Evaluating power consumption

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This code was developed by Miodrag Bolic for the book PERVASIVE CARDIAC AND RESPIRATORY MONITORING DEVICES: https://github.com/Health-Devices/CARDIAC-RESPIRATORY-MONITORING

We would like to acknowledge:

[1] G. Dekkers, F. Rosas, S. Lauwereins, S. Rajendran, S. Pollin, B. Vanrumste, T. van Waterschoot, M. Verhelst and Peter Karsmakers, �A multi-layered energy consumption model for smart wireless acoustic sensor networks,� KU Leuven, Tech. Rep., December 2018. for providing the Matlab code. All the equations are from their paper.

Introduction

A/D Converter

```
% From paper [1]
T=1;
channels=1;
Nadc= 12 ;%                        # ADC resolution [bit]
fs=10000;
Ts=1/fs;
FOM= 100*10^(-13)*10^3;        %    # [mJ/conv]
% ADC consumption
Padc = 2^Nadc * fs * FOM      % [mW] - eq. 10
```

```
Padc = 0.4096
```

```
Eadc = T*Padc*channels;        % [mJ] = [s]*[mW] - eq. 9

% Based on the data sheet for sigma delta ADS1114 from TI
i_oper=0.15;                % [mA]
i_power_down=1e-3;          % [mA]
conversion_time=1/1000;     % [s]
```

```
Vdd=3;                              % [V]
Eadc=Vdd*(i_oper*conversion_time+i_power_down*(Ts-conversion_time));
Padc=Eadc/Ts                        %
```

```
Padc = 4.4730
```

```
% Based on the data sheet for sucessive approximation AD7684 from Analog Devices
i_oper=0.56;                    % [mA]
i_power_down=1e-6;              % [mA]
conversion_time=10e-6;         % [s]
Vdd=3;                          % [V]
Eadc=Vdd*(i_oper*conversion_time+i_power_down*(Ts-conversion_time));
Padc=Eadc/Ts
```

```
Padc = 0.1680
```

```
% Ploting power over sampling rates and Vdd
Vdd1=[2.7, 5];
i=1:1000;
fs1=100*i;
Ts1=1./fs1;
i_oper1=[0.56, 0.8];;
Padc1(1,:)=Vdd1(1)*(i_oper1(1)*conversion_time+i_power_down*(Ts1-conversion_time))./Ts1
Padc1(2,:)=Vdd1(2)*(i_oper1(2)*conversion_time+i_power_down*(Ts1-conversion_time))./Ts1
loglog(fs1,Padc1)
title('Power consumption of ADC AD7684')
xlabel('Sampling frequency (Hz)')
ylabel('Power consumption (mW)')
grid on
legend(['2.7V'], ['5V'])
```

PPG Power consumption based on ADPD144RI

```
fs=100; % data rate
Ts=1/fs;
num_pulses=10;
Vdd=1.8; % [V]
Vled=3.2; % [V]

Toffset=25e-6; %[s]
Tpulseperiod=19e-6;
Tprocessingtime=60e-6;
Tledpulse=3e-6;
Iled=100;  % maximum current [mA]
Istandby=3.5e-3; % [mA]
Iafe=8.9+(Iled-25)/250; %[mA]
Iproc=1.5; % mA
Tslot=Toffset+Tpulseperiod*num_pulses;
Qproc=Iproc*2*Tslot; %[mC]
```

```
Ivdd_ave=(2*Tslot*(Iafe+Iproc)+(Ts-2*Tslot)*Istandby)/Ts % [mA]
```

```
Ivdd_ave = 0.4634
```

```
Iled_ave=(Tledpulse/Ts)*num_pulses*Iled
```

```
Iled_ave = 0.3000
```

```
Pppg=Ivdd_ave*Vdd+2*Iled_ave*Vled
```

```
Pppg = 2.7542
```

```
% Changing the number of pulses
for i=1:10
    num_pulses=i;
    Ivdd_ave=(2*Tslot*(Iafe+Iproc)+(Ts-2*Tslot)*Istandby)/Ts;
    Iled_ave=(Tledpulse/Ts)*num_pulses*Iled;
    Pppg=Ivdd_ave*Vdd+2*Iled_ave*Vled;
    Pout(i)=Pppg;
end
figure
plot(1:10,Pout)
title('Power consumption of the PPG component ADPD144RI versus N_{pulse}')
xlabel('Number of pulses')
ylabel('Power consumption (mW)')
annonation_save('a)',"Fig10.10a.jpg", 1);
```


