In [1]:
```
# Imports
import os
import sys
import cmath
import math
import matplotlib.pyplot as plt
import matplotlib
import numpy as np
import pandas as pd
import ltspice
import sympy as sp
from sympy.utilities.lambdify import lambdify
from scipy import signal
%matplotlib inline
from IPython.core.interactiveshell import InteractiveShell
InteractiveShell.ast_node_interactivity = "all"
from matplotlib.ticker import LogLocator
```

In [2]:
```
def read_ltspice(file_name,ftype='trans',units='db'):
    cols = []
    arrs = []
    with open(file_name, 'r',encoding='utf-8') as data:
        for i,line in enumerate(data):
            if i==0:
                cols = line.split()
                arrs = [[] for _ in cols]
                continue
            parts = line.split()
            for j,part in enumerate(parts):
                arrs[j].append(part)
    df = pd.DataFrame(arrs,dtype='float64')
    df = df.T
    df.columns = cols
    if ftype=='trans':
        return df
    elif ftype=='ac':
        if units=='db':
            for col in cols:
                if df[col].str.contains(',').all():
                    df[f'Mag_{col}'] = df[col].apply(lambda x: x.split(',')[0])
                    df[f'Mag_{col}'] = df[f'Mag_{col}'].apply(lambda x: x[1:-2])
                    df[f'Mag_{col}'] = df[f'Mag_{col}'].astype('float64')
                    df[f'Phase_{col}'] = df[col].apply(lambda x: x.split(',')[1])
                    df[f'Phase_{col}'] = df[f'Phase_{col}'].apply(lambda x: x[0:-2])
                    df[f'Phase_{col}'] = df[f'Phase_{col}'].astype('float64')
        if units=='cartesian':
            for col in cols:
                if df[col].str.contains(',').all():
                    df[f'Re_{col}'] = df[col].apply(lambda x: x.split(',')[0])
                    df[f'Re_{col}'] = df[f'Re_{col}'].astype('float64')
                    df[f'Im_{col}'] = df[col].apply(lambda x: x.split(',')[1])
                    df[f'Im_{col}'] = df[f'Im_{col}'].astype('float64')
        df['Freq.'] = df['Freq.'].astype('float64')
        return df
    else:
        print('invalid ftype')
```

In [3]:
```
k = 1.38e-23
T = 300
q = 1.602e-19
V_T = k*T/q

# Photodiode
Cd = 150*1e-12
Id = 2*1e-6
```

Low-Noise Wideband Transimpedance Amplifier Design [June 2, 2021]

Kevin Egedy

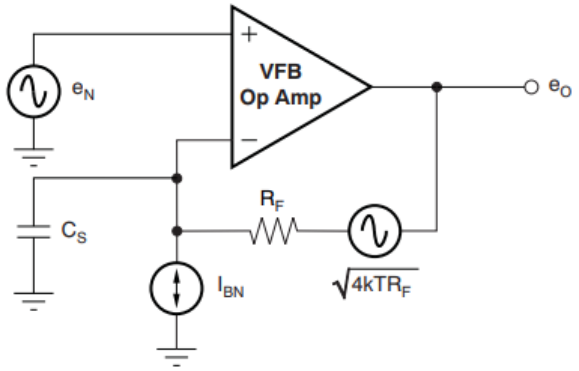
Parameter	Specification
Transimpedance gain (full signal path)	$1\ V/\mu A$

Parameter	Specification
Transimpedance bandwidth (f_{3dB})	$1\ MHz$
Minimum photodiode current (i_d)	$2\ \mu A$
Photodiode capacitance (C_d)	$150\ pF$
Closed-loop gain magnitude peaking	$0\ dB$
rms noise figure ($F = 1 + i_n^2/i_{ns}^2$)	$\leq 0.5\ dB$
Power dissipation ($I_{DD} \cdot (V_{CC} + V_{EE})$)	Optimize mW
Cost-per-unit (1000 units)	Optimize $

Getting Started

Transimpedance Amplifiers (TIA): Choosing the Best Amplifier for the Job (https://www.tij.co.jp/jp/lit/an/snoa942a/snoa942a.pdf?ts=1622056332116&ref_url=https%253A%252F%252Fwww.google.com%252F) [November 2015–Revised May 2017]

- Explore TI Transconductance Amplifiers (http://www.ti.com/lsds/ti/amplifiers/special-function-amplifiers/transconductance-amplifiers-products.page)
- Transimpedance Considerations for High-Speed Amplifiers (http://www.ti.com/litv/pdf/sboa122)



$$i_{n,in} = \sqrt{{i_n}^2 + \frac{4kT}{R_f} + \left(\frac{e_n}{R_f}\right)^2 + \frac{(e_n \cdot 2\pi f_{enb} C_{in})^2}{3}}$$

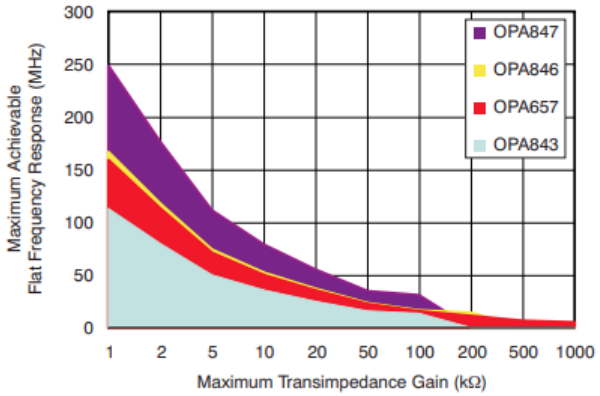
$$R_f = \sqrt{\frac{e_{n(FET)}^2 - e_{n(BJT)}^2}{{i_n}^2_{(BJT)} - {i_n}^2_{(FET)} + \frac{2\pi f_{enb}}{3}(C_{in_{(BJT)}} e_{n(BJT)}^2 - C_{in_{(FET)}} e_{n(FET)}^2)}}$$

Compare OPA657 (FET) and OPA846 (BJT)

Performance upgrade to OPA818 [MAY 2019]

