CML Microcircuits

COMMUNICATION SEMICONDUCTORS

Evaluation Board Quick Start

EV9980

1   Introduction

Thank you for your interest in the EV9980 Evaluation Board.

This quick start guide will help you get started with your CMX998 evaluation. The respective datasheets and user manuals provide full details on the boards but this "quick start" guide consolidates information from multiple sources to accelerate your testing.

This guide walks the user through the following steps:
- Downloading necessary files
- Connecting the EV9980 and PE0003
- Installing PE0003 USB driver
- Using PE0003 graphical user interface (GUI) to configure CMX998 for closed-loop Cartesian feedback operation at 450MHz.

2   History

Version	Changes	Date
1	Initial release	1 April 2016

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3   Preparation

3.1   Required File Downloads
Please visit the CML website (www.cmlmicro.com) and download the following files:
- CMX998 Datasheet
- EV9980 User Manual
- EV9980 Schematic
- EV9980 Evaluation Software package
- PE0003 Driver
- PE0003 User Manual

The following equipment will be needed for EV9980 evaluation:
- +1.2V power supply (used for EV9980 RF PA enable signal)
- +3.6V power supply (rated for 2A, used for EV9980 RF PA)
- +6V power supply (rated for 1A, used with PE0003 and EV9980)
- Baseband signal generator (used as CMX998 I/Q input signals)
- RF signal generator (used as CMX998 LO = 900MHz @ -10dBm)
- RF load (50Ω, 30dB attenuator, for RF PA output)
- Oscilloscope
- RF spectrum analyzer

3.2   Hardware Connections
Connect EV9980 to PE0003 "C-BUS1" connector, and then perform the following steps.
- RF Connections
  - Connect EV9980 "TX-OUT 400MHz" (J9) to a 50Ω load that provides at least 30dB attenuation. An RF spectrum analyzer can be connected to the load output, if desired.
  - Connect RF signal generator to EV9980 "LO-IN" (J1). This is the LO for CMX998.
- Baseband Connections
  - Connect I channel single-ended signal, biased at 0V, to EV9980 "TXI-"(J5).
  - Connect Q channel single-ended signal, biased at 0V, to EV9980 "TXQ-"(J3).
    - Note that the I and Q signals must be biased (driven) at 0V. Do not leave these signals floating.
- Power Connections (Do not enable power supplies yet.)
  - Connect +6V (rated 1A) to PE0003 J11.
  - Connect +6V (rated 1A) to EV9980 "+V" J10.
    - EV9980 user manual mentions +7.2V, but +6V is acceptable and allows dual use for PE0003.
  - Connect +3.6V (rated 2A) to EV9980 "PA" J10.
    - Ensure current rating is set to allow up to 2A of current.
  - Connect +1.2V to EV9980 "CMX981 CONTROL" J12 pin 15.
  - Ensure the supplies have a common ground connection.

Figure 1:Location of +1.2V RF PA Enable Signal

The completed test setup should look like this:

Figure 2:PE0003 and EV9980

3.3   Installing PE0003
Please perform the following steps:
- Unzip the EV9980 evaluation software package. The "Readme.txt" file indicates which zipped folder contains PE0003 files; unzip that folder, locate the graphical user interface (GUI) "ES9942xx.exe", and create a shortcut to it on your desktop.
- Unzip the PE0003 driver package. You will need this driver later.
- Enable the +6V supply to PE0003 (J11) and EV9980.
    - Typical PE0003/EV9980 current consumption at this point is approximately 110mA.
    - Do not enable any other power supplies at this time.
- Connect PE0003 to PC with USB cable.
    - The PC will ask for a USB driver the first time a PE0003 is connected. When prompted, load the USB driver from the unzipped PE0003 Driver package.
    - Your PC may attempt to use "Windows Update" to find the PE0003 USB driver. Cancel the "Windows Update" search. On your PC click "Start" button, right click on "Computer" and select "Properties". Select "Device Manager". Right click "PE0003 Evaluation Kit" and choose "Update driver software". Choose "Browse my computer" and locate the PE0003 driver you downloaded earlier. Click "Install anyway" if you get a driver warning message.