Power consumption of the PPG component ADPD144RI versus N_{pulse}

a)

Power consumption of ADC AD7684
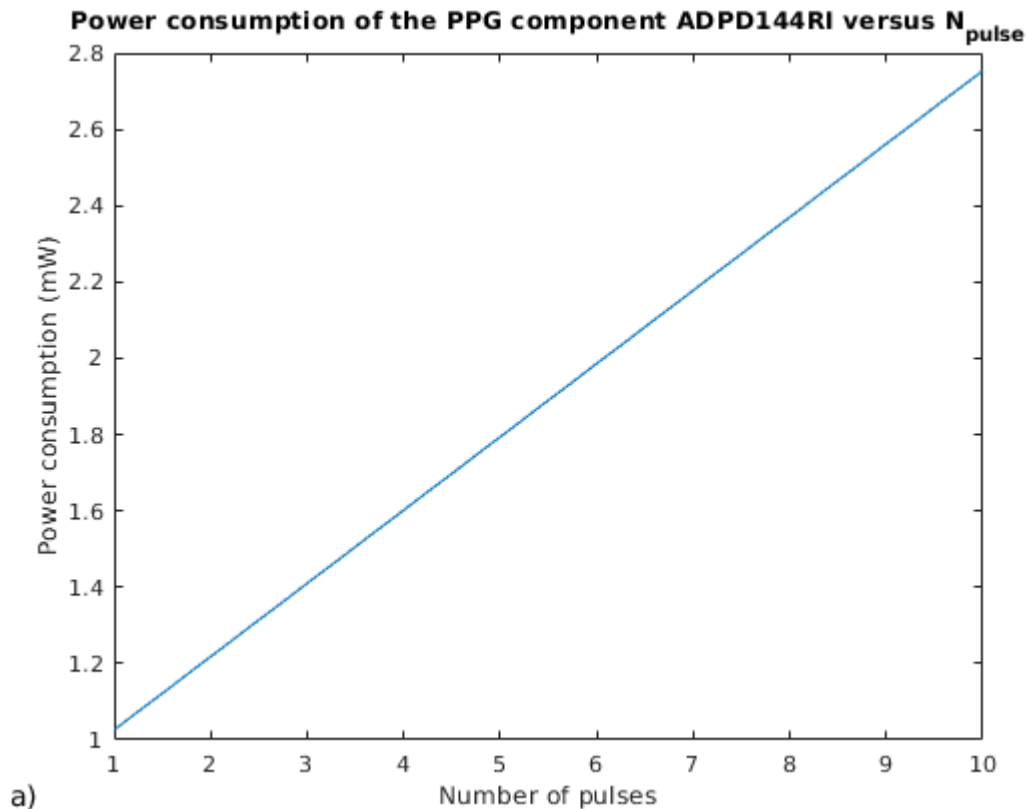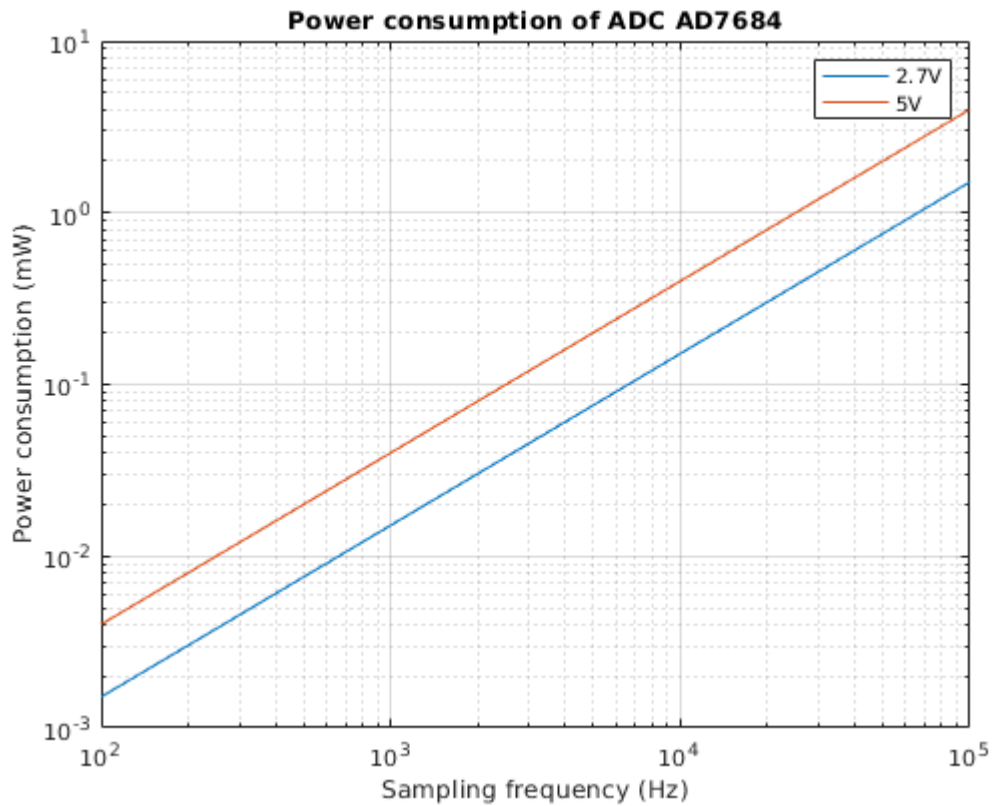
```
% Changing the data rate
for i=1:10
    fs=i*50; % data rate
    Ts=1/fs;

    Ivdd_ave=(2*Tslot*(Iafe+Iproc)+(Ts-2*Tslot)*Istandby)/Ts;
    Iled_ave=(Tledpulse/Ts)*num_pulses*Iled;
    Pppg=Ivdd_ave*Vdd+2*Iled_ave*Vled;
    Pout(i)=Pppg;
end
figure
plot(50:50:500,Pout)
title('Power consumption of the PPG component ADPD144RI versus f_s')
xlabel('Sampling rate f_s (sps)')
ylabel('Power consumption (mW)')
annonation_save('b)',"Fig10.10b.jpg", 1);
```

