Internship report

Evaluation of the Calix Calibration and the CapMem Crosstalk

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Abstract

The current calibration for the BrainScaleS-2 system only allows single operation point calibration, i.e. for each different calibration target, a new calibration needs to be run, which is time consuming. Thus, the goal is to implement a lookup based parameter transformation that transforms model parameters to the digital parametrization of the hardware. In this report first steps are taken toward the implementation of this transformation, by evaluating the current calibration and by investigating a problem of the current implementation of the parameter storage system, which yields shifted results when a large number of digital parameters shares the same value.

Contents

1 Introduction

Tolerances from manufacturing lead to mismatches between identically designed components in the BrainScaleS-2 (BSS-2) system. This means that the same digital parametrization results in different analog behaviour. Calibration solves this problem by finding a set of parameters that yield a targeted behaviour. The current calibration [9] only supports calibration for single operation points, which means that for or each different calibration target, a new calibration needs to be run.

Thus, the goal is to develop a lookup based parameter transformation, which provides the digital parameter settings for arbitrary calibration targets. This will be achieved by recording the model parameters as a function of the digital parametrization for each neuron and then fitting a transformation function to the data. The resulting fit parameters will be stored in a database. Dependencies between model parameters might be taken into account, which means that they might be modelled in the transformation.

The model parameters are controlled by currents and voltages that are stored by a capacitive memory (CapMem) [6]. In the current CapMem implementation, when the values of a large number of digital parameters are identical, the generated voltages and currents change. This crosstalk might pose a problem for the parameter transformation model, because we do not want to model dependencies between the neurons.

The aim of the internship is to evaluate the current calibration in order to be able to compare the calibration from the transformation model to the current calibration. Further, the CapMem crosstalk is investigated for the purpose of evaluating the feasibility of the parameter transformation model. The measurements are carried out for two model parameters: the leak potential V_{leak} and the membrane time constant τ_{mem}, as one of them is current-based (τ_{mem}) and the other voltage-based (V_{leak}).

2 Background

In this report the current version of the BrainScaleS-2 (BSS-2) system, the HICANN-X v4 chip, is used. It is an application-specific integrated circuit (ASIC) consisting of 512 neuron circuits. They are arranged in two rows, which are each split into two halves, i.e. there are four quadrants with 128 neuron each. Each neuron receives input signals from 256 synapses.

These neuron circuits can emulate the adaptive exponential integrate-and-fire (AdEx) model [8] [1]. For each neuron 8 voltages and 16 currents can be uniquely tuned to achieve a desired behaviour [7]. They are stored in a capacitive memory (CapMem) with 10 bit resolution [6] which provides currents and voltages based on digital values. There is one CapMem for each quadrant. A CapMem consists of an array of cells, where each column is assigned to a single neuron circuit [5] and each row is assigned to a parameter of the circuit. Additionally, there are quadrant-wide and chip-wide parameters, which are also generated by CapMem cells.

Currently, the library calix [3] is used for calibration. It contains a base calibration class, from which calibration classes for the individual parameters are derived. The base calibration provides a run() method which uses an algorithm to find the optimal parameters [9]. The algorithm calls a configure_parameters() function which sets the parameters. Then, a measure_results() function, which measures the effect of the parameters on the observable, is called. The result is compared to the calibration target and the parameter settings are changed according to the algorithm. The process of measuring, comparing and setting parameters is repeated until the optimal parameters are reached. For the parameters that affect the observable monotonically, an algorithm based on a binary search is used.

The membrane potential of a neuron can be digitized using either the columnar analog-to-digital converters (CADC) or the membrane analog-to-digital converter (MADC). The MADC is faster than the CADC with a sampling frequency of 30 MHz. The MADC can only connect to one neuron at a time, while the CADC can measure all 256 neurons in one row in parallel.

