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Using LMS7002M with external DAC/ADC interface

- Application note -

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1

External interface to Transmitter baseband

1.1 Description

LMS7002M chip provides a possibility to use external digital-to-analog (DAC) converters or signal sources for the transmitter (TX) chain. When external DACs or signal sources are used, internal DACs must be powered down. It should be noted, that without internal DACs LMS7002M transceiver signal processor (TSP) functions are also unavailable for the TX chain.

The external signal source should be connected to the appropriate external TX input pins, which are given in
are given in

Table 1.

Table 1: TX chain external input pins

Pin No	Pin ID	Pin Name	Pin description
25	P2	tbbqn_pad_1	TX change input pad to externally drive the TX BB Channel 1
26	R5	tbbin_pad_1	TX change input pad to externally drive the TX BB Channel 1
27	R3	tbbqp_pad_1	TX change input pad to externally drive the TX BB Channel 1
28	T6	tbbin_pad_2	TX change input pad to externally drive the TX BB Channel 2
29	T4	tbbip_pad_1	TX change input pad to externally drive the TX BB Channel 1
31	U3	tbbqp_pad_2	TX change input pad to externally drive the TX BB Channel 2
32	U1	tbbqn_pad_2	TX change input pad to externally drive the TX BB Channel 2
33	V2	tbbip_pad_2	TX change input pad to externally drive the TX BB Channel 2

There are three ways to connect external signal sources to the transmitter chain by using the TSTIN_TBB (0x010A[15:14]) control register:

1. Connect to the high band filter input;
2. Connect to the low band filter input;
3. Connect to the current amplifier stage.

It is recommended (in most cases) to connect the external signal source to the current amplifier stage to retain the TX baseband chain gain control option.

A detailed bock diagram of the TX baseband chain and its inputs can be found in the *LMS7002M Programming and Calibration guide, Appendix 2.4*.

1.2 Connection to current amplifier input

A simplified current amplifier input stage of the LMS7002M transceiver is shown in Figure 1. When the signal source is external, the use of current buffer input is recommended in most cases, since it retains the ability to control the TX baseband gain by using the internal current

amplifier gain control. Typical current amplifier input parameters and recommended bias settings are shown in Table 2.

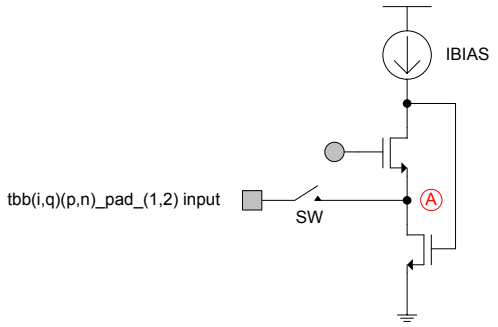

Figure 1. Simplified current amplifier input stage of the LMS7002M

Table 2: Typical current amplifier input parameters and recommended bias settings

Parameter	Recommended, expected values
ICT_IAMP_FRP_TBB (0x0108[9:5])	1
ICT_IAMP_GG_FRP_TBB (0x0108[4:0])	6
Input resistance R_{SW}	Typical 50Ω
Node (A) $U_{(A)bias}$ voltage @ recommended bias settings	0.23V
IBIAS	130uA
Peak-to-peak input current swing at node (A)	1.25mA

Interface between an external DAC and LMS7002M TX current buffer stage is shown in Figure 2.

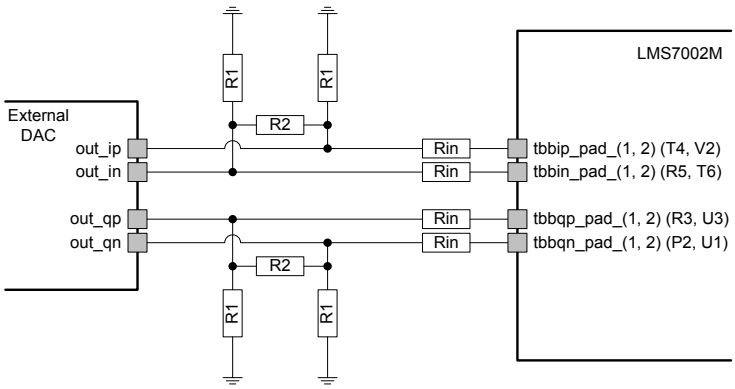

Figure 2. Interface between an external DAC and LMS7002M TX current buffer

The resistor values depend on the DAC output current and LMS7002M current buffer bias settings (controls ICT_IAMP_FRP_TBB (0x0108[9:5]) and ICT_IAMP_GG_FRP_TBB (0x0108[4:0])). The following equations can be used to calculate the resistor values shown in Figure 2 for a number of possible situations:

$$R_{in} = \frac{U_{pkpk} - U_{(A)bias}}{I_{in}} - R_{SW}, \qquad (1)$$

Here:

