

## TDA9102C SELECTION vs HORIZONTAL DUTY CYCLE

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CONTENTS	Page
I. INTRODUCTION .....	1
II. DUTY CYCLE CALCULATION .....	2
II.1. DUTY MIN. ....	2
II.2. DUTY MAX. ....	3
II.3. TYPICAL LIMITS. ....	4
III. APPLICATION FOR INCREASING THE DUTY CYCLE OF A TDA9102C .....	5
III.1. STANDARD APPLICATION .....	5
III.1.1. Modified Application .....	5
III.1.2. Components Calculation in Modified Application .....	6
III.1.3. Summing .....	6
IV. APPLICATION FOR DECREASING THE DUTY CYCLE OF A TDA9102C .....	6
IV.1. STANDARD APPLICATION .....	6
IV.1.1. Modified Application .....	7
IV.1.2. Components Calculation in Modified Application .....	7
V. CONCLUSION .....	8

### I. INTRODUCTION

The TDA9102C is a horizontal and vertical deflection processor particularly well suited for high end monitors.

One of the key parameters is the very low jitter of the horizontal deflection processor.

The horizontal duty cycle is the ratio between the time during which the line switching transistor receives an off command and the line period.

As the monitors are using more and more various and higher line frequencies, this duty cycle must be well adapted to the actual application.

The following pages show how to calculate the min and max duty cycle for which typical application can

work.

For the rare cases where the TDA9102C do not fit to the used diagram, a simple application is given, both to increase or to decrease the device duty cycle. It is anyway important to note that the experience shown that in most of the case, when the TDA9102C does not fit the application, it is because of too low value. Consequently, mainly the application to increase the duty cycle will be used.