Name	GBW	e_n	i_n	C_{in}
OPA846 (http://focus.ti.com/docs/prod/folders/print/opa846.html) (BJT)	1750 MHz	1.2 nV/$\sqrt{\text{Hz}}$	2.8 pA/$\sqrt{\text{Hz}}$	150pF + 3.8pF = 153.8pF
OPA657 (http://focus.ti.com/docs/prod/folders/print/opa657.html) (FET)	1600 MHz	4.8 nV/$\sqrt{\text{Hz}}$	1.3 fA/$\sqrt{\text{Hz}}$	150pF + 5.2pF = 155.2pF
OPA818 (https://www.ti.com/product/OPA818?qgpn=opa818) (FET)	2700 MHz	2.2 nV/$\sqrt{\text{Hz}}$	3 fA/$\sqrt{\text{Hz}}$	150pF + 1.9pF = 151.9pF

TI: Continued

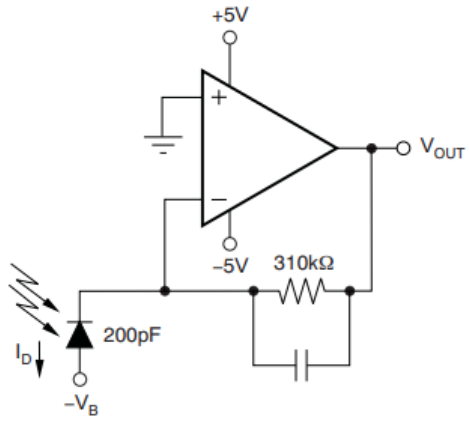


"Using Equation 13 and comparing two amplifiers with very similar GBP—the OPA846 and the OPA657—we can then **determine an appropriate transimpedance gain threshold**. Below this threshold, it is preferable to use bipolar technology to achieve lower noise, while above the threshold it is better to use FET technology ...

the total input-referred noise generated by the OPA657 FET amplifier will be lower than that of the OPA846 bipolar amplifier for any transimpedance gain greater than **2kΩ**.

FET-input operational amplifiers, such as the OPA657, are capable of higher transimpedance, where decompensated bipolar operational amplifiers are capable of much higher bandwidth but are limited in gain range."

TI Continued: DC-Parameters Consideration



"The input bias current of the OPA846, 19μA, generates an output offset voltage with the feedback resistor of 310kΩ of **5.89V**. Because the OPA846 is operating on a ±5V power supply, this offset voltage sends the output into **saturation**. Adding a 310kΩ resistor on the noninverting input allows bias current cancellation but now puts 5.89V common-mode voltage on the input, exceeding the common-mode input range of the OPA846."

Noise Threshold

Parameter	Specification
rms noise figure	$\leq 0.5\ dB$
Minimum photodiode current (i_d)	$2\ \mu A$

$$F = 1 + i_{n,in}^2 / i_{ns}^2$$

$$i_{ns} = \sqrt{2qi_d} = 0.8\ \text{pA}/\sqrt{Hz}$$

$$
\begin{aligned}
0.5 &= 10\log_{10}\left(1 + i_{n,in}^2/i_{ns}^2\right) \\
1.122 &= 1 + i_{n,in}^2/i_{ns}^2 \\
1.122 &= \frac{i_{ns}^2 + i_{n,in}^2}{i_{ns}^2} = \frac{i_{n,tot}^2}{i_{ns}^2} \\
i_{n,tot} &= \sqrt{1.122 \cdot i_{ns}^2} \\
i_{n,tot} &= 1.06 \cdot i_{ns} \\
i_{n,tot} &= 0.85pA/\sqrt{\text{Hz}}
\end{aligned}
$$

Noise Threshold Continued

$$
\begin{aligned}
\frac{v_o}{i_d} &= R_f \frac{\omega_0^2}{s^2 + 2\zeta\omega_0 + \omega_0^2} \\
\frac{e_{na,in}}{e_{na}} &= \left(1 + \frac{Z_f}{Z_{in}}\right) = \frac{1 + s(C_{in} + C_f)R_f}{1 + sC_f R_f}
\end{aligned}
$$

Assume $e_{n,out}$ constant

$$
\begin{aligned}
i_{n,tot} &= 0.85pA \\
\frac{e_{n,out}}{R_f} &\leq 0.85pA \\
e_{n,out} &= \frac{v_o}{i_{n,tot}} i_{n,tot}\Big|_{R_f = 1000K} = 847nV/\sqrt{\text{Hz}} \\
v_{n,out(rms)} &= 847nV/\sqrt{\text{Hz}} \cdot \sqrt{1\ \text{MHz}} = 847uV
\end{aligned}
$$

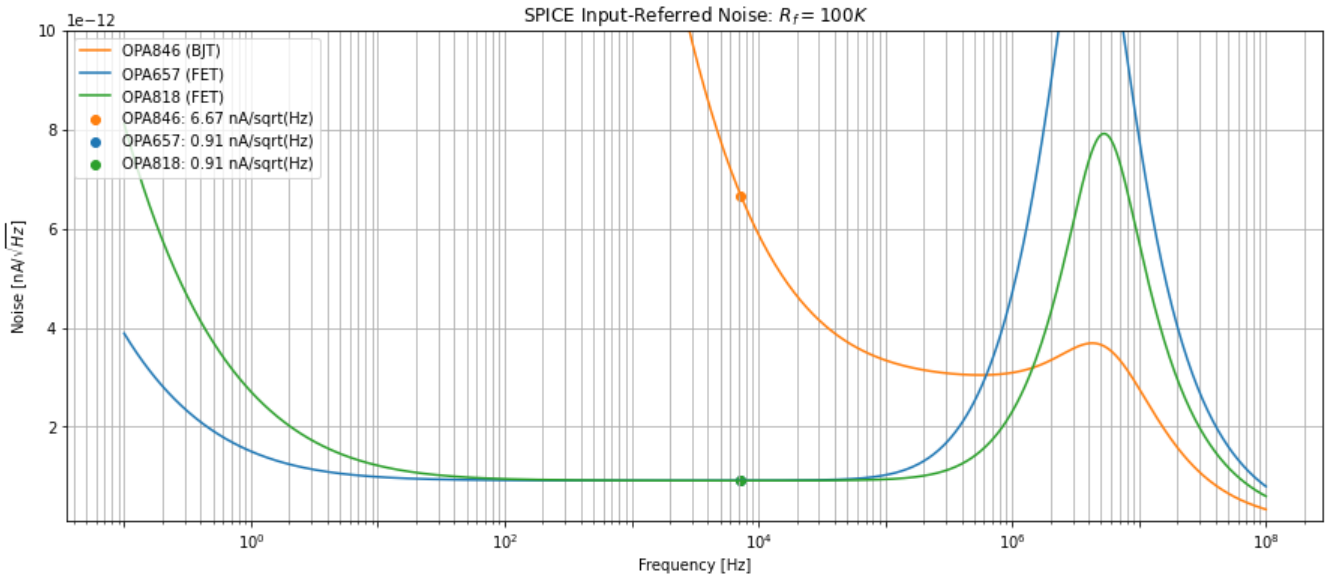
In [4]:

```
filepath1 = 'data/OPA657.txt'
filepath2 = 'data/OPA846.txt'
filepath3 = 'data/OPA818A.txt'
df1 = pd.read_csv(filepath1)
df2 = pd.read_csv(filepath2)
df3 = pd.read_csv(filepath3)
freq = df1['frequency']
onoise1 = df1['V(onoise)']
inoise1 = df1['V(r1)']
onoise2 = df2['V(onoise)']
inoise2 = df2['V(r1)']
onoise3 = df3['V(onoise)']
inoise3 = df3['V(r1)']
```

