Project 11

Design of a feedback amplifier based on BJT and FET plus LC matching circuits

This project is focused on the design of amplifiers consisting of an FET and BJT, both of which have feedback circuits consisting of LC elements.

Design a wideband feedback amplifier based on BJT and FET. Try to reach a flat gain higher than 10 dB and reflections on both ports better than −10 dB in the widest possible frequency range. If it is possible to reach the requirements only up to approx. 500 MHz, choose another transistor. You can find your transistor type in the appended table.

As a design protocol note, please include:

- the chosen transistors,
- final schematics,
- absolute values of S_{11}, S_{21} and S_{22}.

Transistors can be found in LIBRARIES − AWR WEB SITE − PARTS OBSOLETED – AGILENT – DATA − BJT DATA FILES − FET/BJT DATA FILES.

Task No.	BJT filename	FET filename
1	T005358A	F101002A
2	T005358B	F101004B
3	T415115A	F101704B
4	T415118C	F101702A
5	T016008A	F101352A
6	T414118A	F102362A
7	T414118B	F107352A
8	T414358A	F107354B
9	T414358B	F107362A
10	T414708A	F107364B
11	T414708B	F130363A
12	T016008A	F131353A
13	T016008B	F131363A
14	T414858A	F131703A
15	T414858B	F132843A
16	T016358A	F132844B
17	T016358B	F133363A
18	T415118A	F134843A
19	T005728B	F134844B
20	T005728A	F137863B

Project solution procedure

Amplifier with a bipolar transistor

The recommended design process is described in the following example:

- The AT41411 (Agilent) transistor operates in the 8V/10 mA biasing point. Transistor S-parameters can be found in the T414118A.s2p file within LIBRARIES − AWR WEB SITE − PARTS OBSOLETED – AGILENT – DATA − BJT DATA FILES library.
- Find the available frequency band of your transistor. It can be viewed using PROJECT – DATA FILES by double-clicking the S-parameter filename (the data file can also include noise parameters).
- Set the frequency range of your AWR project from 0.1 to 4 GHz (as defined by the transistor's S-parameters).
- Create a new schematic called Transistor, drag in the transistor used, and connect both ports.

The feedback amplifiers use the feedback circuits for equalization of gain in wider frequency bands and for the majority of input and output impedance matching. Create a new rectangular graph called Transistor Parameters and show the transistor magnitudes of S_{11}, S_{21} and S_{22}, see Fig. 1. Without the feedback circuit, the gain decreases steeply, and reflections at both input and output ports are around −7dB.

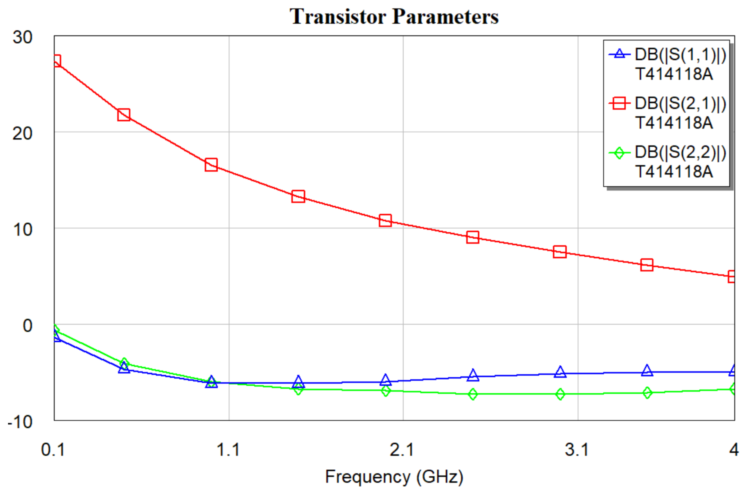

Fig. 1 S-parameters of the transistor T414118A.

In the case of BJT, a combination of serial and parallel dominantly resistive feedback is commonly used, as can be seen in the schematic in Fig. 2. The serial feedback circuit, generally, increases input impedance of the whole circuit and, in the case of the transistor amplifier, is placed between the source (emitter) and the ground. The parallel feedback circuit is connected between the gate (base) and drain (collector) and decreases the input impedance of the whole circuit. The resistive feedback reduces gain frequency dependence, and realizes a significant part of input and output impedance matching. To improve the frequency parameters of the concerned feedback, small serial inductance is added to the parallel feedback and small parallel capacitance is added to the serial feedback.