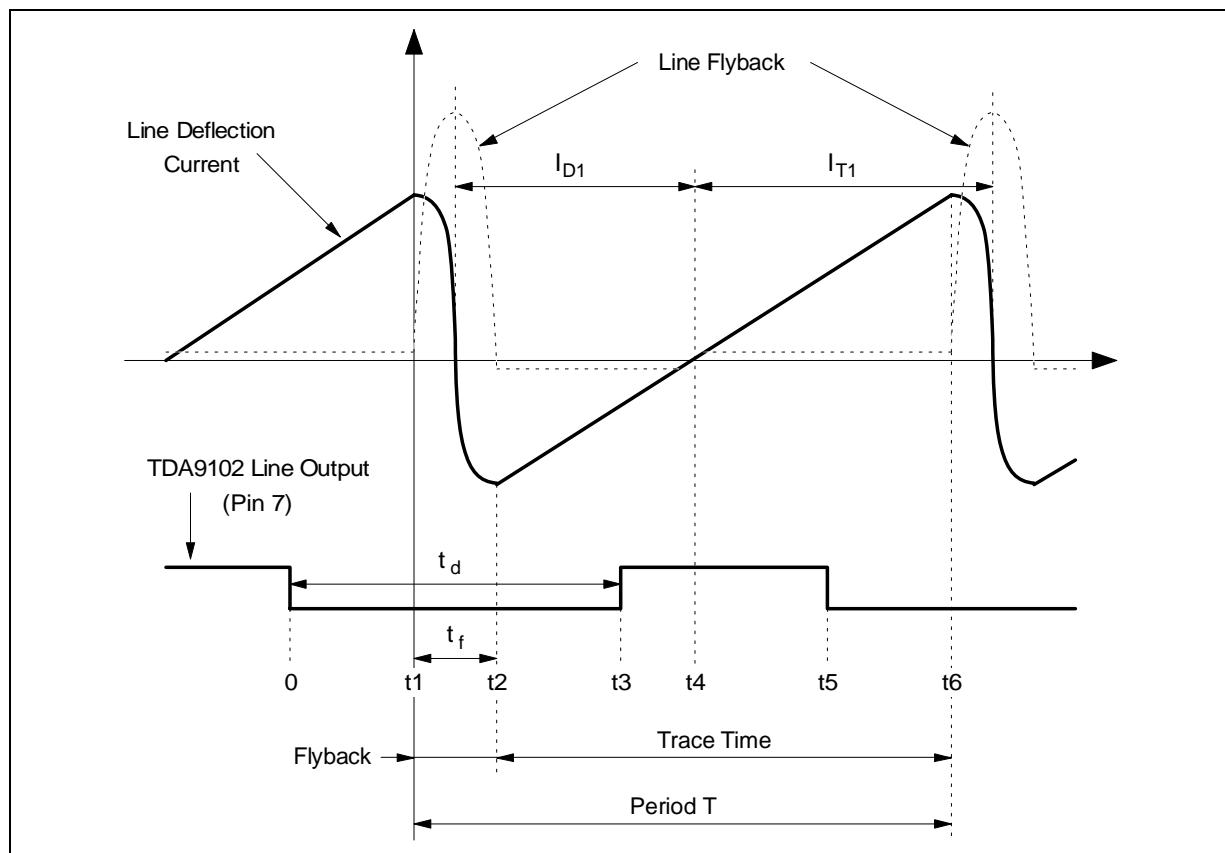
#### **Nota Bene :**

*For a quick over view a floppy disk is available using the formulas given here-after and allowing to find at once the right application.*

*For starting the program, just type "9102"*

II. DUTY CYCLE CALCULATION

Figure 1



II.1. Duty Min.

- When the output of the line processor turns low, it takes a time  $t_1$ , before the line switching transistor actually turns off.
- Then it takes a time  $t_f = t_2 - t_1$  for the current in line yoke to invert (fly back time)
- As soon as the flyback is finished, the line transistor may be turned on again, although it will actually conduct only when the line current becomes positive (at  $t_4$ ).

Thus the minimum off time  $t_d$  is :

$$t_{d \min} = t_{1 \max} + t_{f \max}$$

Since the duty cycle is defined as  $\frac{t_d}{T}$  where T is the

line period :  $d_{\min} = (t_{1 \max} + t_{f \max}) f$  where  $f = \frac{1}{T}$

So the worst case for  $d_{\min}$  is at the highest fre-

quency used in the monitor :

$$d_{\min} = f_{\max} (t_{1 \max} + t_{f \max}) \quad (1)$$

$t_f$  is usually well know by the designer ; shortening  $t_f$  is limited by the switching transistor  $T_1$  breakdown voltage.

$t_1$  is the delay between the command for switching off the line transistor  $T_1$  and its actual switching.

In diagram 1 and 2,  $t_1$  is the recovery time  $t_{r1}$  of  $T_1$  In diagram 3,  $t_1$  is the recovery time  $t_{r1}$  of  $T_1$  added to the turn on time  $t_{o2}$  of transistor  $T_2$ .

So :

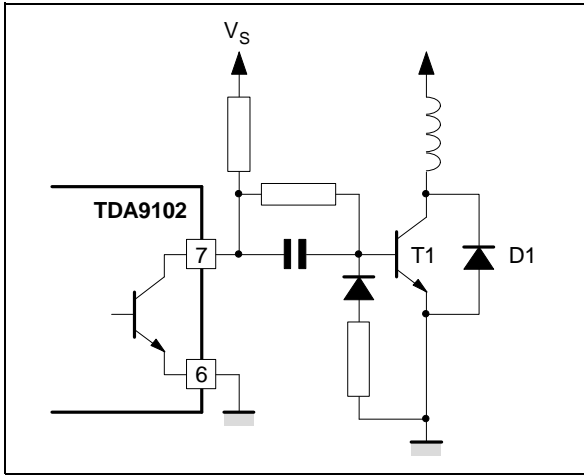
$$d_{\min} = f_{\max} (t_{r1 \max} + t_{f \max}) \quad (2)$$