Power consumption of the PPG component ADPD144RI versus f_s

b)

Power consumption (mW) versus Sampling rate f_s (sps)
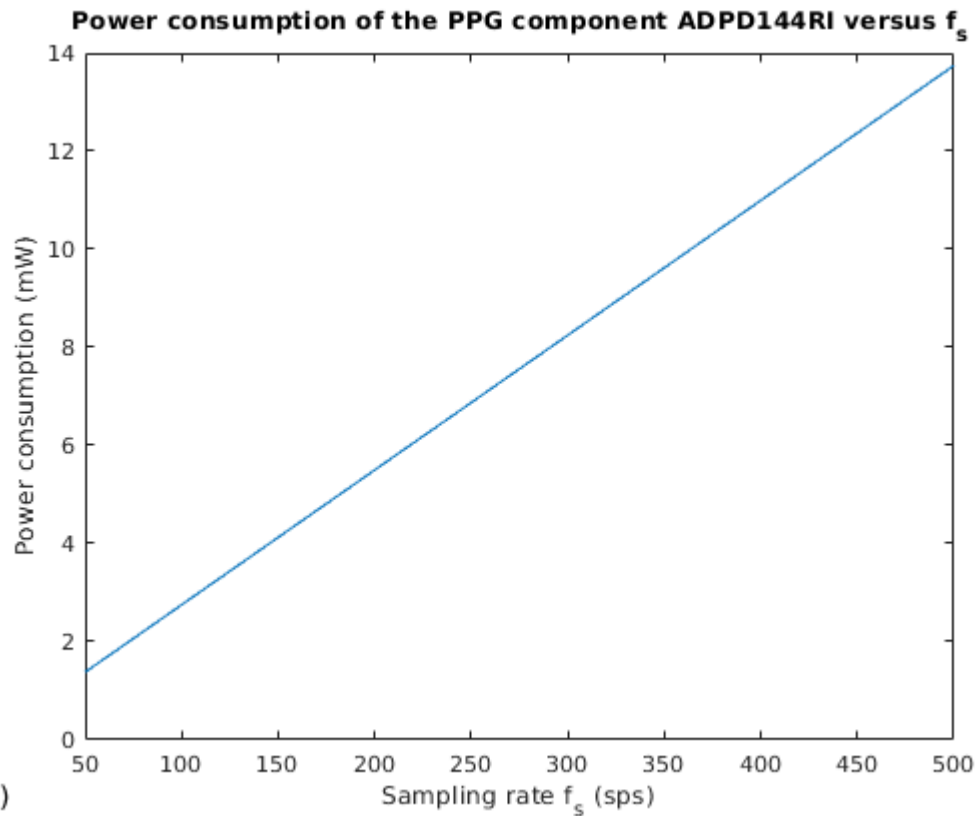
```
% Generating PPG pulses
t=0:1e-6:1200e-6;
DR=100; % data rate
T_DR=1/DR;
num_pulses=4;
Tpulseperiod=30e-6;
Tprocessingtime=60e-6;
Tledpulse=5e-6;

T_sample=0;
out=zeros(1,length(t));
for j=1:2
    for i=0:num_pulses-1
        interval=T_sample+Toffset+i*Tpulseperiod:1e-6:T_sample+Toffset+i*Tpulseperiod+T
        out(round(interval*1e6))=ones(1,length(interval));
    end
