AN6290

Application note

How to use AWS for EMVCo® and NFC Forum in the ST25Rx00 devices

Introduction

This application note is a guide for using the active wave shaping (AWS) in the ST25R300 and ST25R500 devices. It provides to the user the explanations and how to use the registers that affect the waveform as environmental conditions change. Examples on register configuration and resulting waveform are included and must give a visual feedback on its adaptions.

Table 1. **Applicable products**

Type	Products
NFC readers	ST25R300
	ST25R500

1 Description

The active wave shaping mechanism (AWS) in ST25R300 and ST25R500 devices is used to actively shape the reader waveform as required in the presence of various challenging conditions. NFC modulation in ST25R300 and ST25R500 is achieved either by the hard switching on/off of the RF level, or by using an AWS approach that allows a smooth signal transition and shaping. A simple on/off switching of the 13.56 MHz carrier does not permit to actively model the waveform. In this case, the resulting signal envelop only depends on the system response including antenna matching network, antenna parameters and environmental factors. Thanks to the AWS, these circumstances can be improved by a smart configuration of the registers involved in signal preconditioning.

2 AWS mechanism

The ST25R300/500 devices allow active wave shaping on all reader technologies and bitrates as well as on the field on/off transitions. To shape precisely the signal, there are specific tuning options available which are:

- Modulation depth
- Filter and filter speed to shape the falling and rising edge independently
- Passive and active sinks
- Various shaping related timings

Note: The active wave shaping always affects the signal forming in the modulation pause and not the slew rate or similar parameters of the carrier itself.

The following modulation options are available and can be set in the TX modulation register 1 at the 0x04 address:

1. **rgs_am=1, res_am=1: Active wave shaping modulation with resistive modulation support**
   active signals: tx_mod, am_mod (regc), am_filt, en_tx, dres_e, en_pass_sinkx, en_sink_offset
2. **rgs_am=1, res_am=0: pure active wave shaping modulation**
   active signals: tx_mod, am_mod (regc), am_filt<>, en_tx, en_pass_sinkx, en_sink_offset
3. **rgs_am=0, res_am=1: pure resistive modulation**
   active signals: tx_mod, en_tx, dres_e
4. **rgs_am=0, res_am=0: No specific modulation, only square OOK modulation remains**
   active signals: tx_mod, en_tx

The maximum flexibility in shaping the waveform can be achieved with option 1 “AWS modulation with resistive modulation” support, which requires a more complex register setup than option 2. The option 2 with “AWS modulation” support must be effective enough for most reader applications and this option must be tried first.

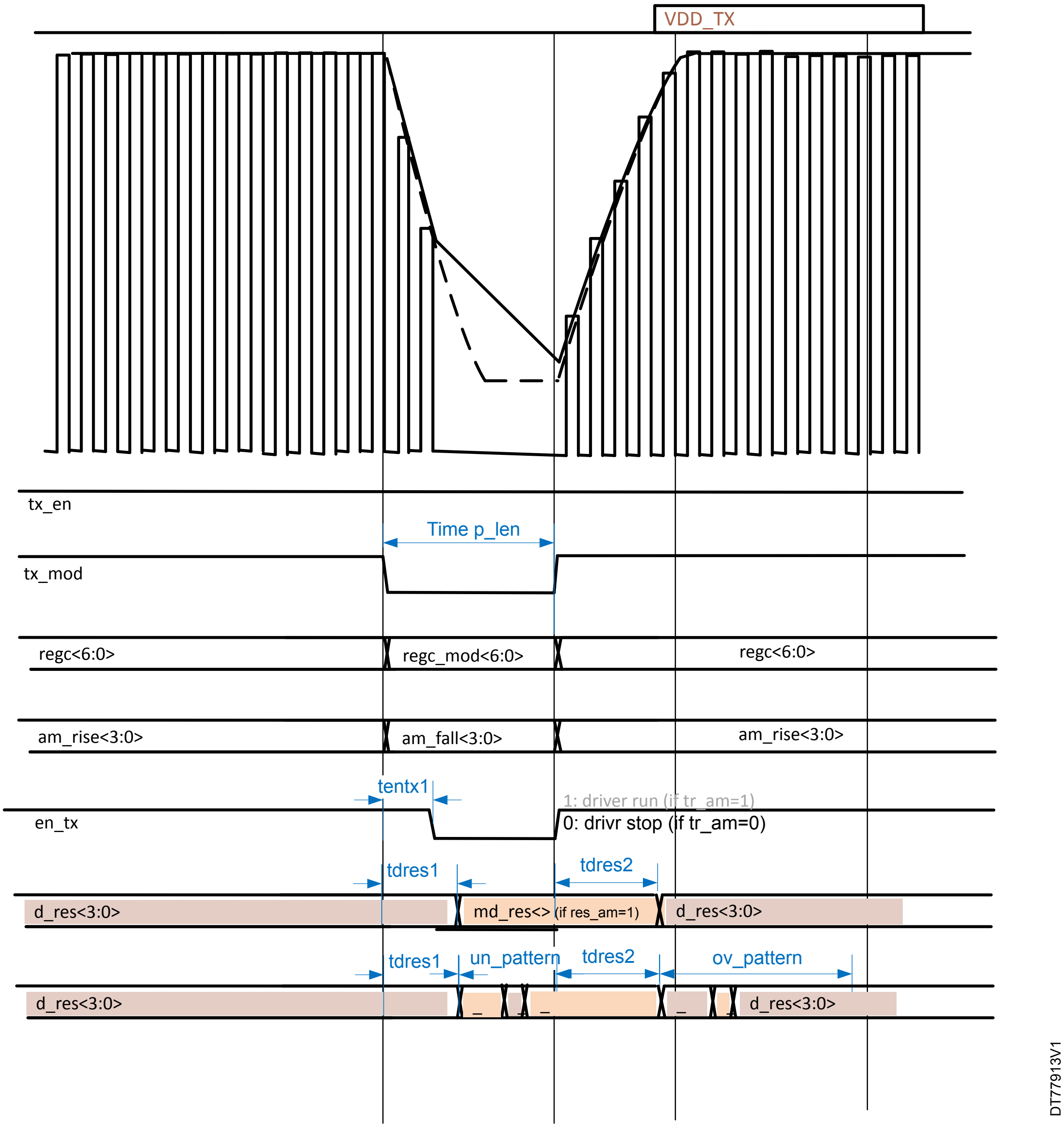
Options 3 and 4 are only mentioned for completeness and do not have a typical applicative relevance.