U_{pkpk} – single ended peak-to-peak voltage swing that will appear at the DAC output, with common mode voltage being $U_{(A)bias}+U_{pkpk}$ / 2. This value should not violate the DAC output requirements. Default – 0.25V;

$U_{(A)bias}$ – voltage at the *(A)* node (see Figure 1), that is set by the bias settings of the current amplifier. Default – 0.23V;

I_{in} – differential input current. Default – should always be set to 1.25mA;

R_{SW} – internal switch and wiring resistance. Default – typical value 50Ω, but may slightly vary due to PVT variations.

$$R_1 = \frac{U_{pkpk} + 2 \cdot U_{(A)bias}}{I_{pkpk} - I_{in}}, \qquad (2)$$

Here:

I_{pkpk} – DAC differential output current. Default – set by DAC specification;

$$R_2 = R_1 \cdot \frac{U_{pkpk}}{U_{(A)bias}}, \qquad (3)$$

General notes:

1. U_{pkpk} should not be lowered too much, since R_{in} value will become small and will be dominated by the less PVT stable internal switch resistance R_{SW};
2. If R_{in} is calculated as negative; increase the U_{pkpk} value (better scenario) or decrease $U_{(A)bias}$ (worse scenario). R_{in} should be at least 3 times larger than R_{SW};
3. $U_{(A)bias}$ value is affected by the bias controls ICT_IAMP_FRP_TBB (0x0108[9:5]) and ICT_IAMP_GG_FRP_TBB (0x0108[4:0]). Figure 3 shows typical $U_{(A)bias}$ value at various bias control codes.

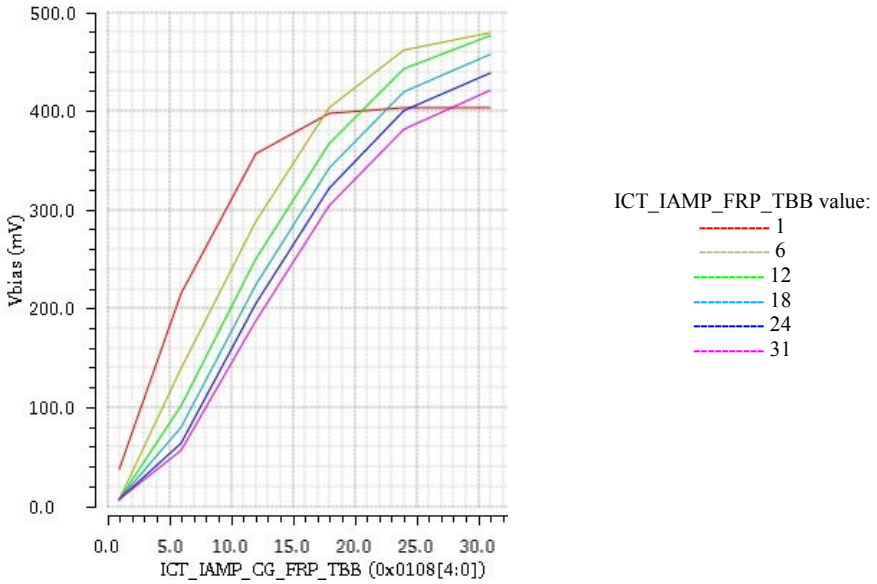

Figure 3. $U_{(A)bias}$ vs bias control value

1.3 Connection to high or low band TX filter input

It is possible to route the external input signal of the LMS7002M to either low or high band TX filter inputs. In this mode, the current amplifier is powered down and the appropriate filter (and its external input switch) is turned on. This mode, however, is mainly reserved for testing purposes and should not be used if an interface with the current amplifier input is possible.