for diagram 1 and 2

$$d_{\min} = f_{\max} (t_{r1 \max} + t_{o2 \max} + t_{f \max}) \quad (3)$$

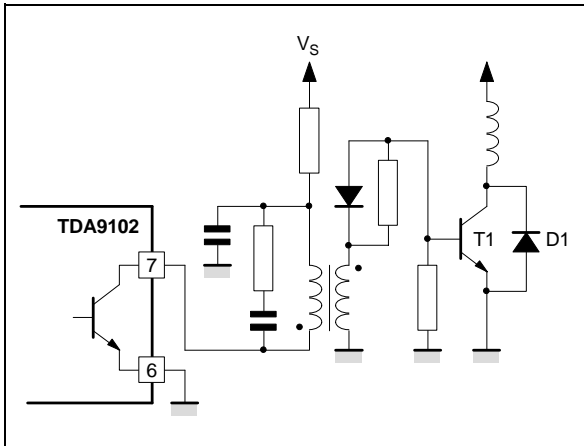
for diagram 3

Diagram 1 : Direct Drive



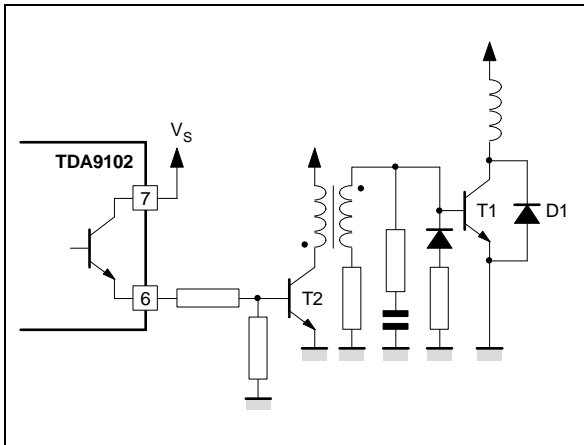
9102007.EPS

Diagram 2 : Transformer Drive



9102008.EPS

Diagram 3 : Indirect Drive



9102009.EPS

II.2. Duty Max.

Referring to Fig 1, the line switching transistor T<sub>1</sub> must be turned on before t<sub>4</sub>, that is to say before the current becomes positive.

Since it takes a time t<sub>0</sub> for T<sub>1</sub> to turn on, the command, that is to say the positive going edge of Pin 7 must arrive at a time t<sub>3</sub> < t<sub>4</sub> - t<sub>0</sub>.

t<sub>4</sub> would be in the middle of the trace time, at  $\frac{t_2 + t_6}{2}$ , if no energy was lost.

Since the negative part of the current (from t<sub>2</sub> to  $\frac{t_2 + t_6}{2}$ ) is giving energy back to the power supply

while the positive part is drawing energy from it, the latter must be greater. The consequence is that t<sub>4</sub> arrives before the first half of the trace time, say at

$$t_4 = t_2 + \frac{k}{2} (t_6 - t_2)$$

$$t_4 = t_2 + \frac{k}{2} (T - t_f)$$

k < 1 is an inefficiency factor.

This sets the maximum allowable off time t<sub>3</sub> to :

$$t_{d \max} = t_{3 \max} = \left( t_1 + t_f + \frac{k}{2} + (T - t_f) - t_{0 \min} \right)_{\min}$$

Since the duty cycle is  $d = \frac{t_d}{T} = f t_d$

$$d_{\max} = \frac{k}{2} + \left( f \left[ t_1 + t_f \left( 1 - \frac{k}{2} \right) - t_{01} \right] \right)_{\min} \quad (4)$$

For applications 1 and 2, t<sub>1</sub> = t<sub>r</sub> (T<sub>1</sub> turn-off time), t<sub>0</sub> = t<sub>01</sub> (T<sub>1</sub> turn-on time)

Since for any transistor t<sub>r</sub> > t<sub>0</sub> and since k ≤ 1, the coefficient of f is always positive.

Therefore, the worst cas is :

$$d_{\max} = \frac{k}{2} + f_{\min} \left[ t_{r1 \min} + t_{f \min} \left( 1 - \frac{k}{2} \right) - t_{01 \max} \right] \quad (5)$$

for applications 1 and 2

For application 3, t<sub>r</sub> = t<sub>r1</sub> + t<sub>02</sub> (T<sub>1</sub> turn-off time + T<sub>2</sub> turn-on time) and t<sub>0</sub> = t<sub>01</sub> + t<sub>r2</sub> (T<sub>1</sub> turn-on time + T<sub>2</sub> turn-off time)

Normally T<sub>1</sub> is a larger transistor working at a higher current than T<sub>2</sub> so that t<sub>r1</sub> + t<sub>02</sub> > t<sub>01</sub> + t<sub>r2</sub> and the coefficient of f in (4) is positive.