A problem occurs with the current CapMem implementation when setting a large number of CapMem cells in a quadrant to the same digital value: the generated voltages or currents differ from the value when only one cell is active [9]. In calix this crosstalk problem is worked around by doing a noisy binary search, which means that a uniform random noise of ± 5 LSB is added to the initial parameters which would otherwise be identical.

2.1 Calibration of the membrane time constant

The membrane time constant is given by $\tau_{\text{mem}} = C_{\text{mem}}/g_{\text{leak}}$ with the membrane capacitance C_{mem} and the leak conductivity g_{leak}. The time constant is calibrated by tuning the bias current of the operational transconductance amplifier (OTA) which controls the leak conductivity g_{leak} while the capacitance is kept constant.

The results for the membrane time constant in this report are calibrated and measured using the membrane analog-to-digital converter (MADC). For the calibration with the MADC a step current is applied to the neuron and an exponential is fitted to the decaying potential to obtain a value for τ_{mem}. The MADC was chosen because the calibration can reach lower time constants than the calibration with the columnar analog-to-digital converters (CADC) [9].

The membrane time constant is adjustable over two orders of magnitude by using a current multiplication and division mode which scale τ_{mem} approximately by an order of magnitude [2].

2.2 Calibration of the leak potential

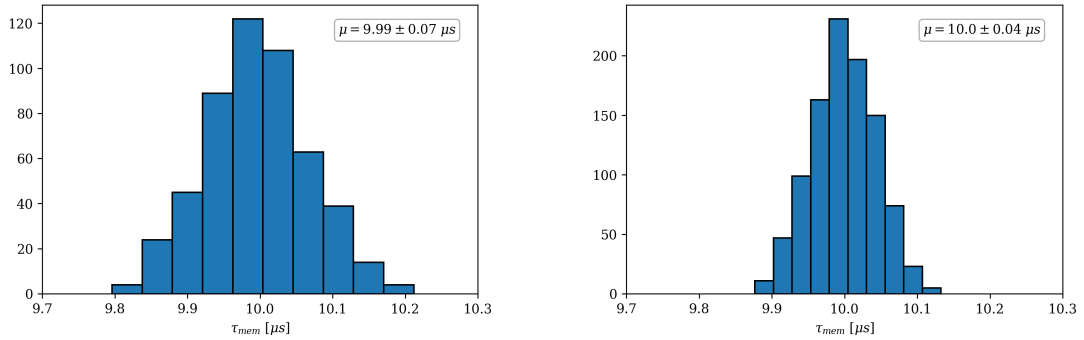
The calibration of the leak potential in calix is carried out by measuring the membrane potential using the CADC while there is no input current and spiking is disabled. The digital value of the CapMem cell for the leak potential is configured accordingly using the noisy binary search algorithm.

3 Results

3.1 Calibration

In this section the results of the evaluation of the calix calibration for τ_{mem} and V_{leak} are presented. The measurement results are obtained using the measure_results() method of the respective calibration class.

3.1.1 Membrane time constant



(a) Neuron-to-neuron distribution of τ_{mem} after calibration for one measurement trial over all 512 neurons on chip W63F3.

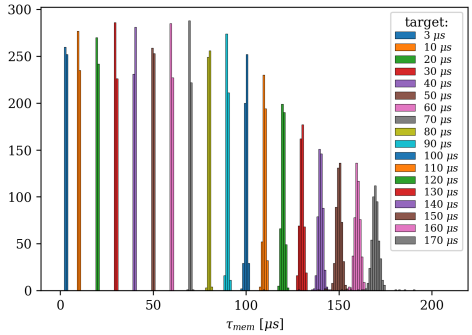
(b) Measurement-to-measurement distribution of τ_{mem} after calibration for neuron 6 on chip W63F3 over 1000 measurement trials.

Figure 3.1: Distributions of τ_{mem} after calibration.

