image2)

Figure 3-2: internal circuit configuration of TDA4863J
3.2 General application

Figure 3-3: application circuit with TDA4863AJ

Figure 3-4: application circuit with TDA4863J
3.3 Device description per functional block / external pin.

3.3.1 Supply voltage calculation

**Pin 1 and 4:**
To calculate the minimum required supply voltage, certain values from the application have to be known. These values are the maximum required deflection current, the coil impedance and the measuring resistor. The coil resistance should be multiplied with a correction factor of 1.2 for hot conditions.

The IC’s internal voltage losses must be taken into account. These losses are given in Table 3-1 and Table 3-2:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{5,4 \text{sat}}$</td>
<td>Output saturation voltage to Vn</td>
<td>$I_S = 1.5 \text{ A}$</td>
<td>-</td>
<td>1.7</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_S = 1 \text{ A}$</td>
<td>-</td>
<td>1.5</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>$V_{5,3 \text{sat}}$</td>
<td>Output saturation voltage to Vp2</td>
<td>$I_S = 1.5 \text{ A}$</td>
<td>-</td>
<td>2.3</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_S = 1 \text{ A}$</td>
<td>2.3</td>
<td>2.0</td>
<td>-</td>
<td>V</td>
</tr>
</tbody>
</table>

The voltage drop across the coil consists of an inductive part and a resistive part. In the first part of the scan the inductive part subtracts from the resistive part, while in the second part of the scan the inductive part adds to the resistive part.

So the voltage needed for Vp1 is:

$$V_{p1} = I_{\text{defl(peak)}} \times (1.2 \times R_{\text{coil}} + R_1) + V_{5,3 \text{sat}} - 2 \times I_{\text{defl(peak)}} \times L_{\text{coil}} \times f_{\min} + V_{D1}$$

The current during the first part of the scan flows from Vp1 through diode D1 into Vp2, through T1 into the deflection coil and measuring resistor R1 (see Figure 3-6 and Figure 3-7).

During the second part of the scan the voltage needed for Vn is:

$$V_N = -(I_{\text{defl(peak)}} \times (1.2 \times R_{\text{coil}} + R_1) + V_{5,4 \text{sat}} + 2 \times I_{\text{defl(peak)}} \times L_{\text{coil}} \times f_{\max})$$

In this part the current flows from earth through R1 and the deflection coil into T2, and back to earth via Vn (see Figure 3-6 and Figure 3-7).

where $I_{\text{defl(peak)}}$ = coil peak current  
$R_{\text{coil}}$ = coil resistance (cold condition)  
$f_{\text{max}}$ = maximum vertical (=frame) frequency  
$f_{\text{min}}$ = minimum vertical (=frame) frequency  
$V_{5,3 \text{sat}}$ = internal output saturation voltage to Vp2  
$V_{5,4 \text{sat}}$ = internal output saturation voltage to substrate ground  
$V_{D1}$ = voltage drop across diode D1

In practise the supply voltages should be chosen somewhat higher to minimise distortion at the top and bottom of the screen.
3.3.2 Flyback supply voltage calculation

**Pin 2/3:**
For the calculation of the flyback supply voltage the required flyback time is needed. The flyback voltage is approximately constant during the whole flyback time, the calculation of this voltage is:

\[
V_{fb} = \frac{I_{\text{def (peak-peak)}} \times (1.2 \times R_{\text{coil}} + R_i)}{1 - e^{-t_{\text{coil}}/\tau}}. \]

A simplified approximation is

\[
V_{fb} = \frac{I_{\text{def (peak-peak)}} \times L_{\text{coil}}}{t_{fb}}.
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{2,3}) (TDA4863J)</td>
<td>Voltage drop during flyback</td>
<td>Reverse</td>
<td>(I_5 = -1.5) A</td>
<td>-</td>
<td>-2.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(I_5 = -1.0) A</td>
<td>-</td>
<td>-1.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forward</td>
<td>(I_5 = 1.5) A</td>
<td>-</td>
<td>3.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(I_5 = 1.0) A</td>
<td>-</td>
<td>2.2</td>
<td>V</td>
</tr>
<tr>
<td>(V_{1,2}) (TDA4863AJ)</td>
<td>Voltage drop during flyback</td>
<td>Reverse</td>
<td>(I_5 = 1.5) A</td>
<td>-</td>
<td>-2.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(I_5 = 1.0) A</td>
<td>-</td>
<td>-1.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Forward</td>
<td>(I_5 = 1.5) A</td>
<td>-</td>
<td>3.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(I_5 = 1.0) A</td>
<td>-</td>
<td>2.2</td>
<td>V</td>
</tr>
</tbody>
</table>