4   Operation

At this point the PE0003 is powered and installed on your PC, and the EV9980 primary power supply is enabled. Perform the following steps to begin EV9980 operation:

- Enable +3.6V to EV9980 RF PA. No current consumption should be observed.
- Enable RF sig gen to create 900MHz @ -10dBm LO.
- Ensure I/Q baseband signals are biased at 0V.
- Launch EV9980 GUI (+6V current consumption increases to approximately 200mA) and configure in accordance with the following images:
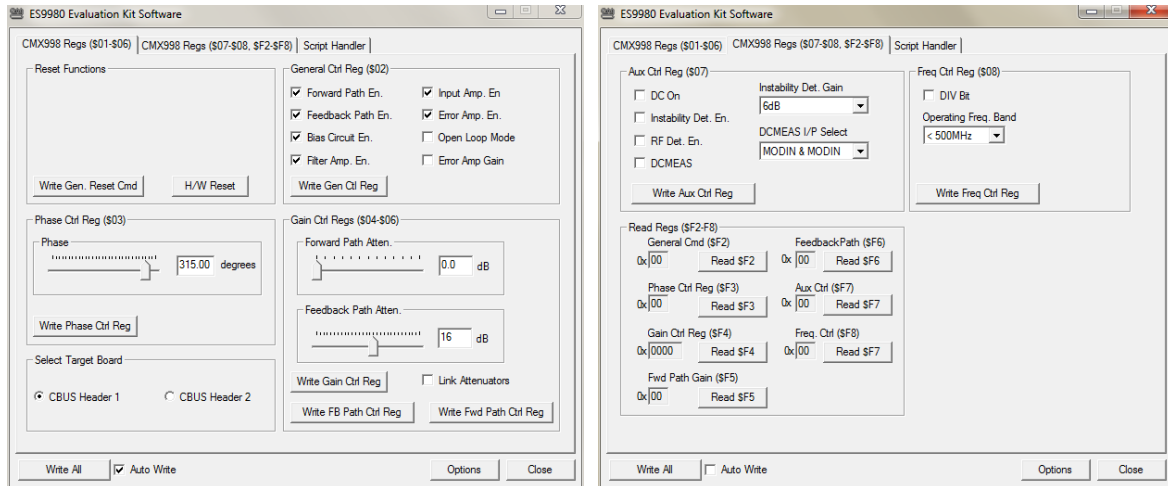

Figure 3: EV9980 GUI Settings

- Click "Write All" to commit all register writes to CMX998. (+6V current consumption should increase to approximately 340mA.)
- Do not apply a modulated signal to I or Q inputs yet (inputs should be driven to 0V dc).
- Enable +1.2V power supply to activate RF PA on EV9980. RF PA current consumption will increase to approximately 400-500mA. RF carrier should be observed at 450MHz (carrier amplitude may vary from that shown here).
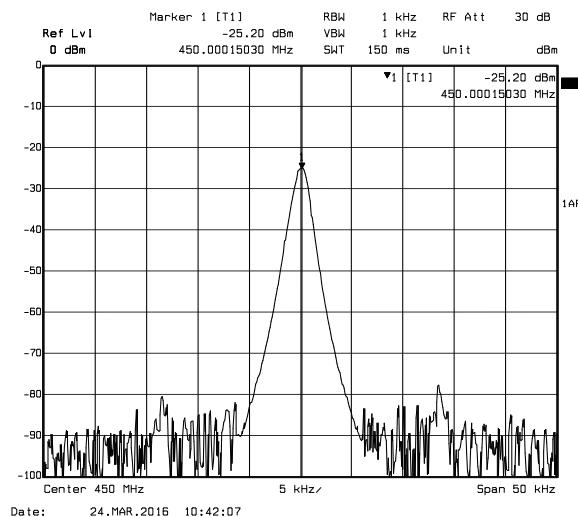