Compare Technology Input-Referred Noise

In [5]:

```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise3/inoise3)**2))
label1 = f'OPA657: {round(onoise1[x1]/(100*1e3)*1e12,2)} nA/sqrt(Hz)'
label2 = f'OPA846: {round(onoise2[x1]/(100*1e3)*1e12,2)} nA/sqrt(Hz)'
label3 = f'OPA818: {round(onoise3[x1]/(100*1e3)*1e12,2)} nA/sqrt(Hz)'
ax.semilogx(freq, onoise2/(100*1e3),label='OPA846 (BJT)',color='tab:orange')
ax.semilogx(freq, onoise1/(100*1e3),label='OPA657 (FET)',color='tab:blue')
ax.semilogx(freq, onoise3/(100*1e3),label='OPA818 (FET)',color='tab:green')
ax.scatter(freq[x1],onoise2[x1]/(100*1e3),label=label2,color='tab:orange')
ax.scatter(freq[x1],onoise1[x1]/(100*1e3),label=label1,color='tab:blue')
ax.scatter(freq[x1],onoise3[x1]/(100*1e3),label=label3,color='tab:green')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise [nA/$\sqrt{Hz}$]')
ax.set_title(r'SPICE Input-Referred Noise: $R_f = 100K$')
ax.ticklabel_format(style='sci', axis='y', scilimits=(-12,-12))
ax.set_ylim(.1e-12,10e-12)
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```

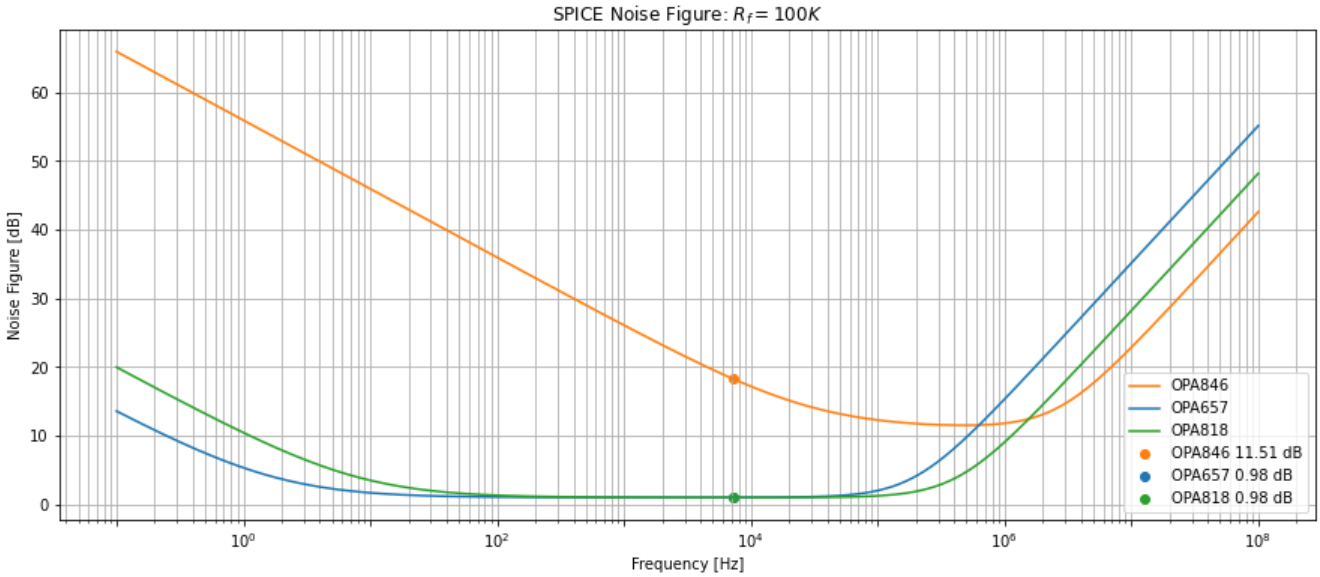


Compare at 100K due to BJT saturation limits.

Compare Technology Noise Figure

In [6]:

```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise3/inoise3)**2))
label1 = f'OPA657 {round(min(10*np.log10((onoise1/inoise1)**2)),2)} dB'
label2 = f'OPA846 {round(min(10*np.log10((onoise2/inoise2)**2)),2)} dB'
label3 = f'OPA818 {round(min(10*np.log10((onoise3/inoise3)**2)),2)} dB'
ax.semilogx(freq, 10*np.log10((onoise2/inoise2)**2),label='OPA846',color='tab:orange')
ax.semilogx(freq, 10*np.log10((onoise1/inoise1)**2),label='OPA657',color='tab:blue')
ax.semilogx(freq, 10*np.log10((onoise3/inoise3)**2),label='OPA818',color='tab:green')
ax.scatter(freq[x1],10*np.log10((onoise2[x1]/inoise2[x1])**2),label=label2,color='tab:orange')
ax.scatter(freq[x1],10*np.log10((onoise1[x1]/inoise1[x1])**2),label=label1,color='tab:blue')
ax.scatter(freq[x1],10*np.log10((onoise3[x1]/inoise3[x1])**2),label=label3,color='tab:green')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise Figure [dB]')
ax.set_title(f'SPICE Noise Figure: $R_f = 100K$')
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