The TX filter stages of the LMS7002M act like transimpedance amplifiers. A simplified diagram for the TX filter inputs is shown in Figure 4. The bandwidth control is done by changing the feedback resistor values. When the bandwidth of the filter gain is changed, the gain of the filter stage also changes. Typical input parameters are shown in Table 3.

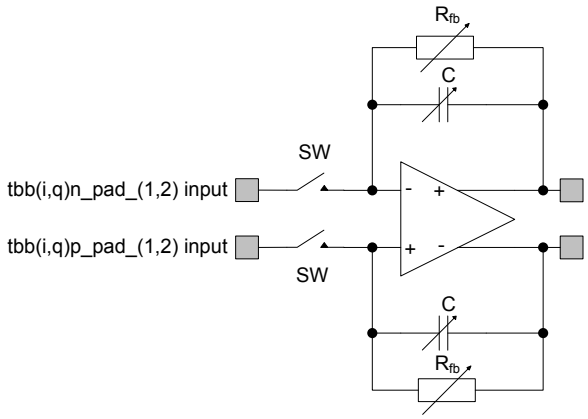

Figure 4. Simplified TX filter input diagram for the LMS7002M

Table 3: Typical TX filter input/output parameters and recommended bias settings

Parameter	Recommended, expected values
Output common mode (V_{cmo}) voltage	0.7V
Differential peak-to-peak output voltage swing	Max: 1.4V
Input common mode (V_{cmi})range	Min: 0.5V; Max: 0.9V
Input resistance R_{SW}	Typical 50Ω
High band stage R_{fb} range	Min: 450Ω, Max: 2.5kΩ
Low band stage R_{fb} range	Min: 4kΩ, Max: 25kΩ

Since the feedback resistance of the TX filter can be high, low current input is needed to prevent saturation of the filter stage. Hence, a voltage input is more conventional when interfacing with the TX filters via external inputs. Furthermore, this minimizes the effects of the input switch resistance. An interface between an external source and LMS7002M TX filter stage is shown in Figure 5.

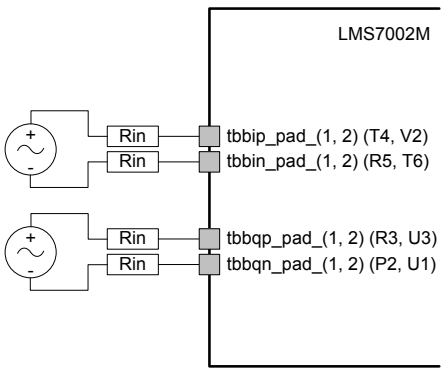

Figure 5. Interface between an external DAC and LMS7002M TX current buffer

Typical R_{fb} resistance values vs bandwidth control codes for the high and low band filter stages are given in Figure 6.