## TDA9102C SELECTION vs HORIZONTAL DUTY CYCLE

In this case :

$$d_{\max} = \frac{k}{2} + f_{\min} \left[ t_{r1 \min} + t_{o2 \min} + t_f \min \left( 1 - \frac{k}{2} \right) - t_{o1 \max} - t_{r2 \max} \right]_{\min} \quad (6)$$

for application 3

However is  $T_2$  is a very cheap transistor versus  $T_1$ , the said coefficient may be negative ; in this case :

$$d_{\max} = \frac{k}{2} - f_{\max} \left[ t_{o1 \max} + t_{r2 \max} - t_f \min \left( 1 - \frac{k}{2} \right) - t_{r1 \min} - t_{o2 \min} \right]_{\min} \quad (7)$$

for application 3 with  $t_{r1} + t_{o2} + t_f \left( 1 - \frac{k}{2} \right) - t_{o1} - t_{r2} < 0$

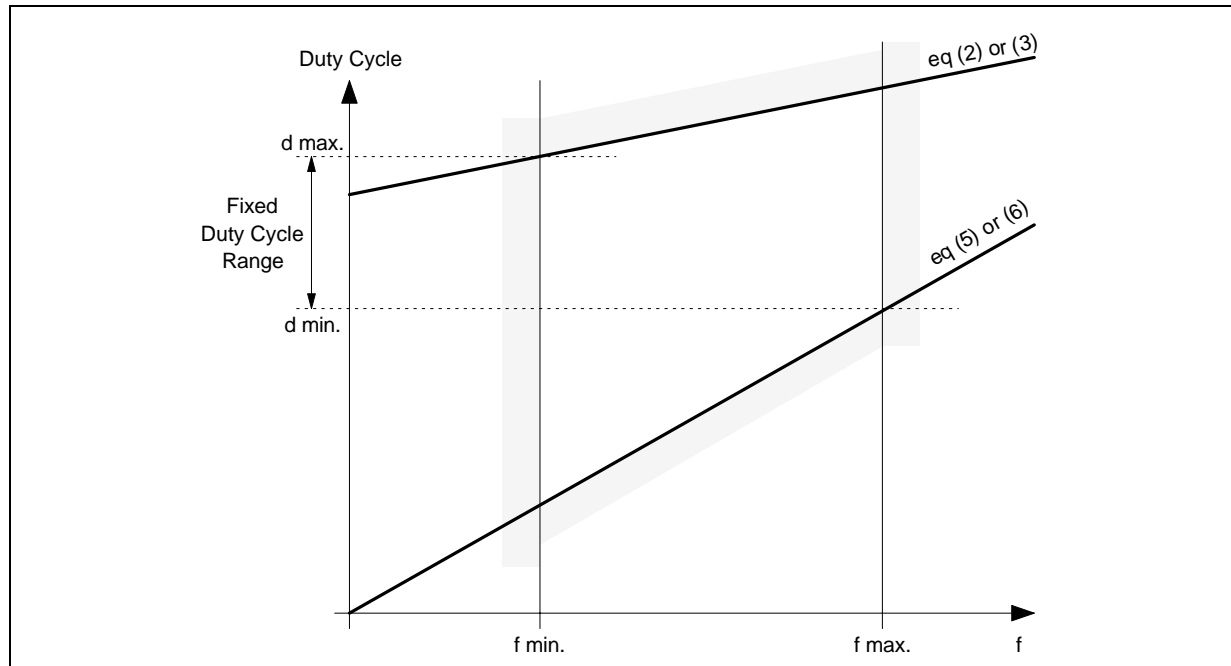
Note that in the general case  $d_{\max}$  worst case is  $\frac{k}{2}$ .

This shows that for high frequency application, where equations (2) and (3) show that the duty cycle can not be too small,  $k$  needs to be as high as possible. This is why it can be interesting to derive the EHT power from a system independant from the deflection one, even for a single frequency terminal.