In practice, the flyback voltage is not constant during the flyback time. In the case of the TDA4863J the current flows from \(R_1\) and the coil via \(D_2\) and \(D_3\) into \(V_{FB}\) during the first part of the flyback, so the voltage across the coil is two diode drops higher than \(V_{FB}\) (see reverse voltage drop during flyback in Table 3-2). When the coil current passes through zero, the current reverses direction and flows through \(T_3\) and \(T_1\), so the voltage is somewhat lower than \(V_{FB}\) (see forward voltage drop during flyback in Table 3-2).

In the case of the TDA4863AJ the current flows from \(R_1\) and the coil via \(D_2\) into \(V_{P2}\) during the first part of the flyback, so the voltage is about one diode drop higher than \(V_{P2}\) (see reverse voltage drop during flyback in Table 3-2). When the coil current passes through zero, the current flows from \(V_{P2}\) through \(T_1\) (see forward voltage drop during flyback in Table 3-2). However, the approximation with the constant voltage is quite good.
3.3.3 Input circuit

Pin 6 and 7:

The input circuit of the TDA4863(A)J is a differential amplifier with voltage inputs. The output current signals of e.g. the TDA485X / TDA484X deflection controller family are as in Figure 3-5.

Figure 3-5: output currents from TDA485X

The common mode current is about 300 uA, while the differential mode peak-to-peak output current is about 850 uA. The output voltage of the TDA485X deflection controller family must be between 0 and 4.2 Volts, while the input voltages of the TDA4863(A)J must be between \( V_{N} + 1.6 \) and \( V_{P} - 1 \) Volts. This means that the voltage must be between 0 and 4.2 Volts.

The maximum output current (with VGA350 vertical overscan) from the TDA485X deflection controller family is 660 uA. At this current the voltage must remain below 4.2 Volts, so \( R_{S1} \) and \( R_{S2} \) must be smaller than \( 4.2 \, \text{V} / 660 \, \text{uA} = 6360 \, \Omega \). A typical value is 1800 \( \Omega \). With the minimum current of 87 uA the voltage will remain well above the 0 Volts.

Now the value of the conversion resistors \( R_{S1} \) and \( R_{S2} \) is known, \( R_1 \) can be calculated:

\[
I_{\text{def}}(\text{peak-peak}) = \frac{I_{\text{diff-in(peak-peak)}} \times R_{S1,2}}{R_1}
\]

so

\[
R_1 = \frac{I_{\text{diff-in(peak-peak)}} \times R_{S1,2}}{I_{\text{def(peak-peak)}}}
\]

If the peak-peak deflection current is 1.5 A, then the value of \( R_1 \) should be 1 Ohm. The rms current through this resistor is:

\[
I_{\text{RMS}} = \frac{1}{3} \sqrt{3} \times I_{\text{def(peak)}} = \frac{1}{3} \sqrt{3} \times 0.75 = 433\, \text{mA}
\]

This means that the power dissipation in \( R_1 \) is:

\[
I_{\text{RMS}}^2 \times R_1 = 188\, \text{mW}
\]

If we make \( R_{S1} \) and \( R_{S2} \) bigger, also the power dissipation in \( R_1 \) becomes bigger, so it is better to keep them like this.

It is also possible to work the other way around. For example if a certain supply voltage is available, then by subtracting the saturation voltage and voltage across the coil at the peak deflection current, the maximum voltage across \( R_1 \) is what is left. So the value of \( R_1 \) is this remaining voltage divided by the peak deflection current. When \( R_1 \) is known, resistors \( R_{S1,2} \) can be calculated by the above formulas.
3.3.4 Vertical output stage

The Philips TDA4863(A)J vertical output stage uses a half bridge concept, which is very suitable for DC coupling of the vertical deflection coil. The deflection coil is connected between pin 5 and resistor $R_1$, which is connected to ground. The resistor $R_1$ converts the current through the coil into a voltage, which is fed back to the inverting input of the amplifier via resistor $R_{S1}$.