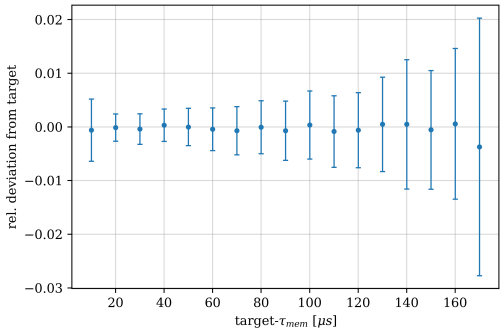
The first step is to calibrate the membrane time constant to 10 µs after applying a default calibration to the chip. Then, τ_{mem} is measured for all neurons for multiple measurement trials. For all measurements of τ_{mem} in this section the synaptic input was disabled. In this section trial-to-trial stands for measurement-to-measurement.

Figure 3.1a shows the neuron-to-neuron distribution for one measurement over the 512 neurons after calibration. Figure 3.1b shows the trial-to-trial distribution for one arbitrarily chosen neuron over 1000 measurements after calibration. The means of the distributions do no deviate significantly from the target value of 10 µs. The neuron-to-neuron standard deviation is smaller than the trial-to-trial standard deviation.

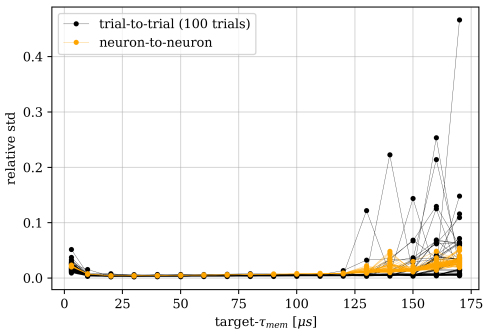
This measurement is repeated for different calibration targets. In calix an upper limit is set for the result of τ_{mem} that the fit to the exponential can return. This upper limit is



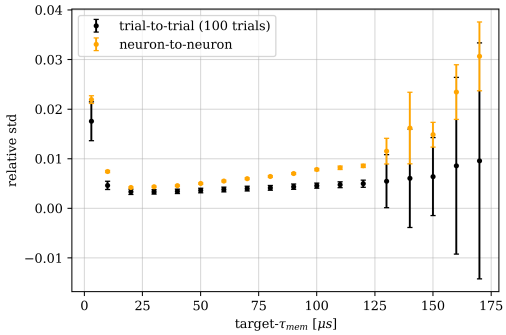
(a) Mean (over 100 trials) neuron-to-neuron distribution of τ_{mem} for different targets. The distributions get wider with increasing target value.



(b) Mean (over all neurons) relative deviation from the target of the measured τ_{mem} (mean over 100 trials). The error bars show the standard deviation over the neurons. No systematic deviation from the target can be observed.



(c) Relative trial-to-trial standard deviation over 100 trials for all neurons (black lines) and relative neuron-to-neuron standard deviation over 512 neurons for 100 trials (yellow lines). For target values above 125 µs there is a increasing number of outlier neurons which have a large relative standard deviation (up to 40 %).



(d) Mean (over all 512 neurons) relative trial-to-trial standard deviation and mean (over 100 trials) relative neuron-to-neuron standard deviation. The mean of the trial-to-trial standard deviation is smaller than the mean neuron-to-neuron standard deviation. The relative standard deviation has a minimum at 20 µs and then increases slightly with increasing target-τ_{mem}.

Figure 3.2: Distributions and properties of the distributions of the measured τ_{mem} after calibration for different targets on chip W63F3.