Further explanations on how the signals and registers interact are given in the following sections.

2.1 Timing related information when using OOK

Figure 1 refers to the relevant signals and registers required to shape the modulation.

Figure 1. Bit and timing relation for OOK waveform



Modulation pause

The modulation pulse width is defined by the number of 13.56 MHz clock periods with the p_len bits at address 0x15h Tx control register 1. The default value as reflected in RFAL fits well for all bit rate and technologies, and it can be adapted if required.

Wave shaping with the AM modulation (rgs_am=1)

For the AWS with the VDD_AM regulator, the rgs_am bit must be set. This must be the default configuration to be used. In this mode, the signal follows a specific filter curve throughout the modulation depth as set by the am_mod register. The modulation depth is set by the bits am_mod<3:0> bits. For OOK, this register must be typically set to the maximum, which corresponds to 0xF or 97% of the modulation index. The modulation level in am_mod is multiplied by regc<6:0> and the result is used as regc_mod<6:0> as denoted in Figure 1.

The AM filter defined with the am_fall and the am_rise bits value in the register AWS configuration register 2 sets the time constant for the first-order filter for the AM reference, which subsequently acts on the signal transition time. The AM filter thus controls the capacitance value of the RC time constant. A higher am_fall and am_rise values prolong the signal transition time, whereas shorter values reduce it.

With the tentx1 bits in the AWS timing register 1, the time in 1/fc periods can be set when the driver stops emitting a field. The driver is only stopped when the tr_am bit is set to 0. For the NFC-A 106 Kbit/s technology, a 100% modulation is required. Thus, at some point, the driver needs to stop and start emitting an RF field. This can be accomplished by setting tentx1; otherwise, the level of VDD_AM would be kept throughout the modulation pause. The tentx1 bits can also be used to influence the shape of the falling edge. The starting of the RF field on the other side is done automatically.

Wave shaping with the resistive modulation support (res_am=1)

Signal modulation can also be accomplished by the so-called resistive modulation. In this mode, the desired signal level (for example, 12% AM modulation) is not achieved by the VDD_AM modulation level but by the respective resistance defined in the md_res bits. When more complex signal preforming is required, typically the resistive mode with the regulated AWS mode can be used. The required bits for resistive modulation are tdres1_2<3:0> and md_res<6:0>. The tdres1 and tdres2 bits define the time period in 1/fc when resistive modulation must take place and can be found in the AWS timing register 1 and the timing register 3, respectively. The md_res bits in the Tx modulation register 2 define the modulation depth. A 100% modulation (OOK) of the signal can be achieved by setting md_res to 0x0. A higher value reduces the modulation depth.