The output stage consists of transistors $T_1$ and $T_2$. During the scan $T_1$ is connected to the supply voltage $V_{P2}$, while $T_2$ is connected to the negative supply voltage $V_{N}$. $T_1$ delivers the positive coil current during the first part of the scan, while $T_2$ sinks the negative coil current during the second part of the scan (see Figure 3-6 and Figure 3-7).

In Figure 3-8 real measurement results are given.
3.3.5 Flyback switch

During flyback the input currents / voltages rapidly change polarity. The output of the amplifier will try to follow this quick change, but its output voltage range is limited to $V_{FB}$. This limits the maximum $di/dt$ in the coil, which in turn can be insufficient to follow the input signal. As a result of this the amplifier comes into an open-loop condition. The normal supply voltage is rather low, therefor it will take quite a long time for the current to reverse direction and follow the input again. With a higher supply voltage the flyback time will certainly decrease. That is why we apply a higher flyback supply voltage. In the TDA4863J this is done by adding an external flyback supply voltage, in the TDA4863AJ the normal positive supply voltage is doubled. But only during the flyback these voltages are applied to the coil, otherwise the power dissipation would increase too much.

At the start of flyback the input signal reverses polarity very rapidly. The circuit tries to follow this and turns off transistor $T_2$. However, the coil current keeps flowing in the negative direction, but now through diodes $D_2$ and $D_3$. The voltage at $V_{P2}$ becomes higher than $V_{P1}$, so the external diode becomes non-conducting. In the TDA4863J the current flows via $D_2$ and $D_3$ into the external coupling capacitor at $V_{FB}$ (see Figure 3-9). The voltage across the coil becomes two diode drops higher than $V_{FB}$ (reverse voltage drop during flyback in Table 3-2). In the TDA4863AJ the current flows via $D_2$ through the external capacitor $C_F$ (which was charged to $V_{P1}-V_N$ during the scan) via $D_3$ into the decoupling capacitor at $V_{P1}$. So the voltage during this part of the flyback is $2*V_{P1}-V_N$ ($V_{Cl}$) plus two diode drops (reverse voltage drop during flyback in Table 3-2), see Figure 3-9.

![Figure 3-9: current flow first part of flyback TDA4863J/ TDA4863AJ](image-url)
When the coil current passes zero transistors $T_3$ is “opened” by the amplifier. Now the current starts flowing in the positive direction, so diodes $D_2$ and $D_3$ become non-conducting. The voltage at $V_{P2}$ is still higher than $V_{P1}$, so the external diode is still non-conducting. In the TDA4863J the current flows from $V_{FB}$ via $T_3$ and $T_1$ through the deflection coil and resistor $R_1$. The voltage across the coil now becomes two $V_{CE(sat)}$ lower than $V_{FB}$ (forward voltage drop during flyback in Table 3-1). In the TDA4863AJ the current flows from $V_{P1}$ via the external transistor $T_3$, capacitor $C_F$ and transistors $T_1$ through the deflection coil and resistor $R_1$. So the voltage during this part of the flyback is $2V_{P1}$ (turnoff voltage drop during flyback in Table 3-1), see Figure 3-10. When the coil current reaches the input-related value, the loop is closed again and normal scan continues.

In Figure 3-11 measurements results are shown.
3.3.6 Power dissipation in the output stage

The power dissipation in the output stage including the deflection coil can be calculated with the following method:

- the current through the coil and measuring resistor as a function of time during scan is given by

\[
I_{def}(t) = I_{def(peak)} - 2 \cdot I_{def(peak)} \cdot \frac{t}{t_{scan}} = I_{def(peak)} \cdot \left(1 - 2 \cdot \frac{t}{t_{scan}}\right)
\]

and the root-mean-square value of this sawtooth coil current (during scan) is:

\[
Irms_{def} = \frac{1}{3} \cdot \sqrt{3} \cdot I_{def(peak)}
\]