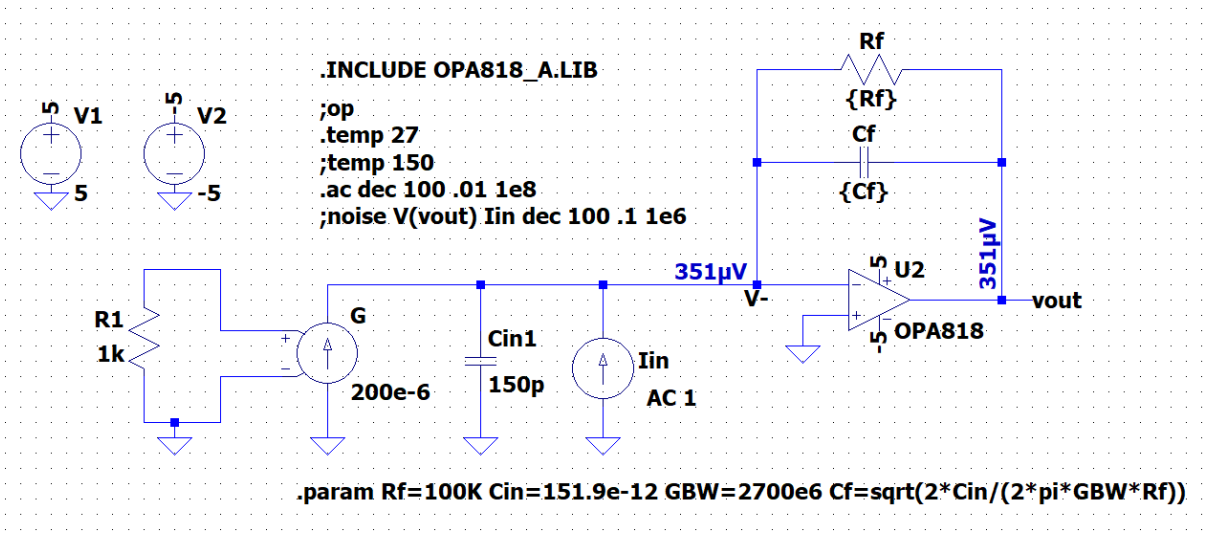
TIA Gain

Paramete	Specification
Transimpedance gain (full signal path)	$1\ V/\mu A$

Desired gain is over $2K\Omega$ threshold, use FET: OPA818 (https://www.ti.com/product/OPA818).

Compare noise at different gains such that R_f = [10K, 100K, 1000K]

$$\frac{v_o}{i_d} = R_f \frac{\omega_0^2}{s^2 + 2\zeta\omega_0 + \omega_0^2}$$



Noise Densities

$$i_{n,in} = \sqrt{{i_{ns}}^2 + {i_{na}}^2 + \frac{4kT}{R_f} + \left(\frac{e_n}{R_f}\right)^2} \leq 0.85pA$$

Photodiode Current Noise Density: $i_{ns} = \sqrt{2qi_d} = 0.8\ \text{pA}/\sqrt{Hz}$

Op Amp Current Noise: $i_n = 3\ \text{fA}/\sqrt{Hz}$

Input-Referred Thermal Noise Density: $\sqrt{\frac{4kT}{R_f}}$

100K	1000K
0.41 pA/$\sqrt{\text{Hz}}$	0.13 pA/$\sqrt{\text{Hz}}$

Input-Referred Op Amp Noise: $\frac{e_n}{R_f}$ and $e_n = 2.2$ nV

100K	1000K
0.022 pA/$\sqrt{\text{Hz}}$	0.002 pA/$\sqrt{\text{Hz}}$

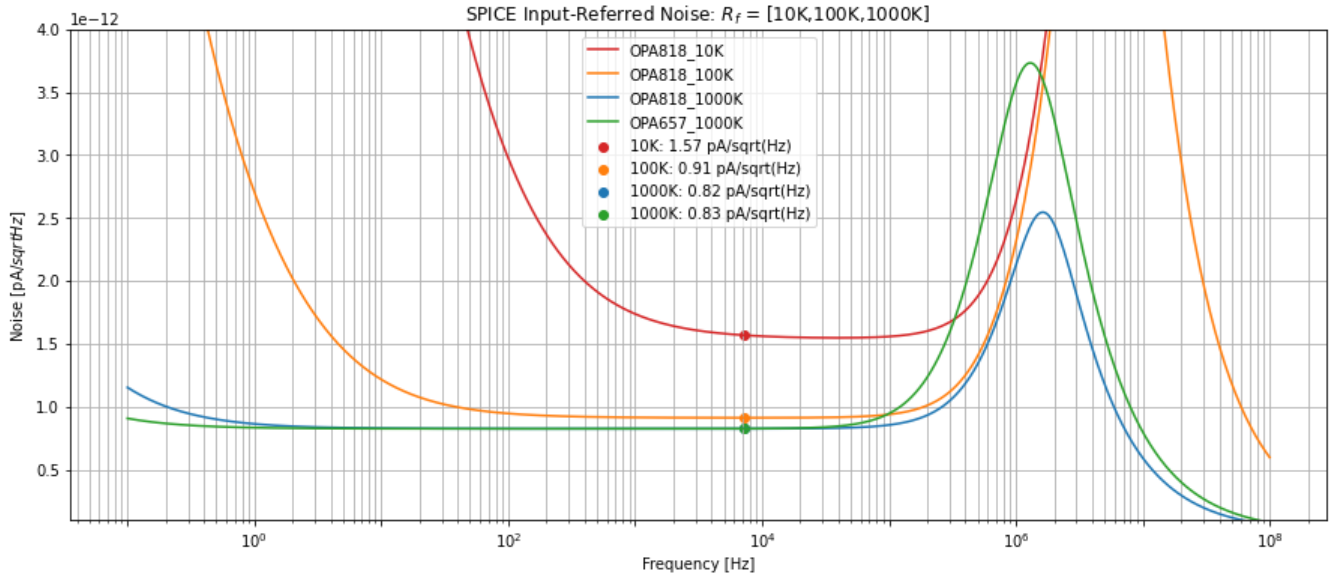
Higher gain improves noise performance so choose $R_f = 1000K\Omega$.