### II.3. Typical Limits

Using (2) or (3) and (5) or (6), the allowable limits can be drawn as in Fig 2 :

Figure 2



#### Example :

using diagram 1, with

$t_{r1} = 2\mu s \pm 0.5\mu s$ ,  $t_{o1} = 0.5\mu s$ ,  $f_{\min} = 31.5\text{kHz}$ ,  $f_{\max} = 56\text{kHz}$ ,  $k = 0.95$ ,  $t_f = 2\mu s \pm 0.2\mu s$

yields to :

$$(2) : d_{\min} = 56 \times 10^3 \times (2.5 + 2.2) \times 10^{-6} = 0.26 \text{ (26 \%)}$$

$$(5) : d_{\max} = \frac{0.95}{2} + 31.5 \times 10^3 \left[ 2 + 1.8 \times \left( 1 - \frac{0.95}{2} \right) - 0.5 \right] \times 10^{-6} = 0.53 \text{ (53 \%)}$$

In this case, TDA9102C (35 to 44 %) can be used. At 78kHz dmin would be 36.2 %. Thus TDA9102C would still fit the application.

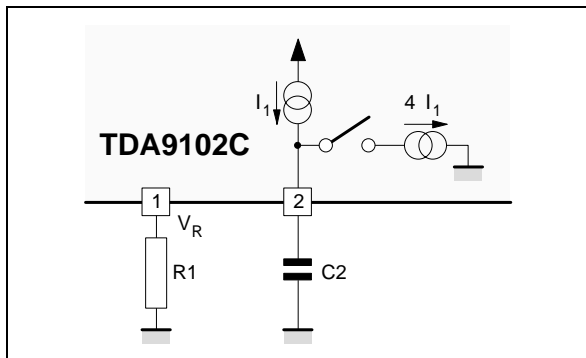
In such applications where it looks safer to center the selected device duty cycle in the allowable duty cycle range, paragraphs III and IV show a way to increase (resp. decrease) the duty cycle of a TDA9102C.

**III. APPLICATION DIAGRAM FOR INCREASING THE DUTY CYCLE OF A TDA9102C**

This application is needed when the minimum duty cycle of the selected TDA 9102C can be lower than the minimum allowable duty cycle of the application. The latter being proportionnal to f max, the calculations must be done at this max frequency.

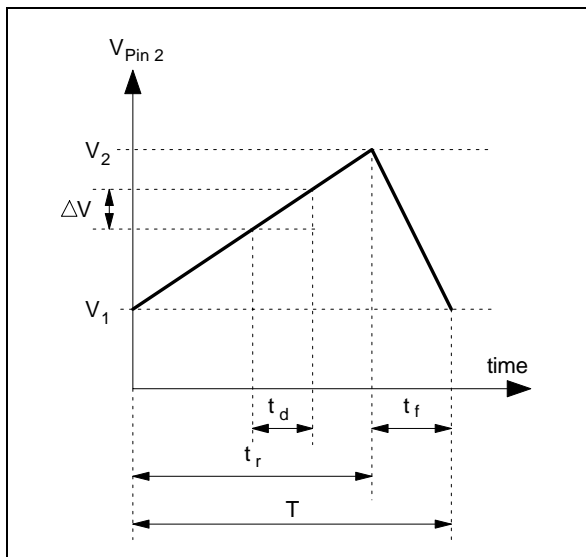
**III.1. Standard application**

Figure 3



9102011.EPS

Figure 4



9102012.EPS

During rise time tr, a current I1, is charging C2. This current is the image of the current driven from Pin 1 by R1 :

$$I_1 = \frac{V_R}{2R_1}$$

When the voltage on pin 2 reaches a threshold V2, a switch is activated so that the capacitor C2 is discharged by a current 4I1 - I1 = 3I1. The fall time tf ends when the threshold value V1 is reached.

Thus :

$$T_r = 2 \frac{V_2 - V_1}{V_R} R_1 C_2$$

$$T_f = 2 \frac{V_2 - V_1}{V_R} \frac{R_1 C_2}{3}$$

$$T = \frac{8}{3} \frac{V_2 - V_1}{V_R} R_1 C_2 \quad (8)$$

The off time td is used to define the duty cycle as :

$$\text{duty cycle} = \frac{t_d}{T}$$

The off time is the time during which Pin 7 is low. ΔV is a fixed voltage difference which determines td.