Undershoot and overshoot pattern

The undershoot and overshoot bits can be applied in addition to the AWS mechanism that is primarily responsible for forming the waveform. An undershoot/overshoot pattern takes effect with the first falling/rising edge pulse, whereas the leading bit or LSB is first emitted. It is recommended that the user first adjusts the waveform through the AWS registers before any additional over- and undershoot patterns are applied. Note that both an undershoot and overshoot pattern must be set to activate the mechanism.

Sinks

The ST25R300 and ST25R500 devices can internally sink a certain amount of current. The current sink is used to drain additional power from the charged VDD_AM decoupling capacitors and therefore have a faster falling edge. The sinks are activated by default.

2.1.1 Explanation of the OOK and AM waveforms and their adaption for the falling and rising edges

When evaluating the characteristics of the antenna waveform, it is recommended to start off with settings that represents a medium transient response. This means that the AWS filter settings and timings are set to a value that is positioned in the center of the available adjustable steps. The usage and interaction of the AWS registers and bits are explained in the following sections. The register configurations are showing only the relevant bit description involved for achieving the desired waveform.

The resulting waveform is always captured once at the antenna as an envelope and once directly at the RFO to visualize the impact on the signal. Thus, channel 1 in yellow shows one modulation pause measured with a pickup coil. The green channel shows the corresponding signal measured directly at one of the RFOs. It is not necessary to capture the RFO when making waveform adjustments, but when it is done, the user can directly see the effect of each bit.

2.1.2 Example of an OOK waveform shaped with the AM regulator and the resistive modulation

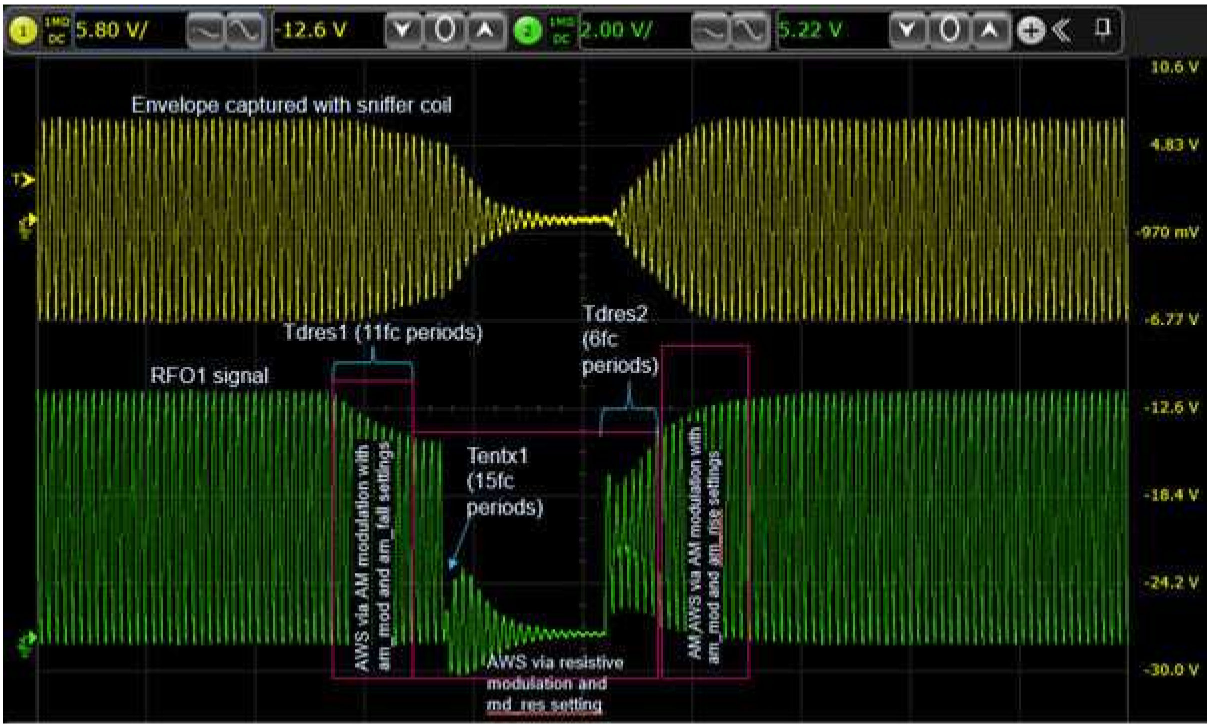
In Figure 2, the device configuration for NFC-A modulation illustrates the interaction of various AWS-related registers.