Figure 4:EV9980 RF Output prior to DC Nulling

- Adjust VR1 (Q channel) and VR2 (I channel) pots to achieve minimum carrier amplitude and RF PA current consumption; you may need to adjust VR1 then VR2 then VR1 again, then VR2 again (etc.) to get the best result.
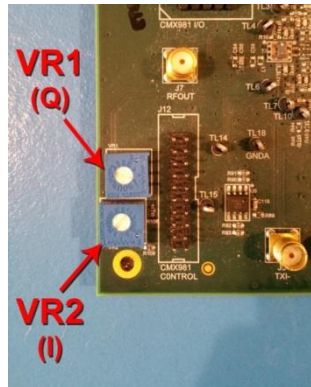

Figure 5:VR1 and VR2 for DC Nulling

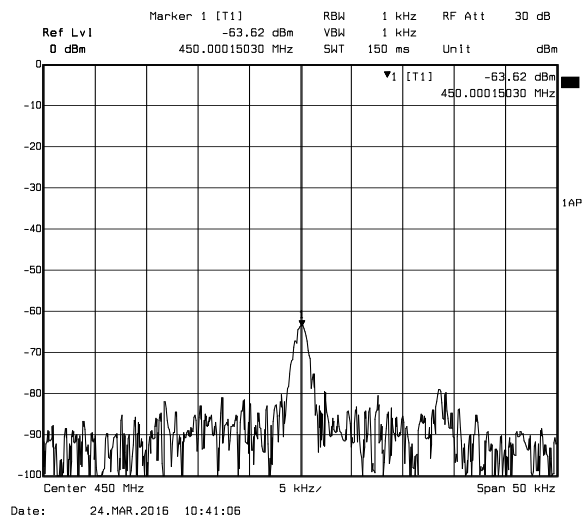- Carrier amplitude should be greatly diminished after nulling.

Figure 6:EV9980 RF Output after DC Nulling

- Apply modulated I/Q input signals to EV9980. Amplitude of input signals should be 1.6Vpk-pk to 2.0Vpk-pk and must be biased at 0V.
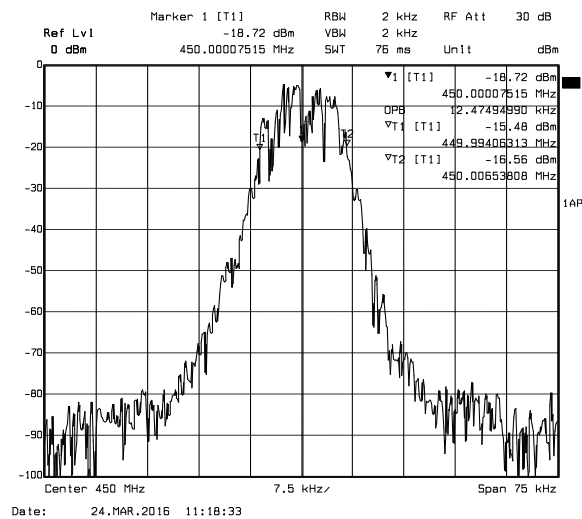
```
                    Marker 1 [T1]          RBW    2 kHz   RF Att    30 dB
        Ref Lvl              -18.72 dBm    VBW    2 kHz
        0 dBm          450.00007515 MHz    SWT    76 ms   Unit         dBm
```

Figure 7:EV9980 RF Output (Closed Loop), 4QAM PRBS, 9.6kbaud

- To terminate testing:
    - <u>Uncheck "Forward Path En" box in ES9980 GUI, and click "Write All".</u>
    - Disable +1.2V to RF PA enable.
    - Disable +3.6V to RF PA.
    - Disable RF LO.
    - Disable I/Q input signal source.
    - Disable +6V to PE0003 and EV9980.