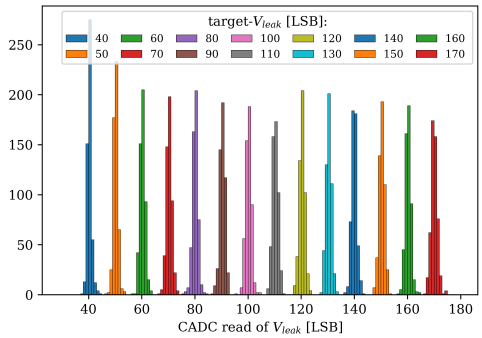
100 µs in calix, but in order to be able to investigate higher τ_{mem}, this maximum is changed to 400 µs. Figure 3.2 shows the distributions for the different targets and properties of these distributions. The measurement is not carried out for values smaller than 3 µs because the chosen calibration method does not support leak multiplication and thus, no target values below 3 µs. The highest target value is 170 µs, because for larger values some neurons reach a CapMem value for τ_{mem} of 0.

The distributions get wider with increasing target value. The mean trial-to-trial standard deviation is smaller than the mean neuron-to-neuron standard deviation for all targets. Furthermore, the relative standard deviation has a minimum at 20 µs and then increases slightly with increasing target-τ_{mem}. Figure 3.2c shows that the relative trial-to-trial standard deviation is up to 40 % for some outlier neurons, but the mean over the neurons of the relative trial-to-trial standard deviation stays below 10 %. In the mean over all neurons, the relative deviation from the target shows no systematic deviation.

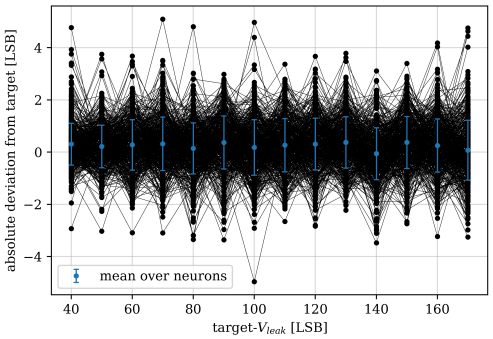
3.1.2 Leak potential

The same measurements as for τ_{mem} are carried out for the leak potential: the calibration from calix is run and then V_{leak} is measured a certain number of trials for all 512 neurons. The distributions and properties of the distributions are shown in Figure 3.3. The range of the target value is chosen such that the majority of the CapMem cells does not reach the minimum or maximum value during or at the end of the calibration: for a target of 40 LSB CADC readout, five cells reached the minimum value 0 and for a target of 170 LSB, two cells reached the maximum value 1022, for all other targets zero cells reached the maximum or minimum. Here, the absolute deviation is chosen because for potentials only the respective difference is of relevance, which means that the characteristics should be independent of the absolute value of the potential. Additionally, the relative standard deviation is plotted in order to have a comparable quantity to the results for τ_{mem}.

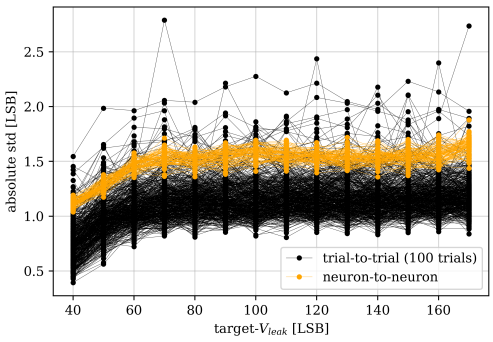
One can see that the mean trial-to-trial standard deviation is smaller than the mean neuron-to-neuron standard deviation for all the target values and that between a target of 40 LSB and 70 LSB the standard deviation increases and then above 70 LSB the standard deviation stays roughly constant. The relative neuron-to-neuron standard deviation declines from 2.75 % to 1 %. The mean absolute deviation from the target over all neurons shows no significant systematic deviation.



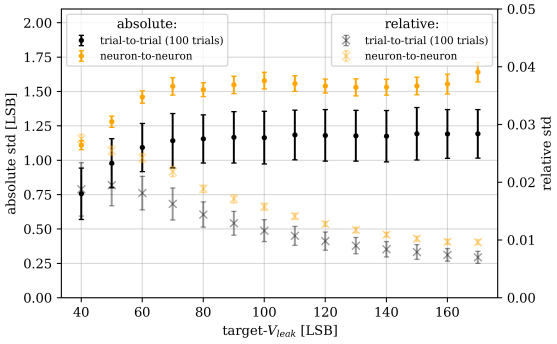
(a) Mean (over 100 trials) neuron-to-neuron distribution of V_{leak} for different targets.