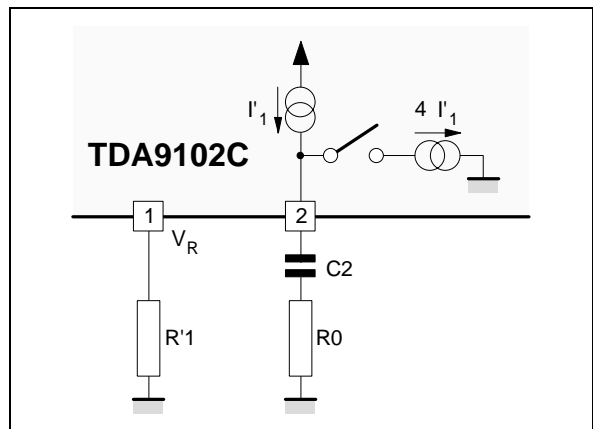
$$t_d = \frac{2\Delta V}{V_R} R_1 C_2 \quad (9)$$

Mixing (8) and (9) yields to :

$$\Delta V = \frac{t_d}{T} \frac{4}{3} (V_2 - V_1) \quad (9')$$

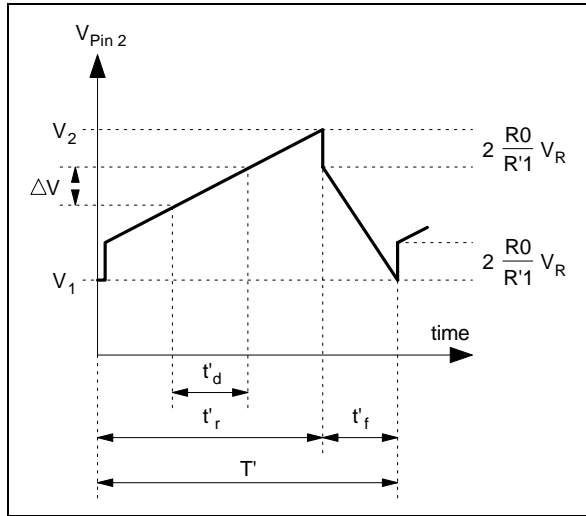
**III.1.1. Modified Application**

Figure 5



9102013.EPS

Figure 6



During rise time, a constant voltage drop  $I_1 R_0$  is added to the voltage across  $C_2$ . During fall time,  $-3I_1 R_0$  is added.

Thus the voltage step is  $4I_1 R_0 = 2 R_0 \frac{V_R}{R_1}$

The new period can be derived from formula (8), provided the voltage threshold difference  $V_2 - V_1$  is decreased by  $2 R_0 \frac{V_R}{R_1}$

Hence :

$$T' = \frac{8}{3} \frac{V_2 - V_1 - 2 \frac{R_0}{R_1} V_R}{V_R} R_1 C_2 \quad (10)$$

The off time  $t_d$  is straight forward :

$$t_d = \frac{2\Delta V}{V_R} R_1 C_2 \quad (11)$$

### III.1.2. Components Calculation in Modified Application

#### III.1.2.1. $R_1$ CALCULATION

$C_2$  is assumed to be constant.

Equation (II) shows that fixing a duty cycle, or an off time  $t_d$  yields to a mandatory  $R_1$ . Then equation (10) gives the adequate  $R_0$  value for the given frequency. However the datasheet does not provide  $\Delta V$  value, but provides  $\frac{t_d}{T}$  in standard application (see formula (9)).

Introducing these known parameters in equation (II) yields to :

$$t_d = \frac{8}{3} \frac{(V_2 - V_1)}{V_R} \frac{t_d}{T} R_1 C_2 \quad (12)$$

$$R_1 = \frac{3}{8} \frac{t_d}{C_2} \frac{V_R}{(V_2 - V_1)} \frac{T}{t_d} \quad (13)$$

$\frac{t_d}{T}$  : device duty cycle,  $t_d$  : needed off time

#### III.1.2.2. $R_0$ CALCULATION

Using (10) :

$$\frac{3}{8} T' \frac{V_R}{R_1 C_2} = V_2 - V_1 - 2 \frac{R_0}{R_1} V_R$$

$$2 \frac{R_0}{R_1} V_R = V_2 - V_1 - \frac{3T'}{8} \frac{V_R}{R_1 C_2}$$

$$R_0 = \frac{V_2 - V_1}{V_R} \frac{R_1}{2} - \frac{3T'}{16C_2}$$

(Replacing  $R_1$  by (13))

$$R_0 = \frac{3T'}{16C_2} \left( \frac{d'}{d} - 1 \right) \quad (14)$$

### III.1.3. Summary

When the minimum duty cycle  $\frac{t_d}{T}$  of your application is higher than the minimum duty cycle  $\frac{t_d}{T}$  of the chosen device, use the modified application of Fig.5, calculating  $R_1$  from (13) and  $R_0$  from (14). Chose the actual values for  $R_0$  and  $R_1$ , so that a safety margin is allowed for component tolerances.