In [7]:
```
filepath1 = 'data/OPA818A_Rf10K.txt'
filepath2 = 'data/OPA818A.txt'
filepath3 = 'data/OPA818A_Rf1000K.txt'
filepath4 = 'data/OPA657_1000K.txt'
df1 = pd.read_csv(filepath1)
df2 = pd.read_csv(filepath2)
df3 = pd.read_csv(filepath3)
df4 = pd.read_csv(filepath4)
freq = df1['frequency']
onoise1 = df1['V(onoise)']
inoise1 = df1['V(r1)']
onoise2 = df2['V(onoise)']
inoise2 = df2['V(r1)']
onoise3 = df3['V(onoise)']
inoise3 = df3['V(r1)']
onoise4 = df4['V(onoise)']
inoise4 = df4['V(r1)']
```

Compare Rf Input-Referred Noise

In [8]:

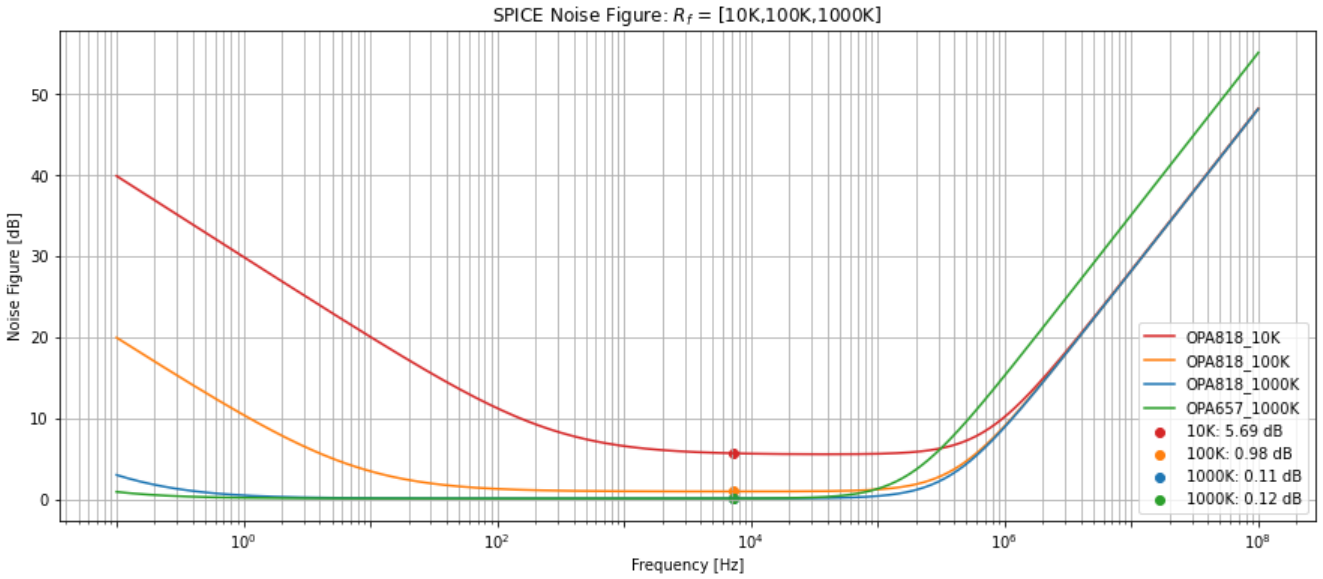
```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise2/inoise2)**2))
label1 = f'10K: {round(onoise1[x1]/(10*1e3)*1e12,2)} pA/sqrt(Hz)'
label2 = f'100K: {round(onoise2[x1]/(100*1e3)*1e12,2)} pA/sqrt(Hz)'
label3 = f'1000K: {round(onoise3[x1]/(1000*1e3)*1e12,2)} pA/sqrt(Hz)'
label4 = f'1000K: {round(onoise4[x1]/(1000*1e3)*1e12,2)} pA/sqrt(Hz)'
ax.semilogx(freq, onoise1/(10*1e3),label='OPA818_10K',color='tab:red')
ax.semilogx(freq, onoise2/(100*1e3),label='OPA818_100K',color='tab:orange')
ax.semilogx(freq, onoise3/(1000*1e3),label='OPA818_1000K',color='tab:blue')
ax.semilogx(freq, onoise4/(1000*1e3),label='OPA657_1000K',color='tab:green')
ax.scatter(freq[x1],onoise1[x1]/(10*1e3),label=label1,color='tab:red')
ax.scatter(freq[x1],onoise2[x1]/(100*1e3),label=label2,color='tab:orange')
ax.scatter(freq[x1],onoise3[x1]/(1000*1e3),label=label3,color='tab:blue')
ax.scatter(freq[x1],onoise4[x1]/(1000*1e3),label=label4,color='tab:green')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise [pA/$sqrt{Hz}$]')
ax.set_title(r'SPICE Input-Referred Noise: $R_f$ = [10K,100K,1000K]')
ax.ticklabel_format(style='sci', axis='y', scilimits=(-12,-12))
ax.set_ylim(1e-13,4e-12)
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



Compare Rf Noise Figure

In [9]:

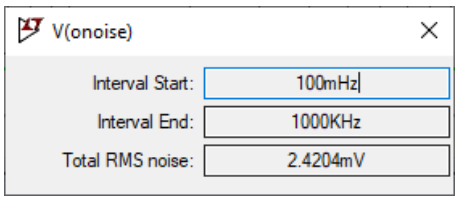
```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise2/inoise2)**2))
label1 = f'10K: {round(10*np.log10((onoise1[x1]/inoise1[x1])**2),2)} dB'
label2 = f'100K: {round(10*np.log10((onoise2[x1]/inoise2[x1])**2),2)} dB'
label3 = f'1000K: {round(10*np.log10((onoise3[x1]/inoise3[x1])**2),2)} dB'
label4 = f'1000K: {round(10*np.log10((onoise4[x1]/inoise4[x1])**2),2)} dB'
ax.semilogx(freq, 10*np.log10((onoise1/inoise1)**2),label='OPA818_10K',color='tab:red')
ax.semilogx(freq, 10*np.log10((onoise2/inoise2)**2),label='OPA818_100K',color='tab:orange')
ax.semilogx(freq, 10*np.log10((onoise3/inoise3)**2),label='OPA818_1000K',color='tab:blue')
ax.semilogx(freq, 10*np.log10((onoise4/inoise4)**2),label='OPA657_1000K',color='tab:green')
ax.scatter(freq[x1],10*np.log10((onoise1[x1]/inoise1[x1])**2),label=label1,color='tab:red')
ax.scatter(freq[x1],10*np.log10((onoise2[x1]/inoise2[x1])**2),label=label2,color='tab:orange')
ax.scatter(freq[x1],10*np.log10((onoise3[x1]/inoise3[x1])**2),label=label3,color='tab:blue')
ax.scatter(freq[x1],10*np.log10((onoise4[x1]/inoise4[x1])**2),label=label4,color='tab:green')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise Figure [dB]')
ax.set_title(f'SPICE Noise Figure: $R_f$ = [10K,100K,1000K]')
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



