GC5016 Application Note:
Digital Up Converter Mode Gain Settings

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Setting the GC5016's gain in the DUC mode

The objective in the DUC mode is to set the gain variables to prevent overflow in the PFIR and CIC and then to adjust G and *sum_shift* to achieve the user's desired overall gain. The cmd5016 program calculates the optimal gain settings based on the user's desired overall gain. The desired overall gain is set using the keyword *overall_gain*.

Note that the gain in the up convert mode is almost always an attenuation. Full scale input data needs to be attenuated in the PFIR to prevent overflow at the PFIR's output. This is because the PFIR filter taps can create peaks in the interpolated data. Attenuation also needs to be added to prevent overflow in the sum of multiple channels. Gain should only be added if the input data is too small. For example, gain may be added if the user mistakenly connected 12 bit input data into the LSBs of the 16 bit GC5016 input ports and sign extended, rather than connecting them into the MSBs.

Gain through the DUC is usually set to optimize the crest factor of the output data. The crest factor is the ratio of the maximum output amplitude to the RMS signal level. For example, a 12 dB crest factor for a 16 bit output word would mean that the maximum "peak" in the data is 32767, and the RMS level is one-fourth that, or 8192.

The user sets the overall gain using the key word overall_gain. The user sets the overall gain to achieve the desired output crest factor. If the input data has a crest factor of 9 dB, and the desired output crest factor is 14 dB, then the overall gain would be set to –5dB (overall_gain = 0.56).

The user must set the overall gain on a per channel basis. If two channels are being added together, then the per-channel gain should be lowered by 3 dB to give the desired output crest factor. If four channels are added together, then the per-channel gain needs to be lowered by 6 dB.

For example, if the input crest factor is 9dB, and the desired output crest factor is 14dB, then overall gain should be –5dB (overall_gain=0.56). If two channels are being added together, then each channel should have an overall gain of –8dB (overall_gain = 0.398). If four channels are being added together, then each channel should have an overall gain of –11dB (overall_gain = 0.28).

How CMD5016 Calculates the Gain settings

Definitions:

NOTE: All variables in italics are key words for the cmd5016 program
overall_gain: User's desired overall gain for each channel.
G: 19 bit unsigned front end gain word, manually set using *gain*, *gain_lsb* or *gain_msb*
gain: Keyword for the front end gain, *gain* = G/4096 = (*gain_msb*$*2^{16}$ + *gain_lsb*)/4096
gain_msb: 3 MSBs of G
gain_lsb: 16 LSBs of G
fir_int: Interpolation in the PFIR
fir_shift: Gain adjustment at the output of the PFIR.
cic_int: Interpolation in the CIC
cic_xmt_5stg: Keyword to set the CIC into the 5stage rather than the standard 6 stage mode.
cic_shift: Gain adjustment in the CIC
sum_shift: Gain adjustment in the sum tree
tout_nsig: Keyword to specify the number of outputs the DUCs are summed into
tout_sumin: Keyword to specify if the sumIO mode is being used
tout_res: Keyword to specify the 22 bit output mode

MAX_PFIR_MAG_SUM: Calculated from the PFIR taps to give the peak gain in the PFIR
FIR_PEAK_GAIN: The peak gain in the PFIR after *fir_shift* is applied
PFIR_SUM: Calculated from the PFIR taps to give the RMS gain through the PFIR
FIR_GAIN: The RMS gain through the PFIR after *fir_shift* is applied
CIC_GAIN: The RMS gain through the CIC after *cic_shift* is applied
SUM_GAIN: The RMS gain through the sum tree after *sum_shift* is applied
OVERALL_GAIN: The overall gain in the chip (should be equal to *overall_gain*)

The DUC gain is set by cmd5016 using the following algorithm:

1) Set G and *fir_shift* to prevent clipping in the PFIR.
    a. Divide the PFIR filter taps into the "*fir_int*" sets of interpolation phases.
    b. Sum the magnitude of the taps in each interpolation phase. The largest sum of magnitude is the MAX_PFIR_MAG_SUM.
    c. Set fir_shift so that FIR_PEAK_GAIN = (MAX_PFIR_MAG_SUM)/($2^{(21-fir\_shift)}$) is between 1 and 2.
    d. Set G so that 1.0 = (G/4096)*FIR_PEAK_GAIN, i.e., G = 4096/FIR_PEAK_GAIN
    e. Calculate the sum of the PFIR taps (PFIR_SUM)
    f. Calculate GAIN=(G/4096)
    g. Calculate FIR_GAIN=(PFIR_SUM)/($fir\_int*2^{(21-fir\_shift)}$)

    Note: G will be between 2048 and 4096 if these are set properly.
2) Set *cic_shift* to prevent overflow in the CIC.
    a. Set *cic_shift* so that CIC_GAIN=($N^{(5-cic\_xmt\_5stg)}$)($2^{(cic\_shift-41)}$) is between 0.5 and 1.0.
3) Set *sum_shift* to get OVERALL_GAIN to be between *overall_gain* and *overall_gain**2.0
    a. In the 22 bit sumIO mode (*tout_nsig*=1, *tout_sumin*=1, *tout_res*=1), use SUM_GAIN=$2^{(sum\_Shift-6)}$
    b. In all other modes use SUM_GAIN=$2^{(sum\_Shift-3)}$
    c. In the four output mode (*tout_nsig*=4), use SUM_GAIN=1.0 and *sum_shift*=3.
    d. Calculate OVERALL_GAIN = GAIN*FIR_GAIN*CIC_GAIN*SUM_GAIN and adjust *sum_shift* so OVERALL_GAIN is between *overall_gain* and 2**overall_gain*.
4) Adjust G to make OVERALL_GAIN = *overall_gain*
    a. Set G = G**overall_gain*/OVERALL_GAIN
    b. While (G<2048, and *fir_shift*>0), set G=G*2, and set *fir_shift* = *fir_shift*-1.
    c. Calculate *gain_lsb* and *gain_msb* from G.
5) Recalculate GAIN, FIR_GAIN, FIR_PEAK_GAIN, CIC_GAIN, SUM_GAIN and OVERALL_GAIN. Cmd5016 should report them to the analysis file.

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