The average power dissipation in the load during scan is:

\[
P_{load} = Irms_{def}^2 \cdot (1.2 \times R_{coil} + R_l)
\]

If we assume that the deflection current is symmetrical around zero (no DC current), then the power distribution is equally divided between the positive (\(V_{p1}\)) and negative (\(V_{n}\)) supply. The current delivered by the positive supply is:

\[
I_{Vp2} = I_{def(peak)} \cdot \frac{t_{scan}}{t}
\]

Figure 3-12: deflection current

\[
I_{Vp2} = I_{def(peak)} \cdot \frac{t_{scan}}{t}
\]

Figure 3-13: left: \(V_{p2}\) supply current during scan; right: \(V_{n}\) supply current during scan
The average current delivered by the positive supply is then:

\[ I_{VP2} = \frac{I_{def(peak)}}{4} \]

Because of the assumed symmetry the current delivered by the negative supply is the same. The voltage at \( V_{P2} \) is \( V_{P1} - U_{D1} \), so the power delivered to the IC output transistors during the whole scan period is:

\[ P_{tot(scan)} = \frac{(V_{P1} - V_{D1}) \times I_{def(peak)}}{4} - V_Y \times \frac{I_{def(peak)}}{4} \]

In the TDA4863J the current delivered by the flyback voltage is about 4 to 5 mA (depending on the system losses), so with a certain flyback supply voltage the power dissipation is:

\[ P_{flyback} = I_{fb} \times V_{fb} \]

Also the rest of the circuitry (e.g. input circuit) consumes some energy. The current flowing into pin 1 (\( V_{P1} \)) and coming out again at pin 4 (\( V_{N} \)) is about 10 mA, so the power dissipation in this part of the circuit is:

\[ P_{qct} = I_{qct} \times (V_{P1} - V_{N}) \]

This means that the total power delivered to the IC is:

\[ P_{tot} = \left( V_{P1} - V_{D1} \right) \times \frac{I_{def(peak)}}{4} - V_Y \times \frac{I_{def(peak)}}{4} + I_{fb} \times V_{fb} + I_{qct} \times (V_{P1} - V_{N}) \]

The power delivered to the deflection was:

\[ P_{load} = I_{rms} \times \frac{1.2 \times R_{cpar} + R_t}{2} \]

so the power dissipation of the IC is:

\[ P_{IC} = P_{tot} - P_{load} \]
3.3.7 External guard circuit

An external guard circuit can be built to prevent the picture tube from spot burn-in when vertical
deflection is absent. The output generates a blanking signal.

In Figure 3-14 the circuit is drawn.

![Guard Circuit Diagram](image)

During normal operation in the first part of the flyback the voltage at pin 5 (output voltage) becomes
higher than the flyback supply voltage at pin 2. During this time transistor $T_1$ and the diode are
conducting, so the capacitor is charged to a value of about $V_{fb} + \text{"reverse voltage drop during flyback"}$. Transistor $T_2$ is constantly conducting, so the guard output is low. When there is something wrong, for
example one of the output transistors is broken, then the voltage at pin 5 does not become higher
than pin 2 anymore. This means that transistor $T_1$ does not conduct, and the capacitor is discharged.
So transistor $T_2$ becomes non-conducting and the guard output becomes high. Note: this guard output
becomes high only in a fault-condition, and is not used for vertical blanking (the TDA485X / TDA484X
deflection controller family already delivers a signal for vertical blanking: CLBL).

3.4 Dynamic behaviour of the amplifier

The open-loop frequency response of the vertical amplifier is like any other amplifier not flat over the
entire frequency band. It has the following properties:

1. it has a certain DC-gain ($A_0$), which is about 18000 (85 dB),
2. it has an output resistance of about $R_{\text{out}}$ of about 50 Ohm,
3. it has two dominant frequency poles at about 200 Hz and 200 kHz.
4. it will oscillate when driving pure inductive loads.