5   Experimentation

5.1   Helpful Test Points

The EV9980 provides test points to allow easy access to the CMX998 internal amplifier chain. Outputs from the input amplifier, filter amplifier, and error amplifier are accessible for both I and Q channels.
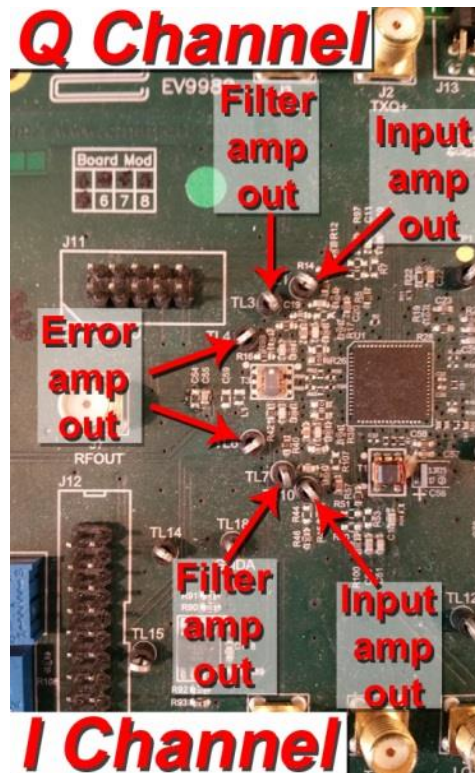

Figure 8**:Helpful EV9980 Test Points**

5.2   Feedback Path LO Phase Adjustment

The optimal feedback path LO phase setting is application dependent. A value of 315º is shown in the EV9980 User Manual, but this setting is only for the default configuration of EV9980 as described in the user manual, it may not yield optimal results with your evaluation configuration.

The impact of feedback LO phase setting can be easily evaluated with the EV9980. Click on the "Phase" slider bar in the EV9980 GUI and use the keyboard arrow keys to increment the LO phase. This will allow observation of good and bad phase settings. (Note that in the images below, the RF span has been increased to 10 MHz allow observation of phase setting on transmitted spectrum).
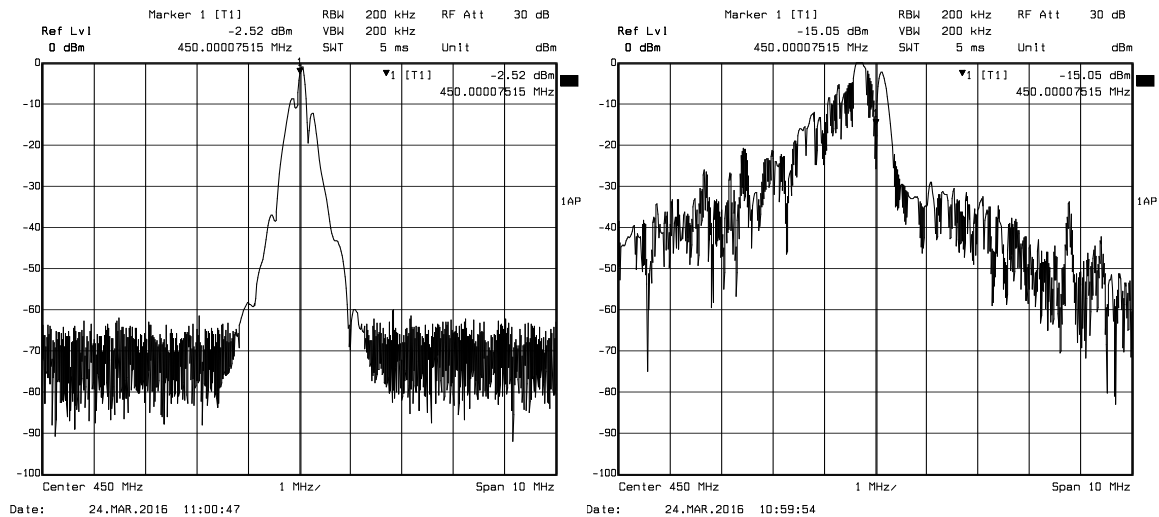
Figure 9: Impact of Good and Bad CMX998 Feedback Path LO Phase Adjustment