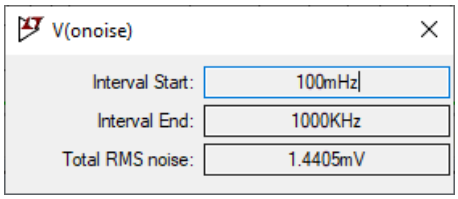
RMS Rf=1000K

Parameter	Specification
Maximum input current ($i_{n,tot}$)	$\leq 0.85\ pA$
rms noise	$\leq 847\ \mu V$

OPA657



OPA818



Not quite there, need to address peaking at 1 MHz.

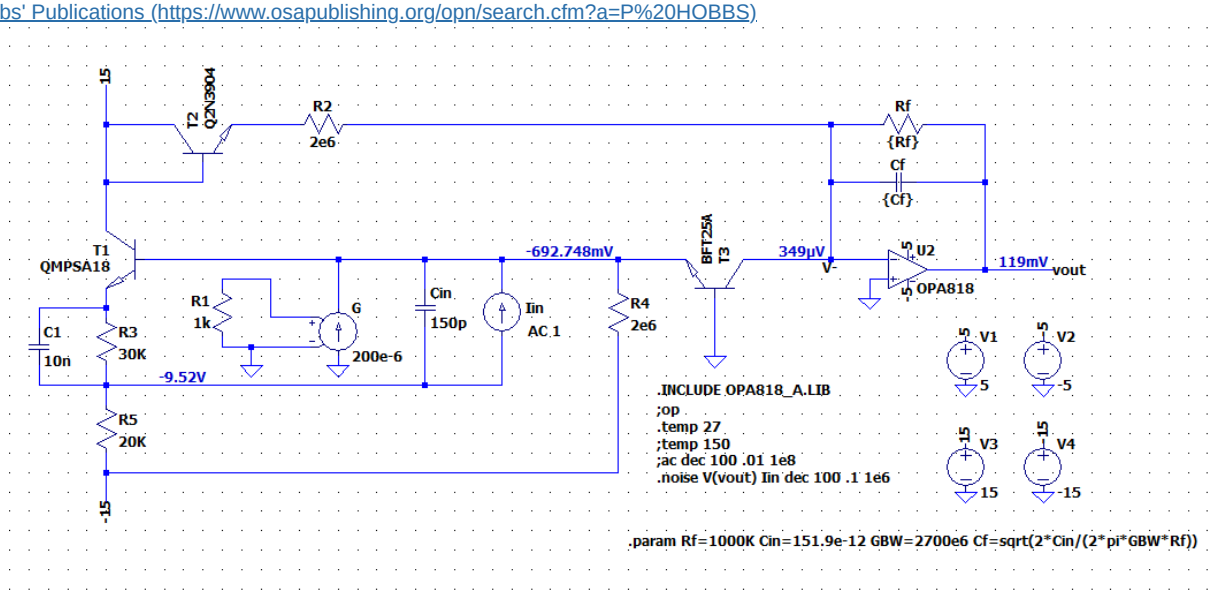
$$\frac{e_{na,in}}{e_{na}} = \left(1 + \frac{Z_f}{Z_{in}}\right) = \frac{1 + s(C_{in} + C_f)R_f}{1 + sC_f R_f}$$

Bootstrapped Cascode TIA

[Photodiode Front Ends: The Real Story (https://www.electrooptical.net/static/oldsite/www/frontends/frontends.pdf)]

[Getting Photodetection Right by Phil Hobbs (https://electrooptical.net/static/oldsite/talks/GettingPDRight11.pdf)]

[Philip Hobbs' Publications (https://www.osapublishing.org/opn/search.cfm?a=P%20HOBBS)]

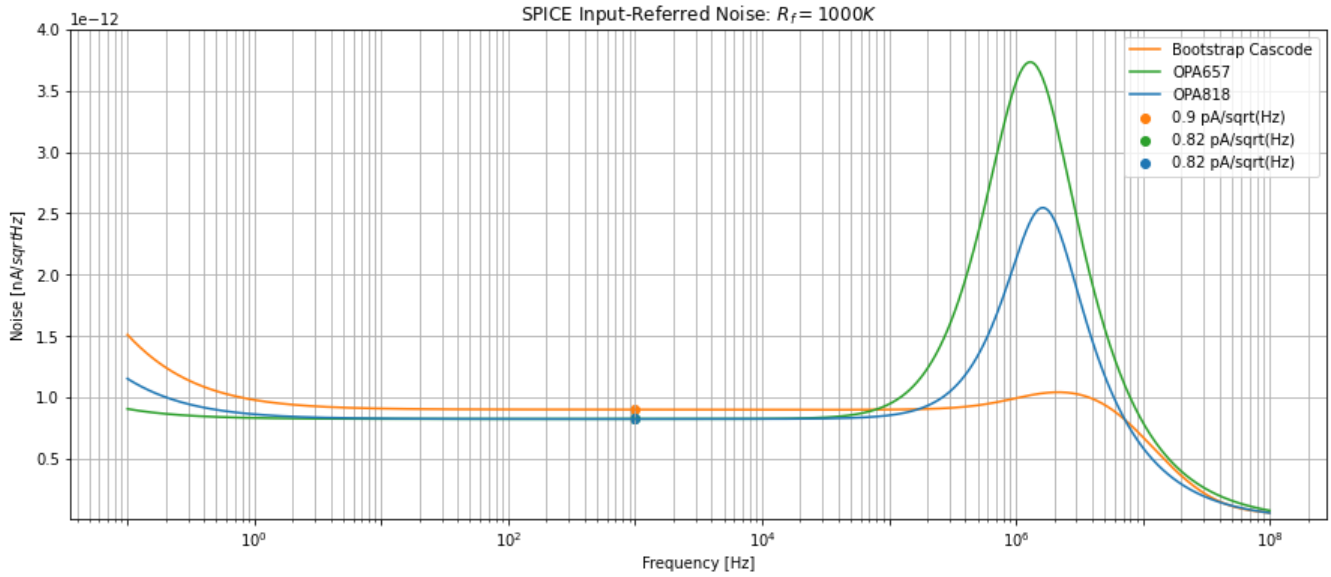


In [10]:
```
filepath1 = 'data/OPA657_1000K.txt'
filepath2 = 'data/OPA818A_Rf1000K.txt'
filepath3 = 'data/OPA818A_bootstrap_Rf1000K.txt'
df1 = pd.read_csv(filepath1)
df2 = pd.read_csv(filepath2)
df3 = pd.read_csv(filepath3)
freq = df1['frequency']
onoise1 = df1['V(onoise)']
inoise1 = df1['V(r1)']
onoise2 = df2['V(onoise)']
inoise2 = df2['V(r1)']
onoise3 = df3['V(onoise)']
inoise3 = df3['V(r1)']
freq3 = df3['frequency']
```