To prevent the amplifier from oscillating when driving an inductive load an additional RC combination
($R_S;C_S$) from the output to the negative supply voltage is needed. Without this RC-combination the
amplifier will oscillate at a frequency of about 7MHz, causing the open-loop gain to drop also at low
frequencies. $R_S$ is fixed (5.6 $\Omega$), while the value of $C_S$ must be small enough, so that it does not
disturb the normal functioning. This value has to be about 100nF. When $C_S$ is too large the flyback
time will increase. In Figure 3-15 and Figure 3-16 the frequency response as a function of the load
impedance is given.
Open-loop frequency response of TDA4863(A)J:

Figure 3-15: open-loop gain amplitude response of the TDA4863(A)J; R_l = 1, 10, 100 and 1000 Ohm

Figure 3-16: open-loop phase response of the TDA4863(A)J; R_l = 1, 10, 100 and 1000 Ohm

With the deflection coil and measuring resistor in series as a load, R_l is about 8 Ohms. In Figure 3-17 and Figure 3-18 the amplifier response is given for this condition, together with the deflection coil impedance, the voltage feedback factor and the total loop-gain of the whole system.
Loop gain stability of the amplifier system:

![Figure 3-17: amplitude response of loop-gain of the amplifier system](image)

![Figure 3-18: phase response of loop-gain of the amplifier system](image)

The phase-margin (a measure of stability) is determined by looking at the phase of the loop-gain w.r.t. zero, at the frequency where the amplitude of the loop-gain goes through 1 (0 dB). This turns out to be at a frequency of 4600 Hz. The phase-margin is about 48 degrees. When the phase-margin is more than 45 degrees, the system is said to be stable (in theory this value can be lower, but then a small noise signal can still cause the system to oscillate).
The transfer-function of the input to output current is drawn in Figure 3-19. In this picture the parallel resistor of the deflection coil is varied. In Philips tubes the deflection coil has a parallel balance potentiometer of 180 Ohm. You can see that with this value the overshoot is quite large. This overshoot also causes an overshoot in the transient response, which can be measured after flyback. When we place an extra resistor parallel to the deflection coil, this overshoot is decreased, as can be seen in the picture. If we make this resistor too small, undershoot on the transient response will appear. So the value of this resistor has to be tuned to the right value (about 220 Ohm, so the total equivalent resistance is about 100 Ohm). Of course, again we must check the loop-gain stability. In fact, the phase-margin has even become bigger, about 68 degrees w.r.t. zero.

Figure 3-19: closed-loop current gain; Rb = 180, 130, 100 and 50 Ohm
3.5 Thermal considerations

When designing the vertical output stage in a real application, you have to make sure that the junction temperature of the device is below the maximum value during operation. So the power dissipation of the device has to be calculated or measured. When the maximum ambient temperature (often approximated at 65 °C) is known, the right value for the thermal resistance of the heatsink can be calculated, resulting in the right dimensions for this heatsink.

The maximum junction temperature of the device is 168 °C, but the thermal protection will already be activated, so the output current is reduced until the junction temperature is below 150 °C (switch-off temperature). But to yield a longer lifetime it is much better to keep the junction temperature below 110 °C. With a dissipation of 3 Watt this will certainly mean that a heatsink is necessary.

The thermal resistance from mounting base to ambient \( R_{th(mb-amb)} \) is so large compared to the thermal resistance from mounting base to heatsink plus heatsink to ambient \( (R_{th(mb-hs)} + R_{th(hs-amb)}) \), that \( R_{th(mb-amb)} \) can be neglected.

The maximum allowed thermal resistance of the heatsink can be calculated by:

\[
R_{th(hs-amb)} = \frac{T_{j(max)} - T_{amb}}{P_{IC}} - \left( R_{th(j-mb)} + R_{th(mb-hs)} \right)
\]

Figure 3-20: IC construction and thermal resistances and the electrical equivalent of the thermal circuit
4. APPLICATION EXAMPLE

Below a design procedure is given along with an example. The values that are used in the example are:

- \( I_{\text{defl(peak-to-peak)}} = 1.5 \ \text{A} \)
- \( L_{\text{coil}} = 6.3 \ \text{mH} \)
- \( R_{\text{coil}} = 6.3 \ \Omega \) (cold condition)
- \( t_{\text{flyback}} = 300 \ \text{usec} \)
- \( f_{\text{max}} = 150 \ \text{Hz} \)

The following steps should be made:

1. Read the minimum, typical and maximum peak vertical deflection current from the picture tube coil specification. The circuit should be designed in such a way that this maximum peak current is not exceeded.
   In this example the maximum peak coil current is half the \( I_{\text{defl(peak-to-peak)}} \), so 0.75 A.