Figure 2. NFC-A polling configuration example with the AM and the resistive modulation

The falling edge is first shaped with 11 fc periods (tdres1) via the AM regulator and the filter settings as defined in am_fall. The am_mod was intentionally set to a very low value (0x05), which corresponds to 30% modulation depth and demonstrates the shaping over a very small portion of the complete signal. The device switches from AM modulation (rgs_am) to resistive modulation (res_am) after 11 fc periods (tdres1) and modulates another four clock cycles with the md_res defined modulation strength. The driver completely stops after a total of 15 clock cycles as defined in tentx1. The time period where regulated modulation takes place is thus calculated with tentx1 - tdres1 = 15 fc - 11 fc = 4 fc.

The rising edge starts automatically and first performs resistive modulation for six clock cycles with tdres2 set to 0x06. Then, the rising edge is shaped again with the am_rise filter constant of 0x7 until the nominal VDD_DR voltage is achieved.

Figure 3. NFC-A resulting waveforms with AM and resistive modulation



2.1.3 Example of an OOK waveform shaped with the AM regulator only

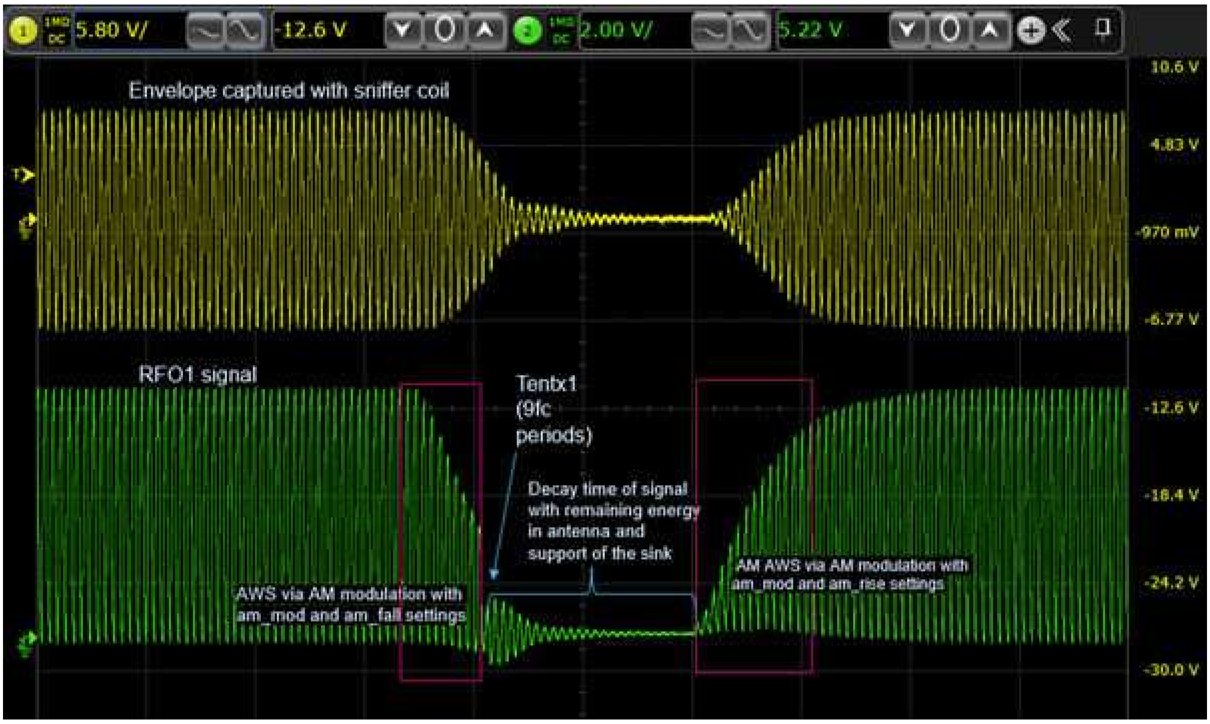
The next configuration in Figure 4 shows AWS with AM regulation only.