    Tslot=Toffset+Tpulseperiod*num_pulses+Tprocessingtime;
    for i=0:num_pulses-1
        interval=T_sample+Tslot+Toffset+i*Tpulseperiod:1e-6:T_sample+Tslot+Toffset+i*Tp
        out(round(interval*1e6))=ones(1,length(interval));
    end
    T_sample=T_sample+800e-6;
end
figure
plot(out)
title('Pulses at the output of the PPG component ADPD144RI')
xlabel('Time (\mus)')
```
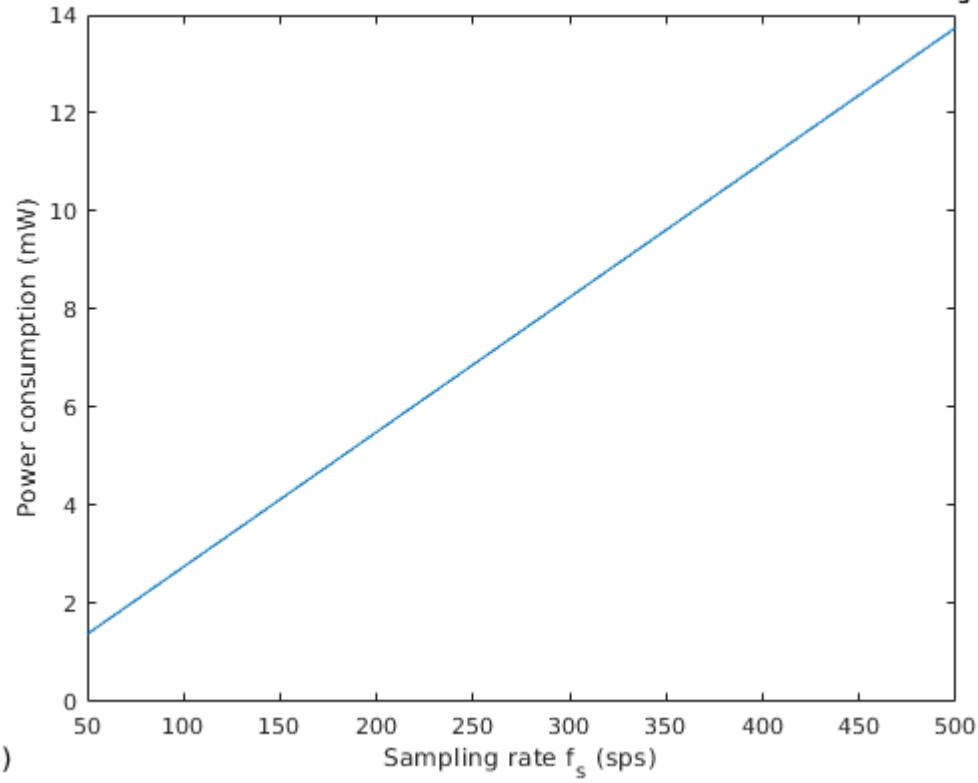
```
ylabel('Amplitude (V)')
ylim([-0.1,1.5])
exportgraphics(gcf,"Fig10.9_smartdraw.jpg", 'Resolution',600)
```
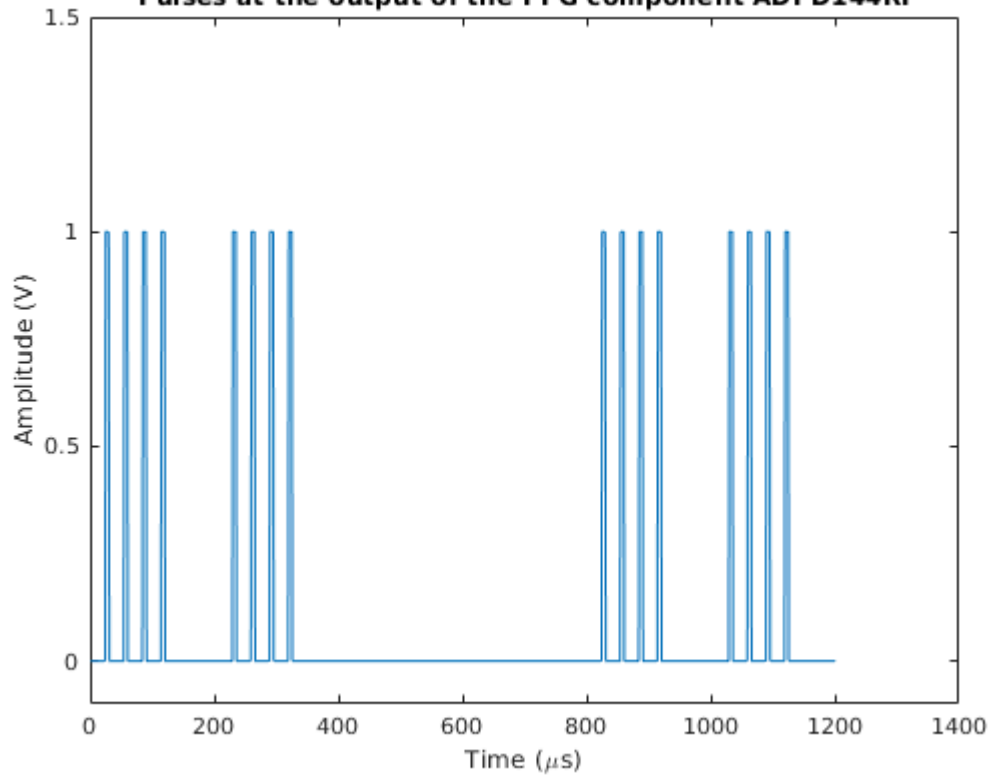