### IV. APPLICATION DIAGRAM FOR DECREASING THE DUTY CYCLE

This application is used when the max duty cycle of TDA9102C can be higher than the max allowable duty cycle of the application. The latter being proportional to  $f_{max}$ , the calculation is to be made at  $f_{min}$ .

#### IV.1. Standard Application : please refer to § III

$$T = \frac{8}{3} \frac{V_2 - V_1}{V_R} R_1 C_2 \quad (8)$$

$$t_d = \frac{2\Delta V}{V_R} R_1 C_2 \quad (9)$$

$$\Delta V = \frac{t_d}{T} \frac{4}{3} (V_2 - V_1) \quad (9')$$

IV.1.1. Modified Application

Figure 7

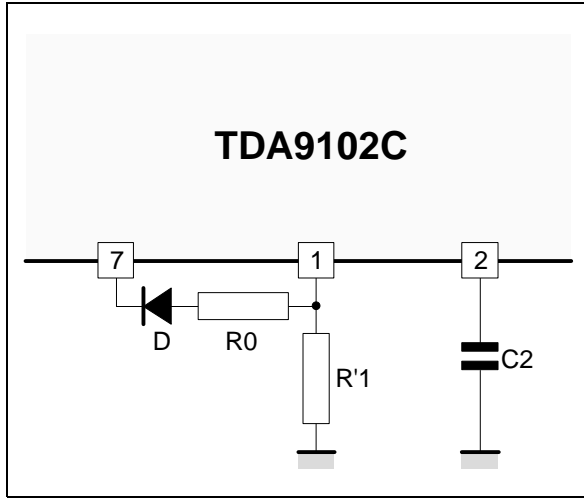
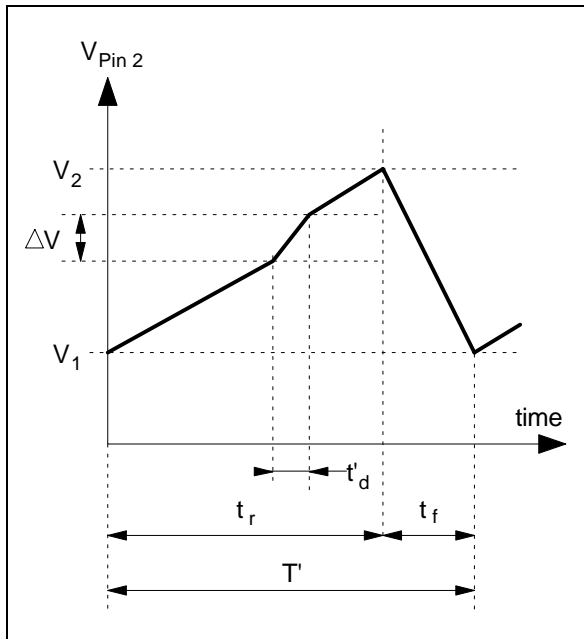


Figure 8



When the off time  $t'd$  starts, pin 7 is low so that  $R_0$  drives an additional current from pin 1, thus increasing the slope on  $C_2$ .

If  $V_D$  is the sum of the saturation voltage on pin 7 and the voltage drop across the diode D, the additional current is :  $I_0 = \frac{V_R - V_D}{R_0}$

Since the current charging  $C_2$  is half the current driven from pin 1, the off time is :

$$t_d = \frac{2\Delta V C_2}{\frac{V_R}{R_1} + \frac{V_R - V_D}{R_0}} \quad (15)$$

using (9') :

$$t_d = \frac{8}{3} \frac{t_d}{T} \frac{(V_2 - V_1) C_2}{\frac{V_R}{R_1} + \frac{V_R - V_D}{R_0}} \quad (16)$$

IV.1.2 Component Calculation of the Modified Application (Fig.5)

definitions :