Figure 4. NFC-A polling configuration example with AM modulation

	Function	Register	Mask	Value	RAW String	Comment
1	am fall & rise	0x99			R:004E M:FF V:99	configure AM reference (AWS) fall + rise time
2	tr_am	OOK			R:0013 M:10 V:00	configure modulation type
3	am_mod	0x0F			R:0004 M:F0 V:F0	set modulation index for AWS filter curve
4	md_res	0x00			R:0005 M:7F V:00	resistive modulation strength
5	rgs_am	Enable			R:0004 M:04 V:04	AWS with AM modulation
6	res_am	Enable			R:0004 M:02 V:00	AWS with resistive modulation
7	tdres1	0x00			R:004F M:0F V:00	time in fc periods when switching from AM to resistive modulation
8	tdres2	0x00			R:0051 M:0F V:00	time in fc periods when switching from resistive to AM modulation
9	tentx1	0x09			R:004F M:F0 V:90	Time in fc periods when driver stops

The AM filter curve is set to 0x99, which results in a medium transient response. In the Tx modulation register 1, the bit rgs_am is set to allow wave shaping via the AM regulator only. With am_mod bits set to its maximum 0x0F, the wave shaping takes place over the complete modulation depth of 97%. Finally, the driver stops after nine clock periods. The driver starts automatically after a specific time, and the emitting field is shaped with the rising edge and a filter curve of am_rise = 0x9. Figure 5 shows the result of this configuration.

Figure 5. NFC-A resulting waveforms with AM modulation



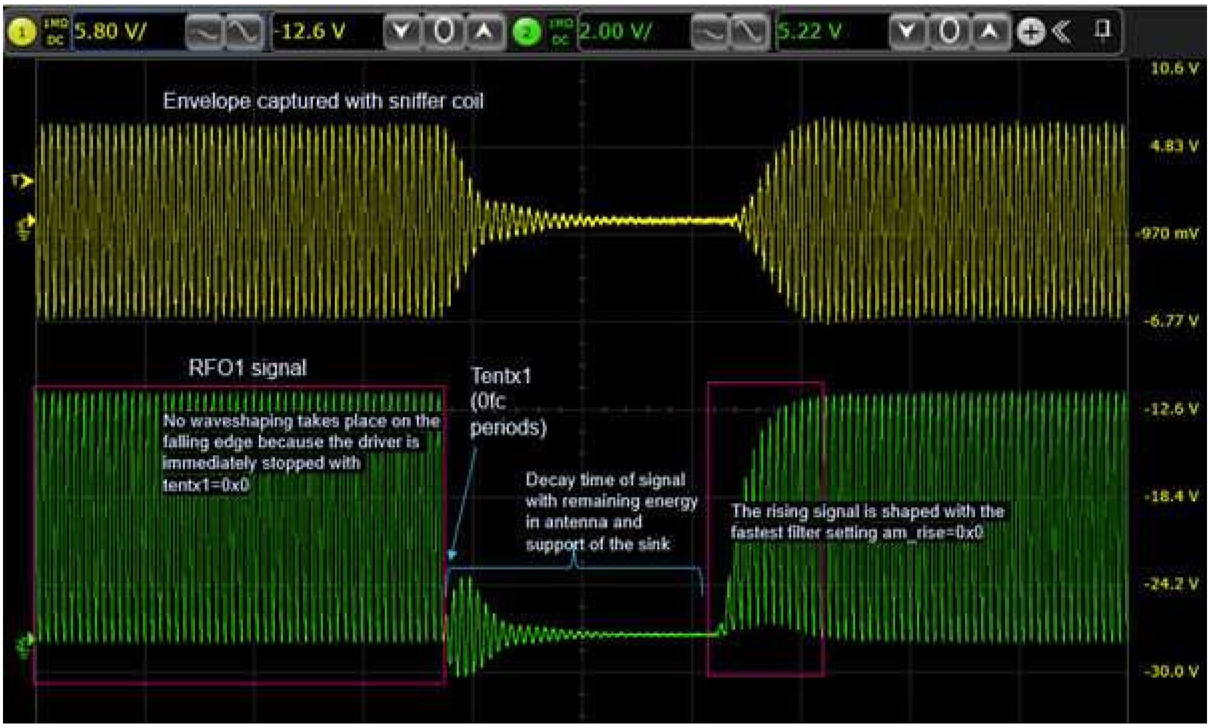
2.1.4 Adaption of registers to achieve faster falling and rising edges

The AM filter configuration from Figure 4 was set to 0x99 for am_fall and am_rise, which represents a medium transient for the waveforms. To achieve a faster slope, we have to reduce the am_fall and am_rise values. Figure 6 shows the fastest setting with am_fall&rises set to 0x00 and tentx1 set to 0x0.