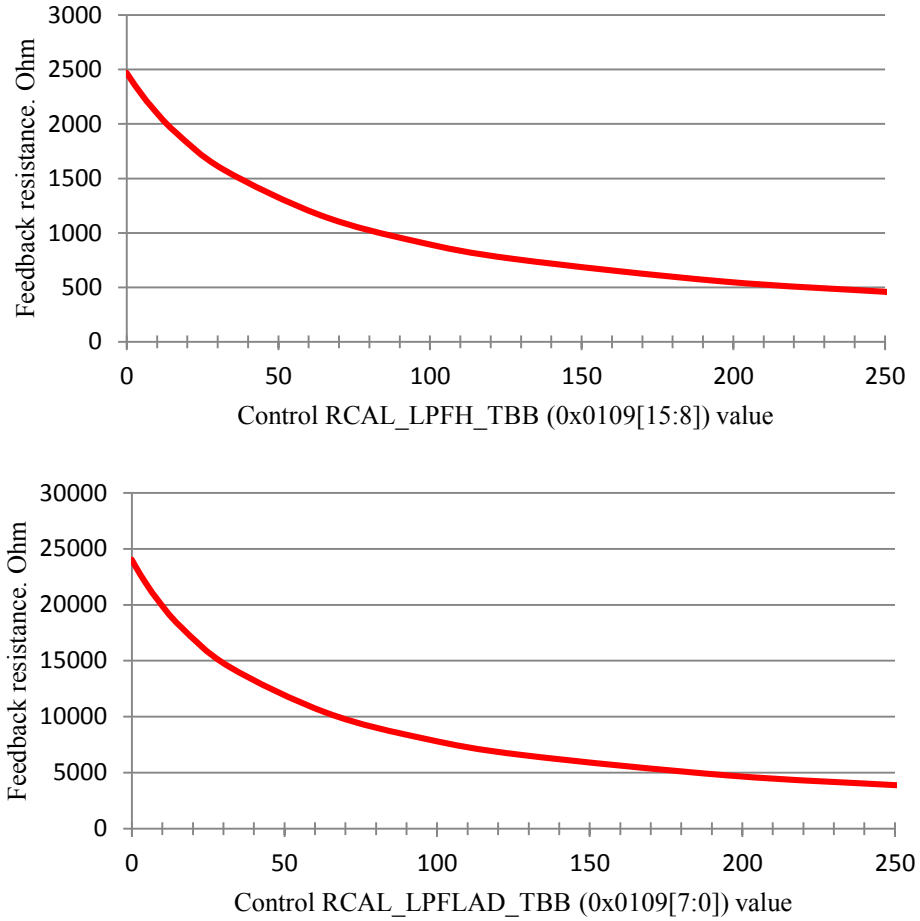

Figure 6. Typical high band (top) and low band (bottom) TX filter R_{fb} resistance vs bandwidth control codes

The gain of the filter can easily be calculated as:

$$A_{gain[dB]} = 20 \cdot \log \cdot \left(\frac{R_{fb}}{R_{in} + R_{sw}} \right), \qquad (4)$$

1.4 Example for external DAC interface

A typical interface for an external DAC is shown in Figure 7. External DAC is connected to the current amplifier stage (TSTIN_TBB (0x010A[15:14]) set to 3) while its bias settings are at default and internal DACs powered down.

The DAC used in this example is Texas Instrument 14 bit DAC5672A.

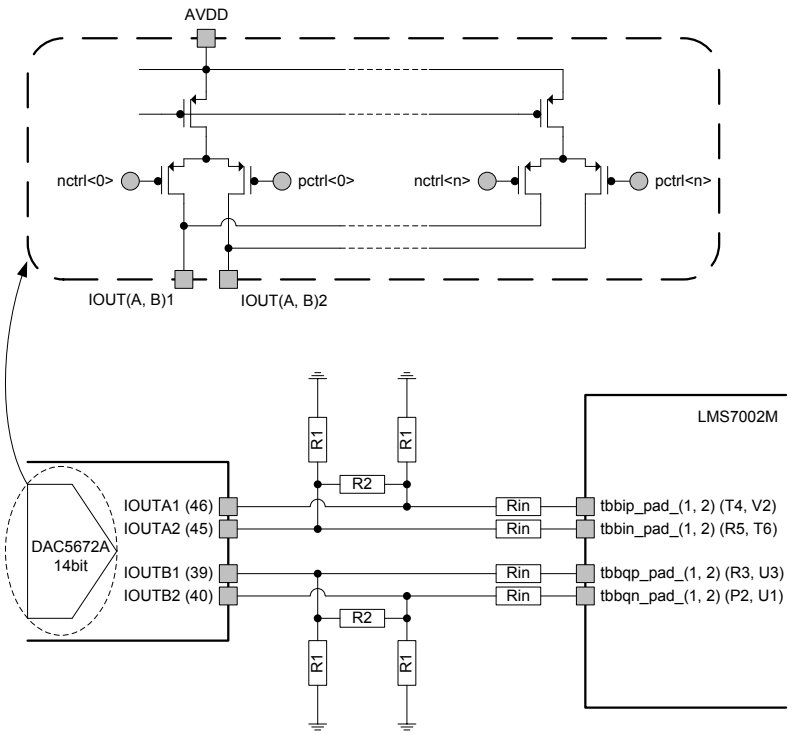

Figure 7. Interface for external DAC to the LMS7002M

DAC5672A output current can be set via external component values. The interface resistor values for different current settings of the DAC5672A are given in Table 4.

Table 4: Resistor values for Figure 7

DAC5672A common mode current, mA	DAC5672A output differential current, mA	U_{pkpk} value, V	Rin, Ohm	R1, Ohm	R2, Ohm
1	2	0.25	150	953	1020
4	8		150	105	115
10	20		150	39	43

2

External interface to Receiver baseband

2.1 Description

LMS7002M chip provides a possibility to use external analog-to-digital (ADC) converters for the receiver (RX) chain. It should be noted, that without internal ADCs LMS7002M transceiver signal processor (TSP) functions are also unavailable for the RX chain.