2. Calculate the value of the conversion resistors \( R_{S1} \) and \( R_{S2} \) and the measuring resistor \( R_1 \).
   Be aware that the output current from the TDA485X deflection controller family has a common mode and a maximum differential mode current, and that the input voltage is maintained between \( V_{\text{IN}}+1.6 \) and 4.2 Volts (see paragraph 3.3.3). For the conversion resistors we take 1800 \( \Omega \), then the measuring resistor is:
   \[
   R_1 = \frac{I_{\text{diff(min,peak-peak)}} \times R_{S1,2}}{I_{\text{defl(peak-peak)}}}
   \]
   \[
   R_1 = \frac{850 \cdot 10^{-6} \times 1800}{1.5}
   \]
   \[ R_1 = 1.02 \Omega \]. So take a value of 1 \( \Omega \).

3. Calculate the main- and flyback supply voltages. They should be as low as possible to minimise the power dissipation.
   For the positive supply:
   \[
   V_{P1} = I_{\text{defl(peak)}} \times (1.2 \times R_{\text{coil}} + R_1) + V_{5,3\text{sat}} - 2 \times I_{\text{defl(peak)}} \times L_{\text{coil}} \times f_{\text{min}} + V_{1}\]

   \[ V_{P1} = 0.75 \times (1.2 \times 6.3 + 1) + 2.3 - 2 \times 0.75 \times 6.3 \times 10^{-3} \times 50 + 1 \]

   \[ V_{P1} = 9.3 \text{Volts} \]. So take a supply voltage from 10 Volts.

   For the negative supply we have:
   \[
   V_{N} = \left( I_{\text{defl(peak)}} \times (1.2 \times R_{\text{coil}} + R_1) + V_{5,4\text{sat}} + 2 \times I_{\text{defl(peak)}} \times L_{\text{coil}} \times f_{\text{max}} \right)
   \]

   \[ V_{N} = (0.75 \times (1.2 \times 6.3 + 1) + 1.7 + 2 \times 0.75 \times 6.3 \times 10^{-3} \times 150) \]

   \[ V_{N} = -9.5 \text{Volts} \]. So take a supply voltage of -10 Volts.

   For the flyback voltage we have:
   \[
   V_{\phi} = \frac{I_{\text{defl(peak-peak)}} \times (1.2 \times R_{\text{coil}} + R_1)}{1 - e^{-\frac{1}{I_{\text{out}}}}}
   \]

   \[ V_{\phi} = 1.5 \times (1.2 \times 6.3 + 1) \]

   \[ 63 \times 10^{-3} \]
Let \( V_{gs} = 38.4\text{Volts} \). So take a supply voltage of 40 Volts. This automatically means that we cannot use the TDA4863AJ for this application, because doubling the supply voltage will not give us the necessary flyback supply voltage for such a short flyback time.

4. Choose the value of damping resistor \( R_p \) about 220 Ohm. This value is dependent on the picture tube coil and should be as high as possible. A wrong value for \( R_p \) results in an under- or overshoot on the coil current. So the actual value must be determined in the final circuit.

5. The value for \( R_s \) is a fixed value of 5.6 Ohm, \( C_s \) can be varied to optimise the flyback time. The value of \( C_s \) should be around 100 nF.

5. Calculate the power dissipation in the IC following the steps below:

The total power dissipated in the IC+load is:

\[
P_{\text{tot}} = (V_{p1} - V_{D1}) \times \frac{I_{d}(\text{peak})}{4} - V_N \times \frac{I_{d}(\text{peak})}{4} + I_g \times V_g + I_{qs} \times (V_{p1} - V_N)\]

\[
P_{\text{tot}} = (10 - 1) \times \frac{0.75}{4} - (0.75) \times \frac{4.5 \times 10^{-3} \times 40 + 10 \times 10^{-3} \times (10 - (-10))}{4} \]

\[
P_{\text{tot}} = 3.94\text{Watt}
\]