Figure 6. NFC-A polling configuration for fastest transients

	Function	Register	Mask	Value	RAW String	Comment
1	am fall & rise	0x00			R:004E M:FF V:00	configure AM reference (AWS) fall + rise time
2	tx_am	OOK			R:0015 M:10 V:00	configure modulation type
3	am_mod	0x0F			R:0004 M:F0 V:F0	set modulation index for AWS filter curve
4	md_res	0x00			R:0005 M:7F V:00	resistive modulation strength
5	rgs_am	Enable			R:0004 M:04 V:04	AWS with AM modulation
6	res_am	Enable			R:0004 M:02 V:00	AWS with resistive modulation
7	tdres1	0x00			R:004F M:0F V:00	time in fc periods when switching from AM to resistive modulation
8	tdres2	0x00			R:0051 M:0F V:00	time in fc periods when switching from resistive to AM modulation
9	tentx1	0x00			R:004F M:F0 V:00	Time in fc periods when driver stops

Figure 7. NFC-A resulting waveforms with fastest transients



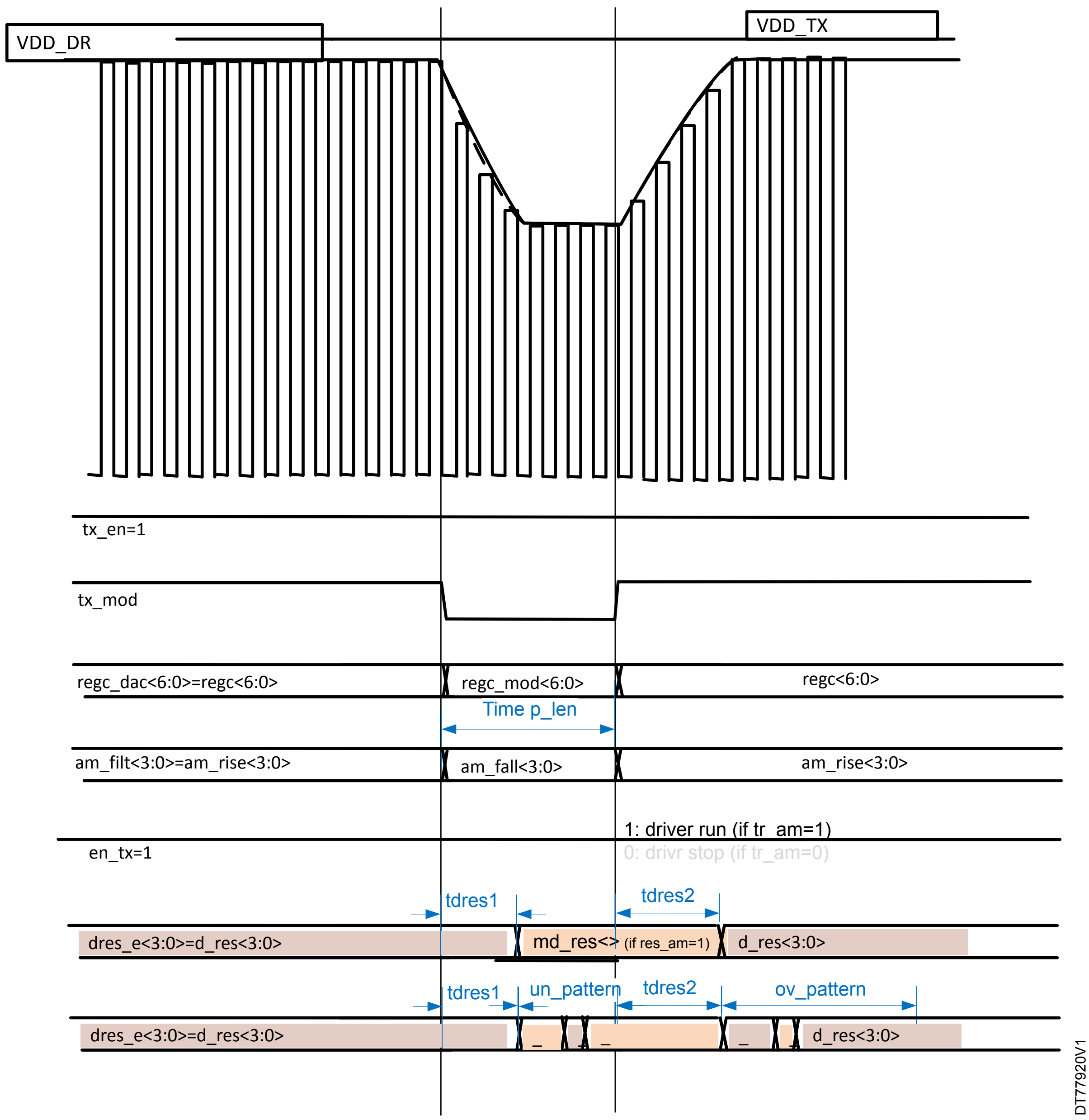
2.2 Timing related information when using ASK

The interaction of registers and signals is the same as for OOK modulation, refer to Section 2.1 for the description of the relevant registers.