- $t_d$  : device off time (normal application)
- $d = \frac{t_d}{T}$  : device duty cycle
- $t'd$  : needed off time (modified application)
- $T'$  : line period (modified application)
- $d' = \frac{t'd}{T'}$  : needed duty cycle
- $V_S = V_2 - V_1$  : voltage swing at pin 2 (4V)
- $V_R$  : voltage at pin 1 (3.5V)
- $V'R = V_R - V_D$  : voltage across  $R_0$  during off time ( $\approx 2.5V$ )

(16) can be rewritten as :

$$t_d = \frac{8}{3} \frac{d V_S C_2}{\frac{V_R}{R_1} + \frac{V'R}{R_0}} \quad (17)$$

and (9') as (9'')  $\Delta V = \frac{4}{3} d V_S$

a second equation is necessary to derive both  $R'_1$  and  $R_0$ .

It is given by calculating the line period  $T'$  :

Referring to Fig.6 :

$$T' = (t_r - t'd) + t'd + t_f = \frac{V_S - \Delta V}{\frac{V_R}{2R_1}} C_2 + \frac{8}{3} \frac{d V_S C_2}{\frac{V_R}{R_1} + \frac{V'R}{R_0}} + \frac{V_S C_2}{\frac{3}{2} \frac{V_R}{R_1}}$$

## TDA9102C SELECTION vs HORIZONTAL DUTY CYCLE

$$\begin{aligned}
 (9') \Rightarrow T' &= \frac{2 R'_1}{V_R} \left( C_2 V_S - \frac{4}{3} d V_S C_2 + \frac{4}{3} \frac{d V_S C_2}{1 + \frac{V'_R R'_1}{V_R R_0}} + \frac{C_2 V_S}{3} \right) \\
 &= \frac{8}{3} \frac{V_S}{V_R} R'_1 C_2 \left( 1 - d + \frac{d}{1 + \frac{V'_R R'_1}{V_R R_0}} \right) \\
 &= \frac{8}{3} \frac{V_S C_2}{\frac{V_R}{R'_1} + \frac{V'_R}{R_0}} \left( 1 - d + (1 - d) \frac{V'_R R'_1}{V_R R_0} + d \right)
 \end{aligned}$$

$$(17) \Rightarrow T' = \frac{t'_d}{d} \left( 1 + (1 - d) \frac{V'_R R'_1}{V_R R_0} \right)$$

$$\frac{T'd}{t'_d} = 1 + (1 - d) \frac{V'_R R'_1}{V_R R_0}$$

$$\frac{d}{d'} - 1 = (1 - d) \frac{V'_R R'_1}{V_R R_0}$$

$$\frac{V'_R}{R_0} = \frac{V_R}{R'_1} \frac{d - d'}{d' (1 - d)} \quad (18)$$

replacing in (17) :

$$\begin{aligned}
 t'_d &= \frac{8}{3} \frac{d V_S C_2}{\frac{V_R}{R'_1} \left( 1 + \frac{d - d'}{d' (1 - d)} \right)} \\
 &= \frac{8}{3} \frac{V_S C_2 R'_1 d' (1 - d)}{V_R (1 - d')}
 \end{aligned}$$

$$R'_1 = \frac{3}{8} \frac{t'_d (1 - d') V_R}{C_2 d' (1 - d) V_S} \quad (19)$$

$$\text{as } d' = \frac{t'_d}{T'}$$

$$R'_1 = \frac{3}{8} \frac{T' (1 - d') V_R}{C_2 (1 - d) V_S} \quad (20)$$

using (18) :

$$R_0 = R'_1 \frac{d' (1 - d) V'_R}{(d - d') V_R}$$

$$R_0 = \frac{3}{8} \frac{T' (1 - d') d' V'_R}{C_2 (d - d') V_S} \quad (21)$$

## V. CONCLUSION

If your maximum allowable duty cycle  $d'$  is lower than the max duty cycle  $d$  of the TDA9102C use application of Fig.5, calculating  $R'_1$  and  $R_0$  from (20) and (21).

The TDA9102C can be used in virtually all monitor application even though the horizontal duty cycle is basically fixed.

This together with the very good jitter figure and all DC control explains the great succes of this device.

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