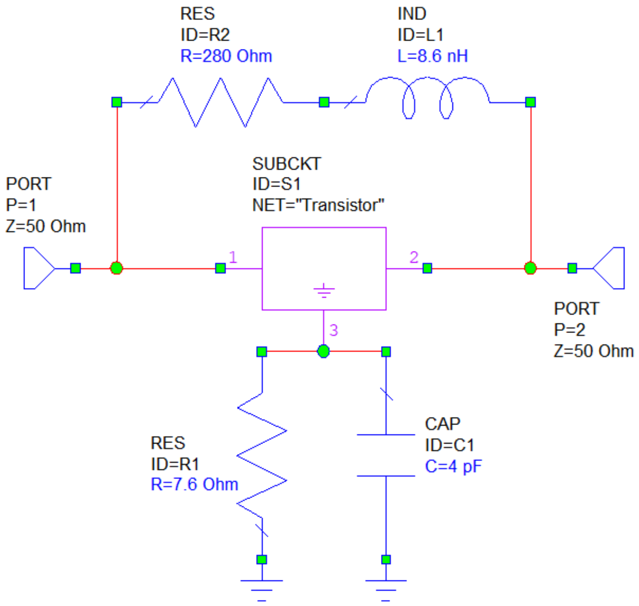

Fig. 2 Schematic of feedback circuit around the FET transistor.

- Create a new schematic called Amplifier and add the Transistor schematic as a subcircuit.
- To include the serial feedback, the transistor must be treated as a tree-port. This can be achieved by:
    - Right-clicking on the transistor element in the concerned schematic.
    - Open PROPERTIES− GROUND.
    - Choose the EXPLICIT GROUND NODE option.
- Add the above-described feedback circuits to the schematic. Set the initial component values to: R1 = 5 Ω, R2 = 300 Ω, L1 = 2 nH and C1 = 2 pF.
- Create a new rectangular graph with feedback circuit S-parameters, and, using Tune Tool, change the values of R1, R2, L1 and C1 to achieve:
    - a flat frequency gain around 10 – 12 dB,
    - the best possible input and output matching,
    - both goals in the widest possible frequency range.
- It is possible to design this type of amplifier using an optimization procedure. This requires you to define two optimization goals: 1.) impedance matching and 2.) a gain as flat as possible. Nevertheless, using Tune Tool is definitely more illustrative and, additionally, you get a better feeling for a component's values influence.
- Results after the optimization may resemble those presented in Fig. 3.

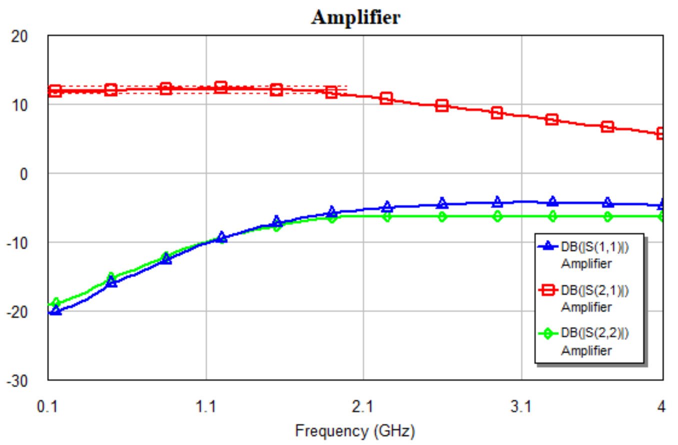

Fig. 3 S-parameters of the optimized amplifier with feedback circuits.

- Using R1 = 7.6 Ω, R2 = 280 Ω, L1 = 8.6 nH and C1 = 4 pF, the gain shows a constant value of approx. 12 dB up to 2 GHz. Nevertheless, reflections are better than −10 dB until the frequency reaches approx. 1.1 GHz.
- The gain of amplifier is acceptable, but the input and output port reflections are still not ideal. To improve this, it is possible to utilize simple additional matching circuits.

The feedback amplifiers are, generally, quite wide-band and capable of operating from very low frequencies, often from DC, to high GHz. To ensure that the additional matching circuits do not disturb these properties, only very simple LC circuits with serial inductance and parallel capacitance are recommended to be utilized as shown in Fig. 4.

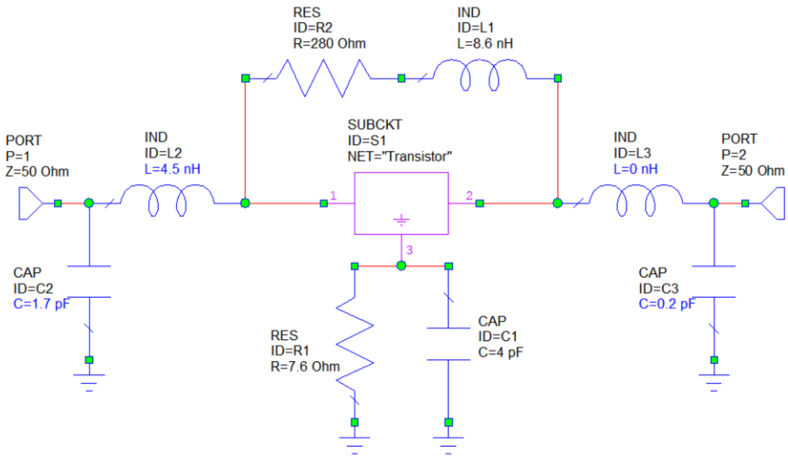

Fig. 4 Feedback amplifier with matching circuits.