Power consumption of ADC AD7684

Power consumption of the PPG component ADPD144RI versus N_{pulse}

a)
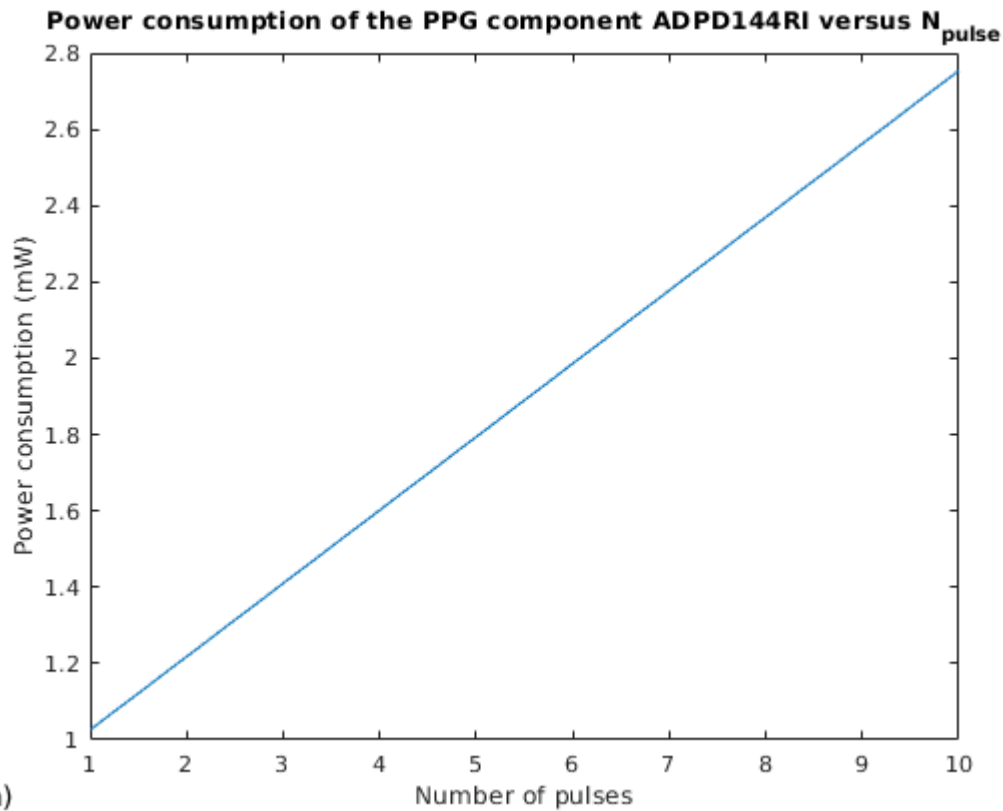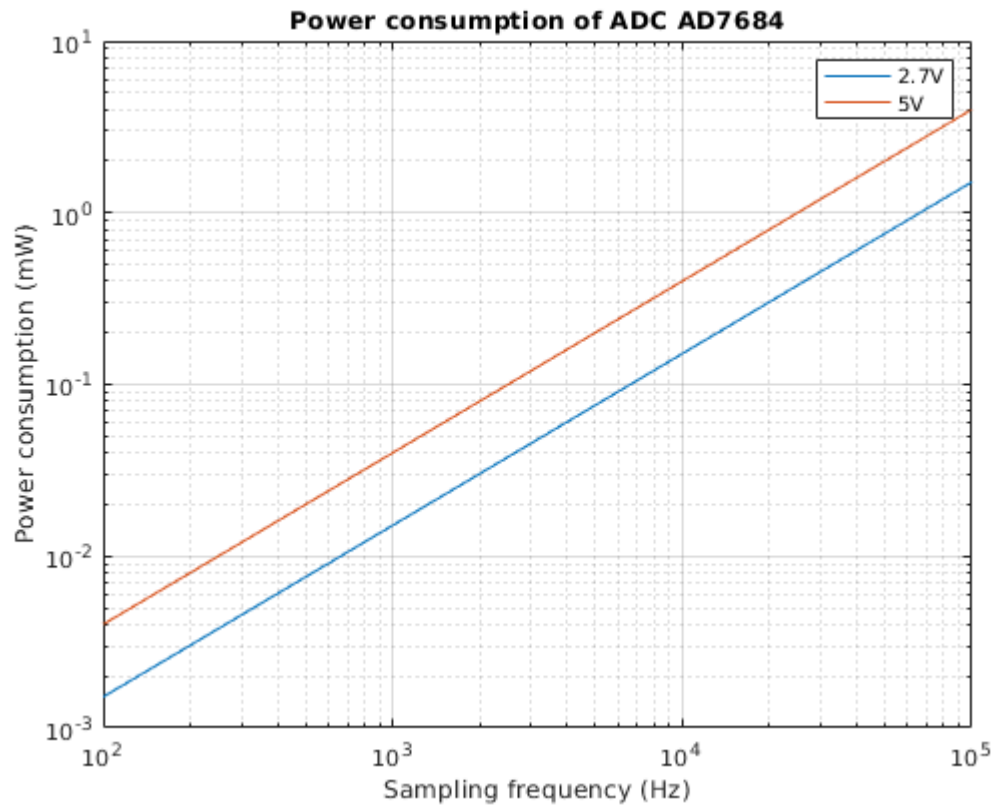
Power consumption of the PPG component ADPD144RI versus f_s

b)