There should be a range of feedback LO phase settings that produce good results where the spectral distribution is reasonably symmetrical . For example, if acceptable operation is achieved in the range of 270º – 45º, choosing an operating point of 337.5º will yield 67.5º phase margin. A feedback LO phase setting that results in at least 45º phase margin should be selected. Moving the feedback LO phase setting beyond the extremes of stability will cause peaking in the noise floor which will rapidly worsen as shown above.

5.3 Forward Attenuator Setting

The CMX998 forward attenuator determines the forward path gain, and this gain must be high in order for the Cartesian feedback loop transfer function to simplify to (1 / FB gain). In other words, if the forward attenuator value is increased too much, the reduced forward gain impacts the transfer function and loop performance degrades.

Conversely, if the forward attenuator value is too small, the outputs of the error amplifiers will also be small and this will raise the noise floor of the overall system. Therefore, a compromise in forward attenuator value must be chosen.

With forward attenuator = 0dB, observe the error amplifier output at TL6 (I channel) or TL4 (Q channel). Increase the forward attenuator value (e.g. from 0dB to 2.5dB). The forward path gain decreases, and the loop will attempt to compensate by increasing the signal drive to the modulator. As forward attenuator value increases, error amplifier output amplitude increases. Eventually a forward attenuator value will be found that results in spikes in the RF output spectrum; now reduce the setting 1dB, this is the limit of acceptable operation.

Normally the loop is set up with forward attenuator = 0dB at maximum output power. As output power reduces loop gain will increase, potentially causing instability, so the forward path attenuation can be increased to compensate. Please note that there are patents that may apply to this technique.

5.4   Feedback Attenuator Setting

So long as forward path gain is high, the Cartesian feedback loop transfer function simplifies to (1 / FB gain). In this situation, decreasing feedback path gain results in an increase in loop output. Increasing the CMX998 feedback path attenuator value (e.g. from 15dB to 16dB) will result in a dB-for-dB increase in RF output power.

A feedback attenuator setting that is too low will cause low RF output power, but a feedback attenuator setting that is too high will cause the loop to overdrive the RF PA, resulting in spikes in the RF output spectrum.

With feedback attenuator = 0dB, observe the error amplifier output at TL6 (I channel) or TL4 (Q channel). Increase the feedback attenuator value (e.g. from 0dB to 1dB). As the value is increased the RF output power and PA current consumption will increase. Eventually a feedback attenuator value will be found that results in spikes in the error amplifier outputs and RF output spectrum, now reduce the feedback attenuator one step; this is the limit of acceptable operation.

5.5   RF Output Power

RF output power developed with Cartesian loop negative feedback can only be changed in two ways:
- Adjust I/Q input amplitude (increasing amplitude => increasing RF output power)
- Adjust CMX998 **feedback** attenuator setting (increasing attenuator setting => increasing RF output power)

5.6   Open Loop vs Closed Loop Operation

It can be useful to change from closed Cartesian loop operation (aka "closed loop") to open loop operation, for example as a test mode or during alignment procedures. This mode change can be evaluated by toggling the "Open Loop Mode" box in the ES9980 GUI.