The external ADC should be connected to the appropriate external RX output pins, which are given in Table 5.

Table 5: TX chain external input pins

Pin No	Pin ID	Pin Name	Pin description
40	Y6	rbbip_pad_1	RX BB output – To use external filtering Channel 1
42	AA5	rbbqn_pad_1	RX BB output – To use external filtering Channel 1
43	AB2	rbbin_pad_1	RX BB output – To use external filtering Channel 1
44	AB4	rbbqp_pad_1	RX BB output – To use external filtering Channel 1
45	AC3	rbbin_pad_2	RX BB output – To use external filtering Channel 2
46	AB6	rbbqn_pad_2	RX BB output – To use external filtering Channel 2
47	AD2	rbbip_pad_2	RX BB output – To use external filtering Channel 2
48	AC5	rbbqp_pad_2	RX BB output – To use external filtering Channel 2

It is recommended (in most cases) to connect the external ADC via a separate amplifier to match the ADC input range specification.

A detailed bock diagram of the RX baseband chain and its output can be found in the *LMS7002M Programming and Calibration guide, Appendix 2.4*.

2.2 Example for external ADC interface

A typical interface for an external ADC is shown in Figure 8. RX baseband signal is routed to the LMS7002M RX chain external outputs by setting the control OSW_PGA_RBB (0x0119[15]) to "1". Typical output parameters and recommended bias settings are shown in Table 6.

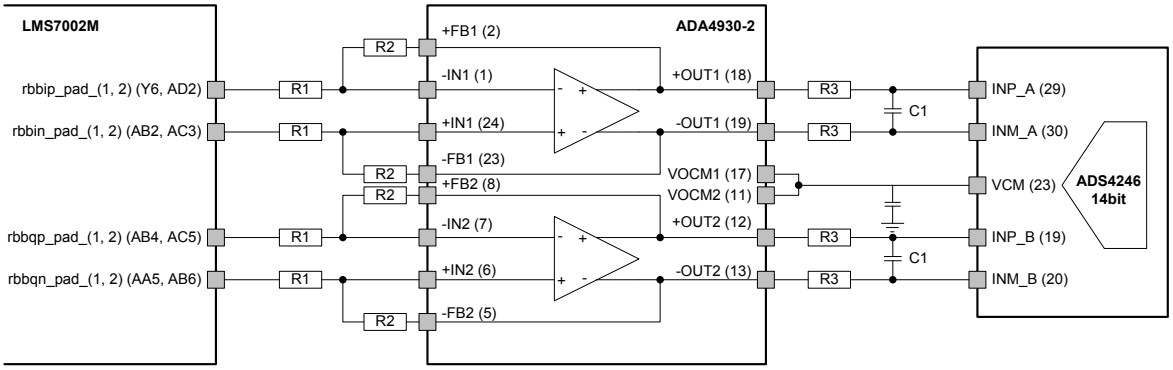

Figure 8. Interface for external ADC to the LMS7002M

Table 6: Typical RX output parameters and recommended bias settings

Parameter	Recommended, expected values
ICT_PGA_OUT_RBB (0x0119[14:10])	24
ICT_PGA_OUT_RBB (0x0119[9:5])	24
Output common mode (V_{cmo}) voltage	0.55V
Differential peak-to-peak output voltage swing	Max: 1.6V
Single ended output current	Max: 1.5mA
Differential output resistance	Typical 20Ω

ADC used in this example is Texas Instrument 14 bit ADS4246. The RX external outputs provide 0.55V output common mode voltage, which do not meet the ADS4246 specification, with an input common mode voltage in the range of 0.9V-1V. A dual differential amplifier ADA4930-2 is used to change the output common mode range and meet the ADC requirements. The LMS7002M output signal is also amplified to maximize the differential voltage swing (LMS7002M differential output swing is 1.6V max). Gain control in this mode can be achieved by changing the LMS7002M programmable gain amplifier gain control settings (G_PGA_RBB (0x0119[4:0])). Additional filtering elements can be added/changed to fit a specific requirement. ADC internal resistance and capacitance must be taken into account for filter chain designs.