(b) Mean (over 100 trials) absolute deviation of V_{leak} from the target for all neurons (black lines) and mean over all neurons. The error bars show the standard deviation over the neurons. The mean (over all neurons) deviation from the target shows no systematic deviation.



(c) Absolute trial-to-trial standard deviation over 100 trials for all neurons (black lines) and absolute neuron-to-neuron standard deviation over 512 neurons for 100 trials (yellow lines).



(d) Mean (over 512 neurons) absolute and relative trial-to-trial standard deviation and mean (over 100 trials) absolute and relative neuron-to-neuron standard deviation. The mean trial-to-trial standard deviation is smaller than the mean neuron-to-neuron standard deviation for all the target values. Between a target of 40 LSB and 70 LSB the absolute standard deviations increase and then above 70 LSB the standard deviations stay roughly constant. The relative standard deviation decreases with increasing target.

Figure 3.3: Distributions and properties of these distributions of the measured V_{leak} after calibration for different calibration targets on chip W63F3.

3.2 Crosstalk

As described in Chapter 2, crosstalk occurs with the current CapMem implementation, when a large number of CapMem cells in a quadrant is set to the same value .

For the parameter transformation model it is relevant to evaluate the crosstalk for two reasons. The first reason is that we do not want to model the influence of the CapMem cell setting on each other, because modelling these complex dependencies is difficult and would lead to a large number of parameters in the database. The second reason is that one can not simply measure all neurons in parallel when recording the observables as a function of the digital hardware parameters.

Figure 3.4 shows the distribution of the CapMem values of the default calibration for the first quadrant. The maximum number of cells with the same value is 19 and the other peeks have a height between 10 and 15. This can be used as a reference for the expected number of cells with the same value for a common calibration. For the lookup-based parameter transformation, the crosstalk effect should be evaluated in this region of the number of cells with the same value.

In this section different aspects of the crosstalk effect are investigated for the two model parameters τ_{mem} and V_{leak}.

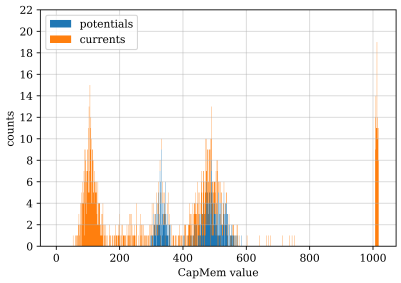
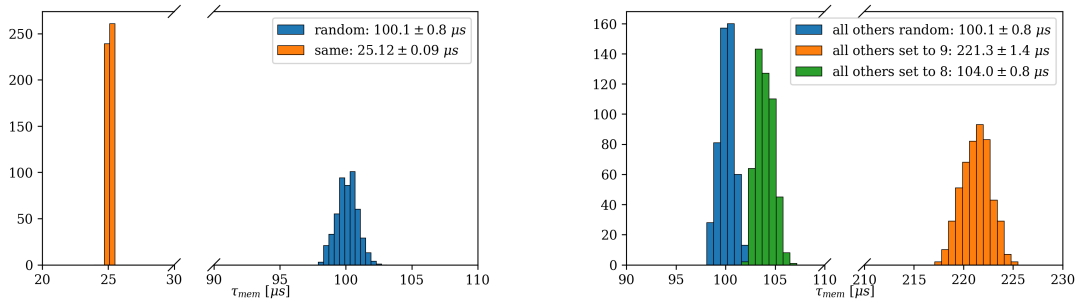


Figure 3.4: Distribution of the CapMem values of the default calibration for the first quadrant. Many cells are set to zero in the default calibration, but they are not shown in this histogram. The values for the current and potential cells are stacked in the plot. The histogram shows that the maximum number of cells with the same value is 19 and the other peeks have a height in the range of 10 to 15.