Changing to open loop mode will dramatically increase RF PA power consumption and occupied RF bandwidth.
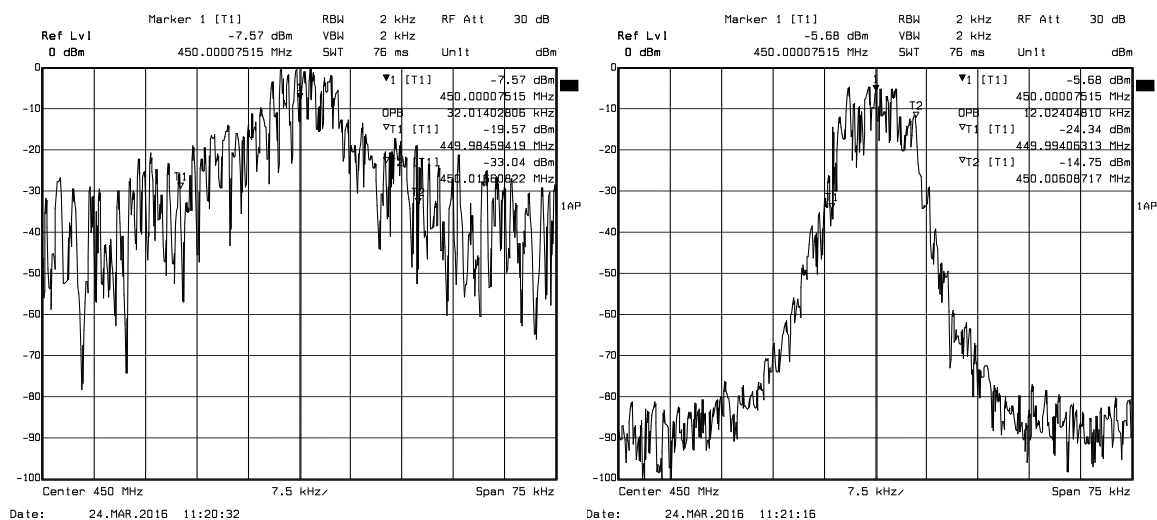

Figure 10:Open Loop (left) vs Closed Loop (right) Operation (4QAM PRBS 9.6kbaud)

6 "Gotchas"

The following items are occasionally encountered by EV9980 customers:
- No RF output power
  - The most likely culprit is a blown output inductor (L23, 2.2nH) downstream of the RF PA. This inductor can be damaged if the previously described EV9980 shutdown sequence is not followed or the PA control is left floating. L23 is located on the back of the EV9980, to the right of the "TX-OUT 400MHz" connector. Check this inductor to ensure it hasn't blown (the inductor will measure as a dc open circuit if it is damaged).

Figure 11: Where to check if no RF output is present

- Spikes in RF spectrum
  - This can be caused by excessive I and/or Q input amplitude to the CMX998. Try reducing I/Q input amplitude or reducing CMX998 feedback attenuator setting (e.g. from 16dB to 15dB) to remove these spikes.
  - These spikes are caused by the loop being asked to deliver more power than the PA can generate (i.e. > P_{SAT}). This can be a confusing effect because the linearised PA mean power might be less than the unlinearised mean power. In the unlinearised case, however, the modulation will be compressed and the peak-to-average power ratio reduced, with the corresponding negative impacts on EVM and spectrum.
- Excessive RF PA current consumption
  - Ensure CMX998 I/Q input amplitude is not excessive.
  - Ensure CMX998 FB attenuator setting is appropriate.
- "Bizarre" EV9980 operation
  - Check that the current limit on the +3.6V RF PA supply is set to 2.0A.

7   Helpful Hints

Detailed PE0003 driver installation information can be found in the PE0003 User Manual. For Win7 and Win8 driver signing issues see the FAQ tab on the CML website's PE0003 Product page.

Detailed information on GUI operation can be found in the PE0003 User Manual.

A reference document for the Script language can be downloaded from the CML website's PE0003 product page on the Knowledge Base tab.

Keep a reasonable space between RF evaluation boards to avoid RF coupling issues.

Keep RF leads routed away from the boards and other when making precise measurements. This will avoid signal coupling affecting the results.

The PE0003 generates high spurious noise typical of high speed processors and this may be coupled into the RF circuits. While every care has been taken to avoid issues, optimum performance will be achieved with a production design that includes overall shielding and consideration of the layout with respect to the processor speed and proximity.

Please contact CML Technical Support if you have any questions or require further assistance.

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