Pulses at the output of the PPG component ADPD144RI

Microcontroller

```
IRTC= 1.3e-3; %[mA]
```

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```matlab
Itimer=6e-3;
II2C=126e-3;
Iradio=12;
ICPUnormal=6.81;
ICPUstop=204e-3;
ICPUVLLS=0.56e-3;
Tnormal=0.5;
Tstp=0.48;
Tcomm=0.02;

Itot_normal=ICPUnormal+IRTC+Itimer+II2C;
Itot_comm=Itot_normal+Iradio;
Itot_stop=ICPUstop+IRTC;

t=0:0.001:1;

for i=1:length(t)
    if t(i)<Tnormal
        Iout(i)=Itot_normal;
    elseif t(i)<Tnormal+Tcomm
        Iout(i)=Itot_comm;
    else
        Iout(i)=Itot_stop;
    end
end
figure
plot(t,Iout)
hold on
plot(t,mean(Iout)*ones(1,length(t)))
title('Current profile')
xlabel('Time (s)')
ylabel('Current (mA)')
legend(['Current in each mode'],['Average current'])
exportgraphics(gcf,"Fig10.11.jpg", 'Resolution',600)
```
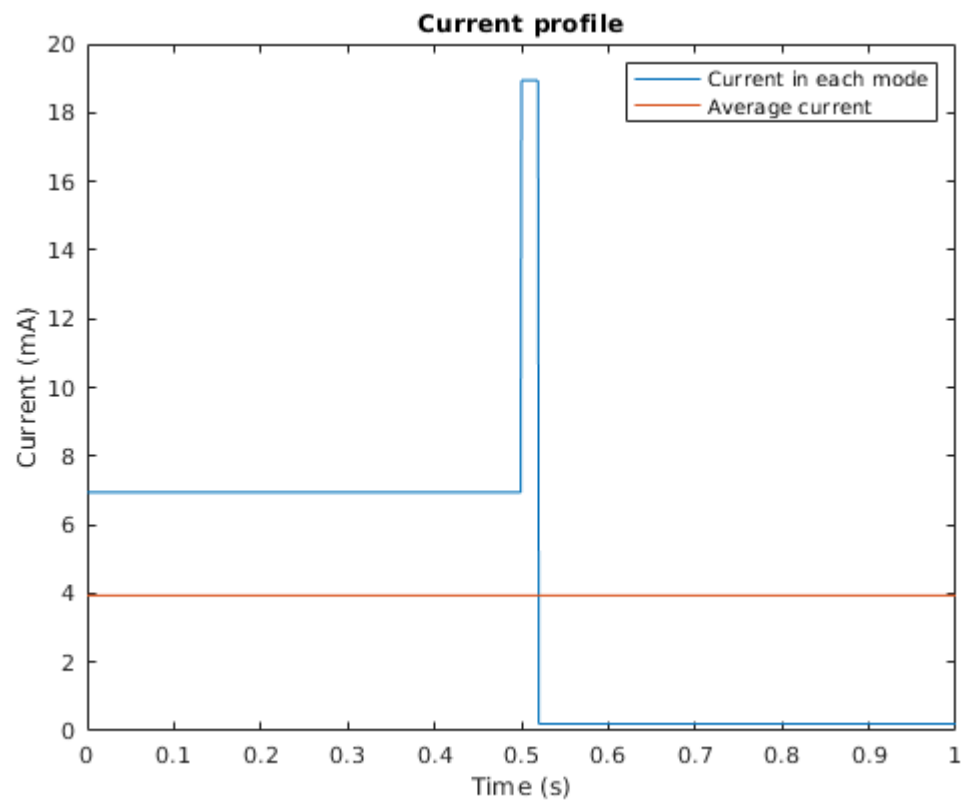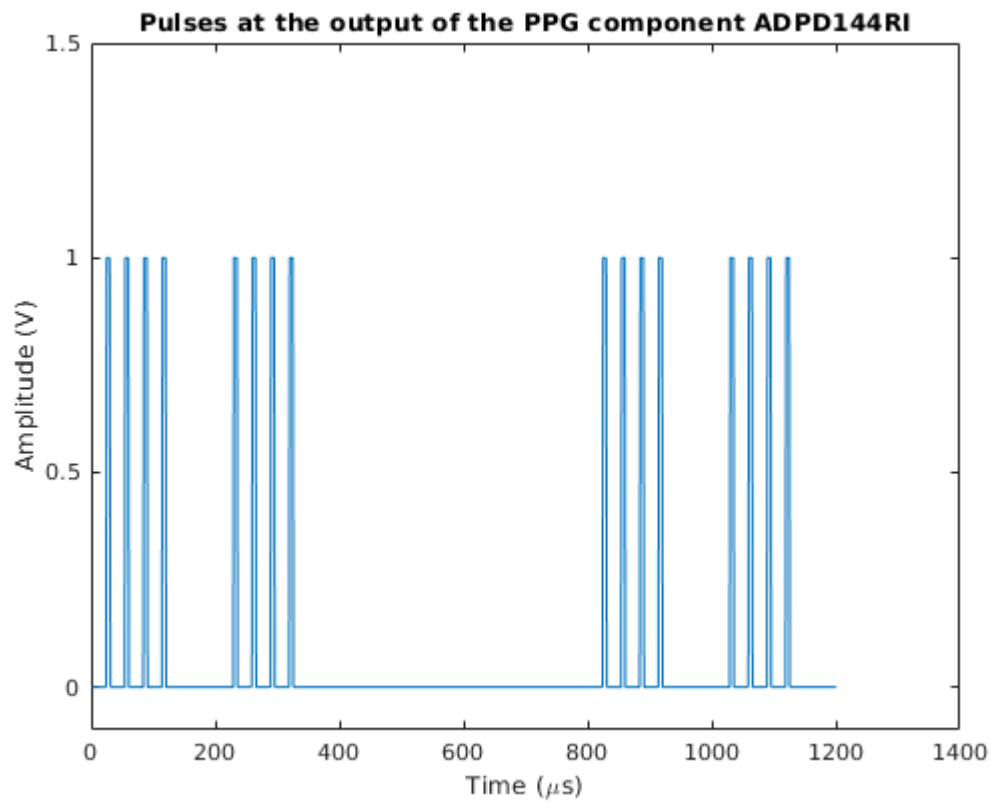
Pulses at the output of the PPG component ADPD144RI

Current profile

Computing the power at the output