- Add to the Amplifier schematic the above-described LC matching circuits.
- Set the initial values to L2 = 1 nH, C2 = 1 pF, L3 = 1 nH and C3 = 1 pF.
- Using Tune Tool, change the values of the components to reach reflections less than −10 dB in the widest possible frequency band. Because of a high number of potential tuning values, it may be beneficial to use the optimization procedure. It can be seen in Fig. 4, that the value of L3 is zero, hence it can be omitted from the final design.
- An example of amplifier parameters reached is shown in Fig. 5.
- The amplifier shows very good parameters up to 1.7 GHz where the input port reflection is less than −10dB.

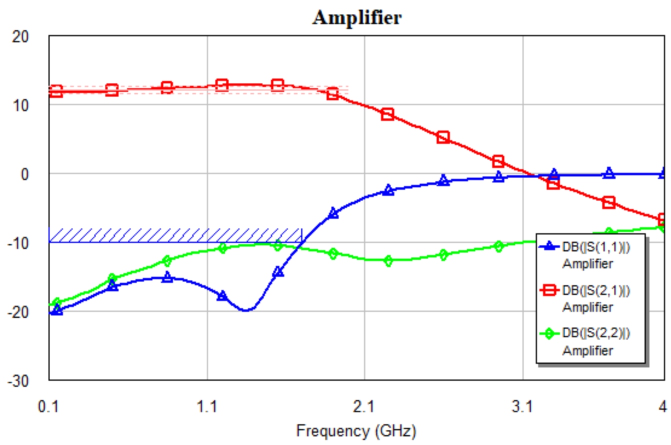

Fig. 5 S-parameters of the amplifier with matching circuits.

Amplifier with a unipolar transistor

FET type transistors show commonly high input impedance which is why it is useless to use a serial feedback (R1, C1) which increases the input impedance even more. In this case, only the parallel feedback and simple LC matching circuits are used. In relation to BJTs, FETs usually show lower $|S_{21}|$ with slower decreasing frequency dependences. This is why FET-based feedback amplifiers can be designed for operations up to significantly higher frequencies than BJT.

- Fig. 6 provides an example of an amplifier with an FET transistor F102352A (2 V/25 mA) with only a resistive parallel feedback circuit (L1 = 0).
- The resulting amplifier works well up to 5 GHz, as shown in Fig. 7.
- Utilize Tune Tool or Optimizer to set a component's values to reach the design criteria.

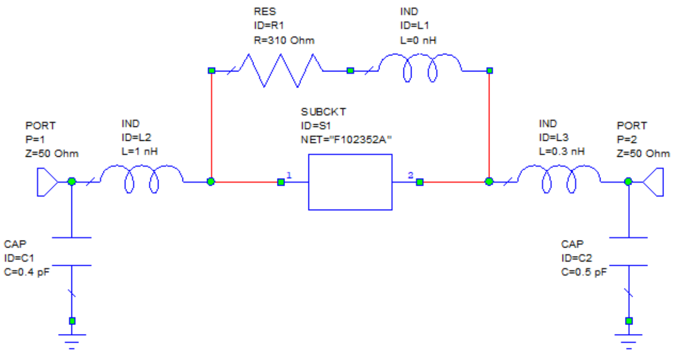

Fig. 6 Schematic of the amplifier with FET and a parallel feedback circuit.

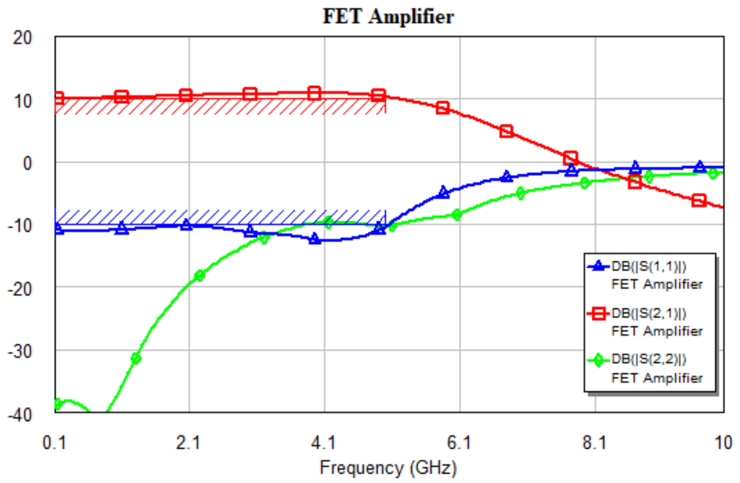

Fig. 7 S-parameters of the amplifier with FET.