The difference is that drivers are not stopped with the tentx1 signal, because the modulation continues during an ASK modulation. Thus, the VDD_AM modulation level is kept throughout the entire modulation pause. The ASK modulation is enabled by setting the tr_am bit to 1.

In Figure 8, the graph represents the interaction of bits and timings during active wave shaping in ASK modulation.

Figure 8. Timing related information for ASK modulation



For the ASK modulation, there is typically no need for complex signal preforming to achieve specific standard compliance. That is why a simple setup with AWS via AM regulator is sufficient in most cases. The AM filter can be set independently for falling and rising edges. An example is given in the next section.

2.2.1 Example of an ASK waveform shaped with the AM regulator only

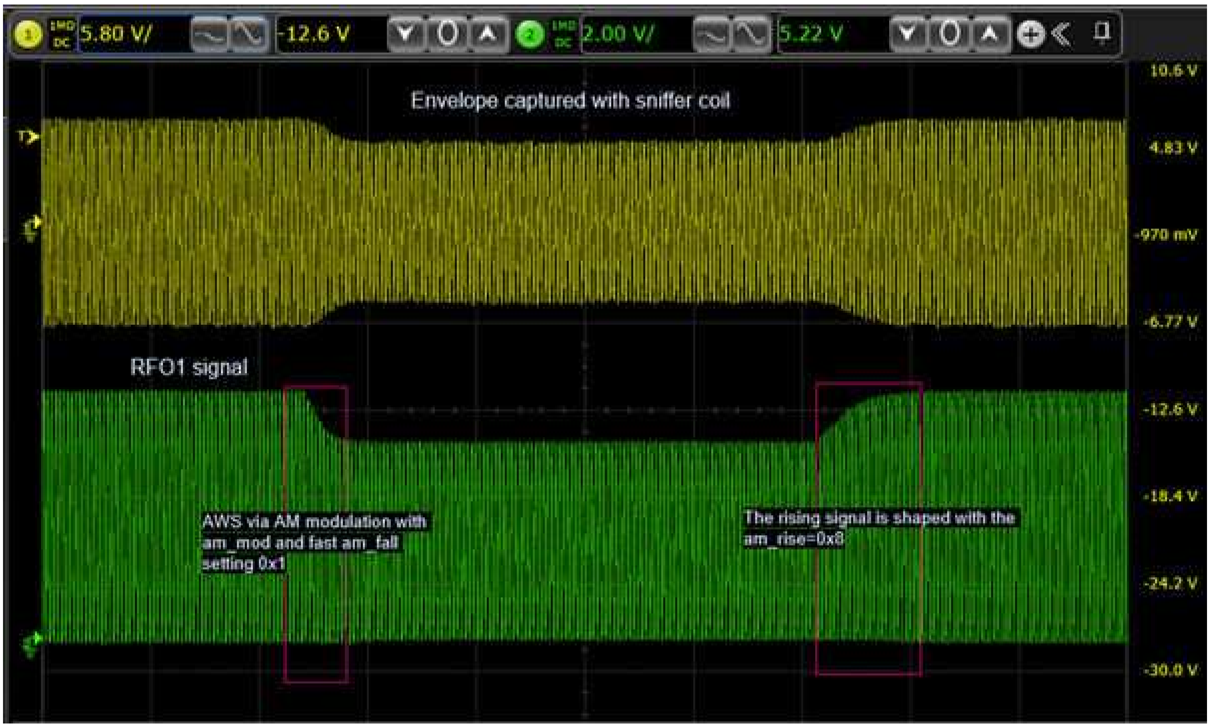
The following register settings in Figure 9 are necessary for the ASK modulation and its wave shaping.

Figure 9. NFC-B polling configuration

	Function	Register	Mask	Value	RAW String	Comment
1	tr_am	ASK			R:0015 M:10 V:10	Modulation type configuration, ASK
2	rgs_am	Enable			R:0004 M:04 V:04	Enable AWS via AM modulation
3	am fall & rise	0x18			R:004E M:FF V:18	configure AM reference (AWS) fall + rise time
4	am_mod	0x03			R:0004 M:F0 V:30	Modulation index, ~12%

The tr_am bit is set to ASK modulation in the Tx protocol register 1. The rgs_am bit is enabled to allow AWS via the AM regulator. The falling edge is set to a low and rising edge to a higher value to demonstrate the effect on the waveforms. The modulation index is set with am_mod and a setting of 0x03 corresponds to approximately 12% modulation depth.