```matlab
% Case 1
IRTC= 1.3e-3; %[mA]
Itimer=6e-3;
II2C=126e-3;
Iradio=6.3;
ICPUnormal=6.71;
ICPUstop=204e-3;
ICPUVLLS=0.56e-3;
Tnormal=0.025;
Tstp=0.225;
Tcomm=0.02;

Itot_normal=ICPUnormal+IRTC+Itimer+II2C;
Itot_comm=Itot_normal+Iradio;
Itot_stop=ICPUstop+IRTC;
Iproc_ave=(Itot_normal*Tnormal+Itot_comm*Tcomm+Itot_stop*Tstp)/(Tnormal+Tstp+Tcomm);

P=2.75 +Iproc_ave*1.2+0.05*2.05
```

```
P = 4.9865
```

```matlab
Ptotal=P/0.85
```

```
Ptotal = 5.8664
```

```matlab
TotalDuration=3.6*1000/Ptotal
```

```
TotalDuration = 613.6618
```

```matlab
days=floor(TotalDuration/24)
```

```
days = 25
```

```matlab
hours=TotalDuration-days*24
```

```
hours = 13.6618
```

```matlab
% Case 2
Tnormal=0.5;
Tstp=0.492;
Tcomm=0.008;

Itot_normal=ICPUnormal+IRTC+Itimer+II2C;
Itot_comm=Itot_normal+Iradio;
Itot_stop=ICPUstop+IRTC;
Iproc_ave=(Itot_normal*Tnormal+Itot_comm*Tcomm+Itot_stop*Tstp)/(Tnormal+Tstp+Tcomm);

P=2.75 +Iproc_ave*1.2+0.05*2.05
```

```
P = 7.2059
```

```matlab
Ptotal=P/0.85
```

```
Ptotal = 8.4775
```

```
TotalDuration=3.6*1000/Ptotal
```

TotalDuration = 424.6541

```
days=floor(TotalDuration/24)
```

days = 17

```
hours=TotalDuration-days*24
```

hours = 16.6541