3.2.1 Membrane time constant

The synaptic input is disabled for all measurements of τ_{mem} in this section. The worst case would be if all voltage and all current cells in a quadrant were set to the same digital value [9]. However, we first measure the effect for CapMem cells in one row, i.e. what happens if the CapMem values of one parameter were set to the same value for all 128 neurons in one quadrant and for the rest of the parameters the default calibration is applied.

To investigate this, two opposing cases are compared. For the first case, where no crosstalk is expected, the digital CapMem value for τ_{mem} of the chosen neuron is set to 10, while the CapMem value for τ_{mem} of the remaining 127 neurons are chosen randomly between 0 and 1022, excluding 10. For the second case, all the CapMem values for τ_{mem} are set to 10. The measurement consists of 500 trials with 10 measurements each. The membrane time constant of the chosen neuron is the quantity that is measured. A trial here means that the CapMem values are set and a measurement means using the measure_results() function. New random parameters are drawn for each trial. Figure 3.5a shows the distribution of the mean (over the 10 measurements) of τ_{mem} over 500 trials for the two cases for neuron 0. One can clearly see the crosstalk effect, as there is a shift of $-75\,\mu s$.



(a) Distributions of the measured τ_{mem} (over 500 trials) for neuron 0 for two settings of the remaining neurons in the first quadrant. The case "same" means that all CapMem values for τ_{mem} in the first quadrant are set to the same digital value 10, "random" means that the CapMem value for τ_{mem} of neuron 0 is set to 10 and all others in the first quadrant are set to a random value between 0 and 1022 and not 10. The mean value for τ_{mem} shifts by 75 µs.

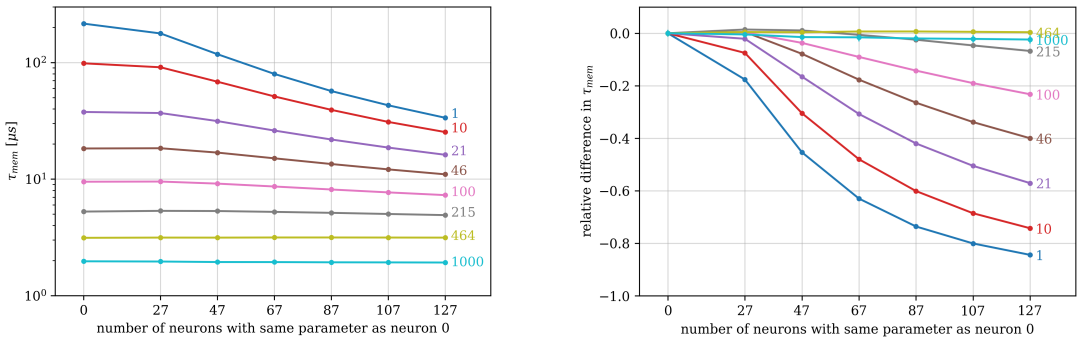
(b) Distributions of the measured τ_{mem} (over 500 trials) for neuron 0 for three settings of the remaining neurons in the first quadrant. The CapMem value of τ_{mem} for neuron 0 is set to 10, while all other neurons in the first quadrant are either set to 8 or 9 or to a random value between 0 and 1022 and not 10. For both cases (all others to 8 or 9) a shift of the mean can be observed.

Figure 3.5: Trial-to-trial distributions of τ_{mem} of neuron 0 on chip W63F3, while the setting of all other neurons in the first quadrant is changed.