Figure 10. NFC-B resulting waveforms

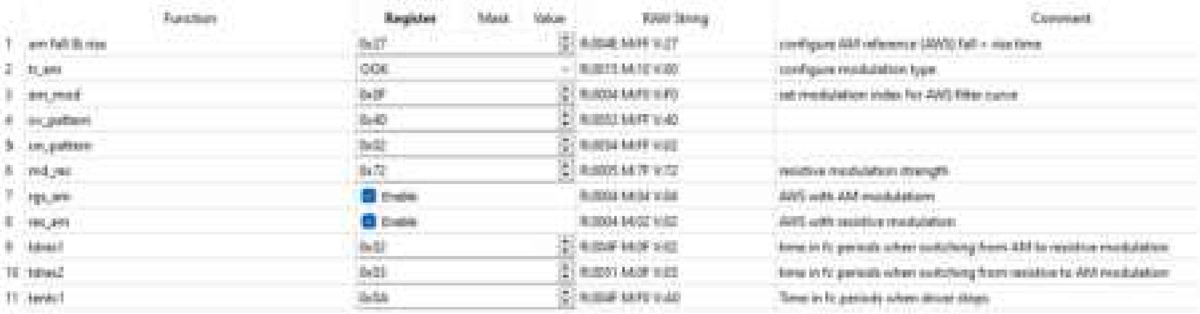


2.3 Overshoot and undershoot patterns

Undershoot and overshoot bits can be applied in addition to the AWS mechanism and configuration. The waveform, however, must be preformed first by using the possibilities available in the AWS registers. If additional reduction of peaks is still necessary, then over- and undershoot patterns can be applied. An undershoot or overshoot pattern takes effect with the first falling or rising edge pulse, whereas the leading bit or LSB of a pattern is transmitted first.

Note: The overshoot and undershoot mechanism is only activated when a bit pattern for both overshoot and undershoot is defined in the registry.

Figure 11. Example of a configuration for over- and undershoot pattern



	Function	Register / Mask / Value	RAW String	Comment
1	am fall & rise	0x27	R:0048 M:FF V:27	configure AM reference (AWS) fall + rise time
2	tx_am	OOK	R:0013 M:10 V:00	configure modulation type
3	am_mod	0x0F	R:0004 M:F0 V:F0	set modulation index for AWS filter curve
4	ov_pattern	0x40	R:0052 M:FF V:40	
5	un_pattern	0x02	R:0054 M:FF V:02	
6	md_res	0x72	R:0005 M:7F V:72	resistive modulation strength
7	rgs_am	Enable	R:0004 M:04 V:04	AWS with AM modulation
8	res_am	Enable	R:0004 M:02 V:02	AWS with resistive modulation
9	tdres1	0x02	R:004F M:0F V:02	time in fc periods when switching from AM to resistive modulation
10	tdres2	0x03	R:0051 M:0F V:03	time in fc periods when switching from resistive to AM modulation
11	tentc1	0x0A	R:004F M:F0 V:A0	Time in fc periods when driver stops

The res_am modulation must be configured to enable the overshoot and undershoot mechanism. For example, the ov_pattern is defined with 0x40 and the un_pattern with 0x02. In Figure 12, one can see that the undershoot pattern is effective in the second clock cycle, which corresponds to the bit 2 as set in register 0x54=0x02. The overshoot pattern is modulated with bit 8. In this instance, the overshoot protection pattern ov_pattern<7:0> is applied to LSB first. For the first clock cycles after the transition, each bit of the overshoot protection pattern specifies which driver resistance to apply. Thus, ov_pattern<0> defines which driver resistance to apply for the first clock cycle after the transition from an unmodulated to a modulated state, and ov_pattern<7> defines which driver resistance to apply for the eighth clock cycle after the transition from an unmodulated to a modulated state. From the eighth clock cycle onwards, the settings from the TX driver register are used. Since ov_pattern<7> is set to 1 with pattern 0x40, the pattern is enabled with the eighth clock cycle.

Figure 12. NFC-A waveform with overshoot and undershoot pattern activated

3 Conclusion

This application note provides the user with an initial guidance to set up the various AWS registers and bits for different configurations. It is recommended to start with an AWS configuration that uses wave shaping through AM regulation only and then improve these settings step by step. The principles for waveform adjustments for OOK and ASK are similar, but the differences in terms of modulation index settings are important. The usual circuit theory on signal response also applies to active waveshape adjustments. Thus, a fast slope transition setting may help achieve certain standard requirements but is also prone to produce an overshoot to a certain degree. Always watch for a good compromise between matching circuit components and AWS settings to achieve a good signal response and result in the overall measurement volume.

Revision history

Table 2. **Document revision history**

Date	Version	Changes
27-Mar-2025	1	Initial release.

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