The ADC interface example values for given in Table 7. Resistors R3 and C1 create a low-pass filter with a bandwidth of 300MHz.

Table 7: Resistor values for Figure 8

R1, Ohm	R2, Ohm	R3, Ohm	C1, pF
300	560	27	6.8

3

External interface from Receiver baseband to Transmitter baseband

3.1 Description

LMS7002M chip provides a possibility to use an external analog IF chain loopback from RX baseband output to TX baseband input. It can be used as a replacement for the internal digital loopback in applications where the digital TSP functionalities are not needed (i.e. for repeaters) or low system power consumption is a priority.

When using the external analog IF chain loopback, the external RX baseband (BB) outputs should be connected to the external TX BB inputs in a way shown in Table 8. Matching of the differential (P/N) and quadrature (I/Q) lines on the PCB should be a priority to minimize the unwanted gain/phase errors across each channel.

Table 8: RX BB output and TX BB input pins and their pairing

Channel	RX outputs			TX input			Description
	Pin No	Pin ID	Pin Name	Pin No	Pin ID	Pin Name	
1	40	Y6	rbbip_pad_1	29	T4	tbbip_pad_1	RX BB output – To – TX BB input, Channel 1, IP
	43	AB2	rbbin_pad_1	26	R5	tbbin_pad_1	RX BB output – To – TX BB input, Channel 1, IN
	44	AB4	rbbqp_pad_1	27	R3	tbbqp_pad_1	RX BB output – To – TX BB input, Channel 1, QP
	42	AA5	rbbqn_pad_1	25	P2	tbbqn_pad_1	RX BB output – To – TX BB input, Channel 1, QN
2	47	AD2	rbbip_pad_2	33	V2	tbbip_pad_2	RX BB output – To – TX BB input, Channel 2, IP
	45	AC3	rbbin_pad_2	28	T6	tbbin_pad_2	RX BB output – To – TX BB input, Channel 2, IN
	48	AC5	rbbqp_pad_2	31	U3	tbbqp_pad_2	RX BB output – To – TX BB input, Channel 2, QP
	46	AB6	rbbqn_pad_2	32	U1	tbbqn_pad_2	RX BB output – To – TX BB input, Channel 2, QN

3.2 Connecting RX output to TX filter inputs

To connect the RX baseband analog output to TX baseband filter input via external analog loopback, the following criteria must be met:

1. RX PGA output should be routed to external output pins – OSW_PGA_RBB (0x0119[15]) set to 1;
2. TX external input switches must be enabled for either low or high band filters – TSTIN_TBB (0x010A[15:14]) set to 1 and 2 for high band or low band filter stages;
3. TX current amplifier must be powered down – PD_LPFIAMP_TBB (0x0105[3]) set to 1.

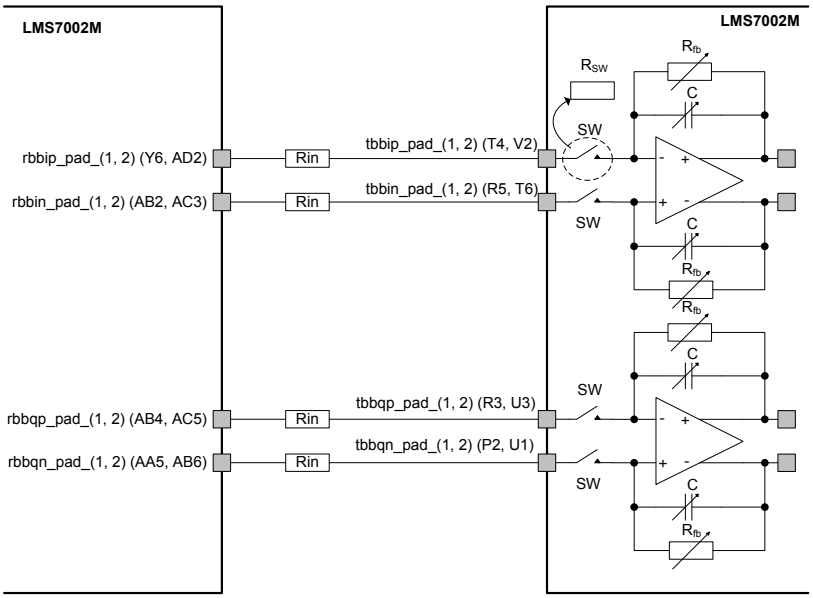

Figure 9. Interface for external loopback from RX BB output to LMS7002M TX filter inputs