Bootstrap Cascode Input-Referred Noise

In [11]:

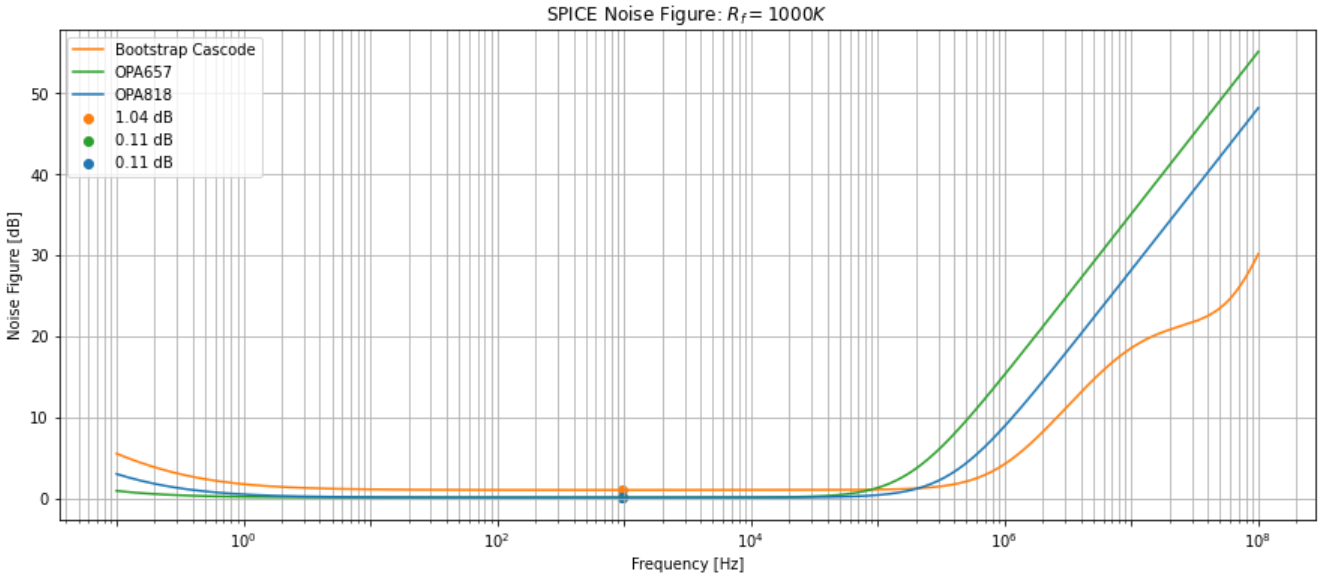
```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise2/inoise2)**2))
label1 = f'{round(onoise1[x1]/(1000*1e3)*1e12,2)} pA/sqrt(Hz)'
label2 = f'{round(onoise2[x1]/(1000*1e3)*1e12,2)} pA/sqrt(Hz)'
label3 = f'{round(onoise3[x1]/(1000*1e3)*1e12,2)} pA/sqrt(Hz)'
ax.semilogx(freq, onoise3/(1000*1e3),label='Bootstrap Cascode',color='tab:orange')
ax.semilogx(freq, onoise1/(1000*1e3),label='OPA657',color='tab:green')
ax.semilogx(freq, onoise2/(1000*1e3),label='OPA818',color='tab:blue')
ax.scatter(freq[x1],onoise3[x1]/(1000*1e3),label=label3,color='tab:orange')
ax.scatter(freq[x1],onoise1[x1]/(1000*1e3),label=label1,color='tab:green')
ax.scatter(freq[x1],onoise2[x1]/(1000*1e3),label=label2,color='tab:blue')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise [nA/$sqrt{Hz}$]')
ax.set_title(r'SPICE Input-Referred Noise: $R_f = 1000K$')
ax.ticklabel_format(style='sci', axis='y', scilimits=(-12,-12))
ax.set_ylim(.1e-13,4e-12)
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



Bootstrap Cascode Noise Figure

In [12]:

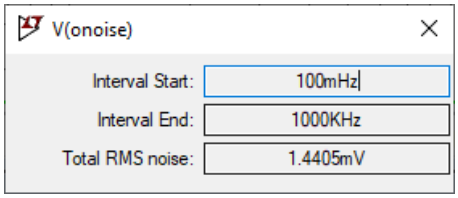
```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.argmin(10*np.log10((onoise2/inoise2)**2))
label1 = f'{round(10*np.log10((onoise1[x1]/inoise1[x1])**2),2)} dB'
label2 = f'{round(10*np.log10((onoise2[x1]/inoise2[x1])**2),2)} dB'
label3 = f'{round(10*np.log10((onoise3[x1]/inoise3[x1])**2),2)} dB'
ax.semilogx(freq, 10*np.log10((onoise3/inoise3)**2),label='Bootstrap Cascode',color='tab:orange')
ax.semilogx(freq, 10*np.log10((onoise1/inoise1)**2),label='OPA657',color='tab:green')
ax.semilogx(freq, 10*np.log10((onoise2/inoise2)**2),label='OPA818',color='tab:blue')
ax.scatter(freq[x1],10*np.log10((onoise3[x1]/inoise3[x1])**2),label=label3,color='tab:orange')
ax.scatter(freq[x1],10*np.log10((onoise1[x1]/inoise1[x1])**2),label=label1,color='tab:green')
ax.scatter(freq[x1],10*np.log10((onoise2[x1]/inoise2[x1])**2),label=label2,color='tab:blue')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel(r'Noise Figure [dB]')
ax.set_title(f'SPICE Noise Figure: $R_f = 1000K$')
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