The power dissipated in the load is:

\[
P_{\text{load}} = \frac{1}{3} \times \sqrt{3} \times 0.75 \times (1.2 \times 6.3 + 1)
\]

\[
P_{\text{load}} = 1.61\text{Watt}
\]

So the power dissipation of the IC is:

\[
P_{Ic} = P_{\text{tot}} - P_{\text{load}}
\]

\[
P_{Ic} = 3.94 - 1.61 = 2.33\text{Watt}
\]

6. Calculate the maximum thermal resistance of the heatsink:

\[
R_{th(\text{h-amb})} = \frac{T_{(\text{max})} - T_{\text{amb}}}{P_{Ic}} - (R_{l(Ic-\text{mb})} + R_{h(\text{mb-amb})})
\]

\[
R_{th(\text{h-amb})} = \frac{110 - 65}{2.33} - (6) = 13.3\text{K/W}
\]

7. Calculate the values of the components in the guard circuit:

Suppose \( I_{C(T2)} \) is 1 mA, then

\[
R_4 = \frac{V_{p1} - V_{C(T2)\text{sat}}}{I_{C(T2)}} = \frac{9 - 0.2}{1 \times 10^{-3}} = 8800\Omega \text{, so take } R_4 = 8200.
\]

If the base current is \( 0.1 \times I_{C(T2)} \), and the current through \( R_2 \) is \( 0.05 \times I_{C(T2)} \), then

\[
R_2 = \frac{V_{BE(T2)}}{0.05 \times I_{C(T2)}} = \frac{0.7}{0.05 \times 1 \times 10^{-3}} = 14k\Omega \text{, so take a value of 15 k\Omega.}
\]

The current through \( R_3 \) is the sum of the base current of \( T_2 \) and the current through \( R_2 \), so
If the time constant is about 5 frames, then $C_1$ should be:

$$C_1 = \frac{5 \times \frac{1}{f_{\text{min}}}}{R_2 + R_3} = \frac{5 \times \frac{1}{50}}{14000 + 270000} \approx 330 \text{nF}.$$ Within one frame the voltage across $C_1$ will drop about 10 Volts now, but is still high enough to keep transistor $T_2$ in saturation. For the value of $R_5$ a value of 2.2 Ohm is chosen, its purpose is only to limit the current during start-up.
5. EMC LAYOUT RECOMMENDATIONS

In the layout and circuit diagram take care that the vertical amplifier with its external components will not disturb other electronic circuits (radiation). Also the circuit must not be disturbed by radiation coming from other electronic circuits (susceptibility/immunity). There are three kinds of measures to improve the circuits immunity and radiation:

- limit the bandwidth of the system,
- keep current loops physically as small as possible to reduce magnetic field pick-up and radiation,
- keep PCB tracks as short as possible to reduce electric field pick-up and radiation.

Not always all three measures can and must be taken.

The following recommendations are applicable to the vertical deflection circuit:

1. Bandwidth: do not make the bandwidth larger as needed. Not only will this reduce disturbances from other electronic circuits, but also noise is reduced.
2. Input tracks: keep the input tracks as short as possible. This measure is sometimes hard to implement, but keep it in mind. Anyhow, it is also very important to keep them close together to minimise the loop area.
3. Input decoupling: place decoupling capacitors of 10 nF at the inputs of the TDA4863(A)J. This filters the inputs from high frequency disturbance.
4. Power supply: place decoupling capacitors from all supply pins to ground. Combine the grounds of all decoupling capacitors to one ground return track to the SMPS of the monitor. Do not use this ground return track for other circuits in the monitor. This makes sure that there are no high frequency disturbances on the supply voltages.
5. Heatsink: make sure that the heatsink is electrically connected to PCB ground, so it is not floating. However, the heatsink must be isolated from the back of the TDA4863(A)J, because the back of the IC is not at ground potential. The isolation must have a small thermal resistance, so heat is transferred easily through the isolation.
6. REFERENCES

- AN99009, Application information for TDA8358J deflection output circuit and East-West, July 1999, Dick v.d. Brul, Bas Kasman, Pieter v. Oosten

- AN00038, EMC of Monitors, February 2000, G. Tent, H. Verhees