Figure 9 shows a typical connection between the RX output and TX input. Resistor R_{in} value is chosen from the graph shown in Figure 6 and the desired gain. Recommended R_{in} value for a voltage gain factor of 0dB:

$$R_{in} = R_{fb} - R_{sw}, \qquad (5)$$

Here:

R_{SW} – internal switch and wiring resistance. Default – typical value 50Ω, but may slightly vary due to PVT variations.

Example: if TX high band filter is set to 40MHz bandwidth, the R_{in} value would be 1.62kΩ. If the TX high band filter bandwidth would be extend to its maximum limits, R_{in} value would drop to 499Ω

3.3 Connecting RX output to TX current amplifier inputs

To connect the RX baseband analog output to TX current amplifier input via external analog loopback, the following criteria must be met:

1. RX PGA output should be routed to external output pins – OSW_PGA_RBB (0x0119[15]) set to 1;
2. TX external input switches must be enabled to the current amplifier input – TSTIN_TBB (0x010A[15:14]) set to 3;
3. TX DAC must be powered down – PD_TX_AFE1: (0x0082[2]) or/and PD_TX_AFE2: (0x0082[1]) set to 1.

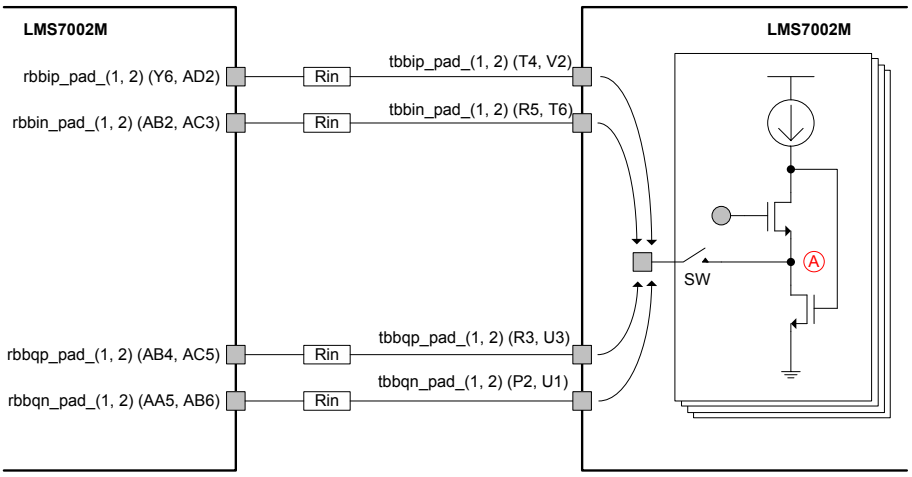

Figure 10. Interface for external loopback from RX BB output to LMS7002M TX current amplifier inputs

Figure 10 shows a typical connection between the RX output and TX input. Resistor R_{in} value is can be obtained from the following equation:

$$R_{in} = \frac{U_{RXcmo} - U_{(A)bias}}{3.15 \cdot e^{-5} \cdot ICT\_PGA\_OUT\_RBB} - R_{SW}, \qquad (6)$$

Here:

U_{RXcmo} – RX chain output common mode voltage. Typical value – 0.55V;
$U_{(A)bias}$ – voltage at the *(A)* node (see Figure 1), that is set by the bias settings of the current amplifier. Default – 0.23V;
ICT_PGA_OUT_RBB – RX output amplifier output stage bias setting. Recommended value - 24;
R_{SW} – internal switch and wiring resistance. Default – typical value 50Ω, but may slightly vary due to PVT variations.

It is recommended, that RX output swing should not be lower than $U_{(A)bias}$ (the current amplifier should be sinking current).

Typical R_{in} value with recommended bias control values are given in Table 9.

Table 9: Typical resistor R_{in} values for

Parameter	Recommended values
ICT_IAMP_FRP_TBB (0x0108[9:5])	1
ICT_IAMP_GG_FRP_TBB (0x0108[4:0])	6
ICT_PGA_OUT_RBB control value	24
Rin	390Ω