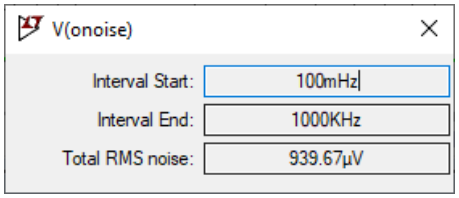
RMS Bootstrap Cascode (Rf = 1000K)

Parameter	Specification
Maximum input current ($i_{n,tot}$)	$\leq 0.85\ pA$
rms noise	$\leq 847\ \mu V$

OPA818



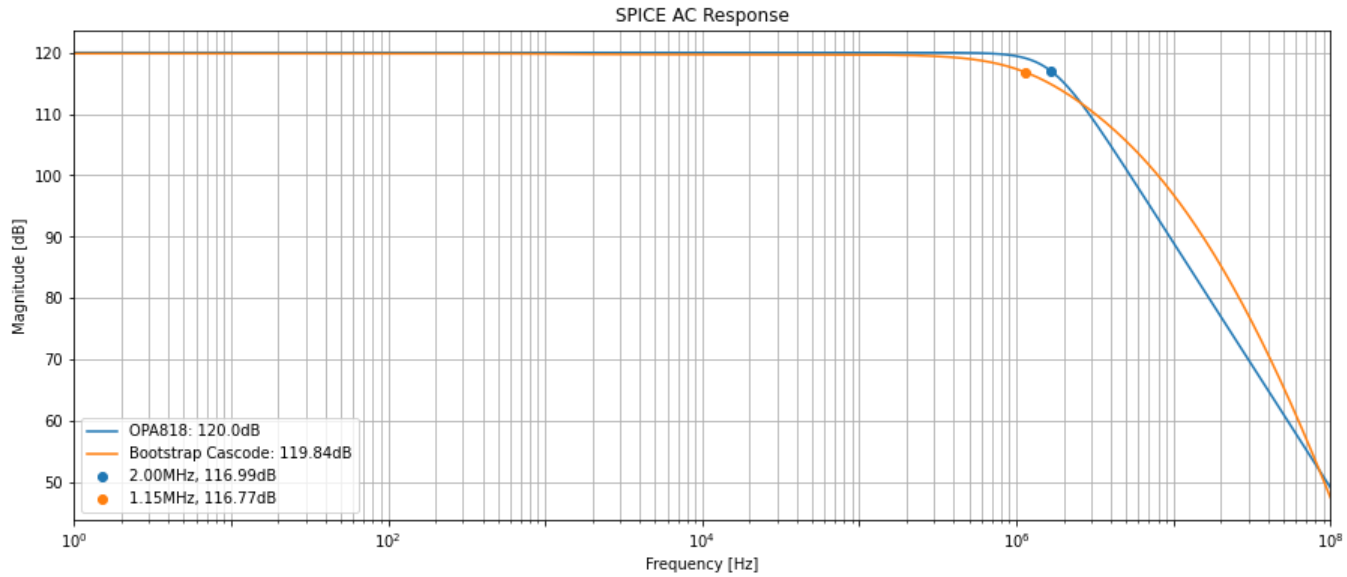
Bootstrap Cascode



In [13]:
```
filepath1 = 'data/OPA818A_Rf1000K_ACanalysis.txt'
filepath2 = 'data/OPA818A_bootstrap_Rf1000K_ACanalysis.txt'
df1 = read_ltspice(filepath1,'ac')
df2 = read_ltspice(filepath2,'ac')
freq1 = df1['Freq.']
freq2 = df2['Freq.']
mag1 = df1['Mag_V(vout)']
mag2 = df2['Mag_V(vout)']
```

AC Response

In [14]:
```
fig, ax = plt.subplots(1,figsize=(15,6))
x1 = np.where(mag1<=mag1[0]-3)[0][0]
label1 = "{:.2f}MHz, {:.2f}dB".format(round(freq1[x1]/1e6), mag1[x1])
x2 = np.where(mag2<=mag2[0]-3)[0][0]
label2 = "{:.2f}MHz, {:.2f}dB".format(freq2[x2]/1e6, mag2[x2])
ax.semilogx(freq1, mag1, color='tab:blue',label=f'OPA818: {round(max(mag1),2)}dB')
ax.semilogx(freq2, mag2, color='tab:orange',label=f'Bootstrap Cascode: {round(max(mag2),2)}dB')
ax.scatter(freq1[x1],mag1[x1],label=label1,color='tab:blue')
ax.scatter(freq2[x2],mag2[x2],label=label2,color='tab:orange')
ax.grid(True,which='both')
ax.set_xlabel('Frequency [Hz]')
ax.set_ylabel('Magnitude [dB]')
ax.set_title(f'SPICE AC Response')
ax.set_xlim(1e0,1e8)
ax.xaxis.set_major_locator(LogLocator(numticks=15)) #(1)
ax.xaxis.set_minor_locator(LogLocator(numticks=15,subs=np.arange(2,10))) #(2)
for label in ax.xaxis.get_ticklabels()[::2]:
    label.set_visible(False) #(3)
ax.legend()
plt.show();
```



Price vs Power

Name	Price ($)	Power (mW)
OPA657 (http://focus.ti.com/docs/prod/folders/print/opa657.html)	5.14	TBD
OPA818 (https://www.ti.com/product/OPA818?qgpn=opa818)	3.10	TBD

*Older generation OPA657 has greater price than OPA818 due to supply shortage most likely.

Thank you!

More resources:

https://escholarship.org/content/qt0pt906pn/qt0pt906pn_noSplash_2cb4a2cab826f5430baba523ff3690d2.pdf (https://escholarship.org/content/qt0pt906pn/qt0pt906pn_noSplash_2cb4a2cab826f5430baba523ff3690d2.pdf)

http://www.janascard.cz/PDF/Ultralownoisehighbandwidthtransimpedanceamplifiers.pdf (http://www.janascard.cz/PDF/Ultralownoisehighbandwidthtransimpedanceamplifiers.pdf)

https://nvlpubs.nist.gov/nistpubs/jres/092/jresv92n6p383_a1b.pdf (https://nvlpubs.nist.gov/nistpubs/jres/092/jresv92n6p383_a1b.pdf)

In [ ]:
```
1
```