A different aspect to investigate is, what happens when all 128 neurons except for the chosen neuron are set to a CapMem value which is one or two below or above the value of the chosen neuron. When setting neuron 0 to 10 and the rest to 11 no crosstalk effect is measured. But, when setting neuron 0 to 10 and the rest to 9 or 8, an effect is observed. Figure 3.5b shows that τ_{mem} shifts significantly to higher values in the case where all other neurons are set to 9, and in the case where they are set to 8, a small shift to lower values occurs. In order to check whether any other values have an impact on the chosen neuron, neuron 0 is set to 10 and all other 127 are varied in parallel from 0 to 1022. Only for 8,9

and 10, a significant shift was observed, but this measurement was only done with a small number of measurements trials. To be certain, that the other settings do not have an impact on neuron 0, more measurement trials would have to be done.

A calibration result is an object that contains the digital CapMem values, which are the result of a calibration, or in the case of the calibration database the result of the translation from target model parameters to digital hardware parameters. As shown in Figure 3.4, a calibration result where all digital parameters are equal is very unlikely, therefore we measure the effect for a smaller number of shared digital parameters. Additionally we measure the effect for different CapMem values. The measurement as described above is repeated, but with only 100 trials and the number of neurons that have the same CapMem value for τ_{mem} as neuron 0 is varied. The neurons for which the CapMem value for τ_{mem} is chosen randomly are selected randomly each trial. Figure 3.6a shows the mean over the 100 trials of the mean over 10 measurements of τ_{mem} for different CapMem values for τ_{mem} of neuron 0 as a function of the number of neurons that share the same CapMem value for τ_{mem} as neuron 0.



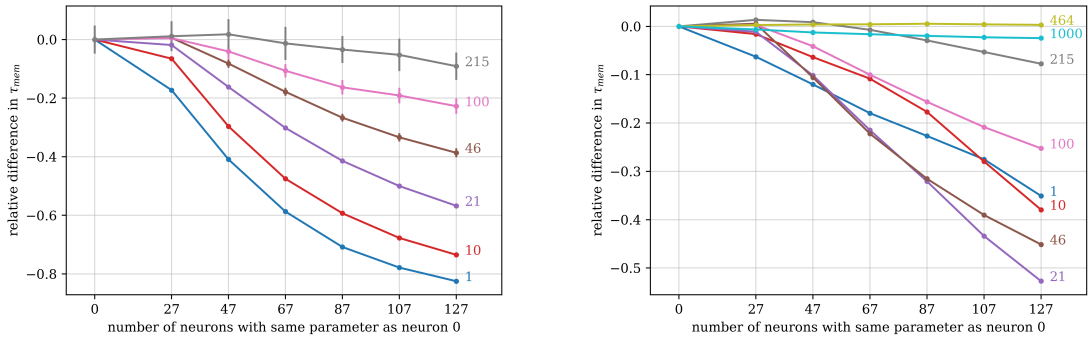
(a) Measured τ_{mem} of neuron 0 as a function of the number of neurons that share the same digital parameter for τ_{mem} as neuron 0 for different CapMem values (numbers in the plot).

(b) Relative difference in τ_{mem} compared to the value where zero neurons have the same CapMem value for τ_{mem} as neuron 0 for different CapMem values. As expected the absolute value of the difference increases with the number of cells with the same parameter. The difference decreases with increasing CapMem value.

Figure 3.6: Crosstalk effect for τ_{mem} as a function of the number of neurons that have the same digital parameter for τ_{mem} as the measured neuron 0. The numbers next to the curves indicate the CapMem values for τ_{mem} of neuron 0. Measurements were performed on chip W63F3.

Figure 3.6b shows the relative difference in τ_{mem} compared to the τ_{mem} where zero neurons have the same value as neuron 0. Relative means that the difference was divided by the value at zero. For this measurement leak division and multiplication are disabled. Furthermore, the default calibration is adjusted because many parameters are set to a CapMem value of 0

and as shown, crosstalk also occurs if a large number of cells is set to a value one below the value of the measured neuron. Thus, all cells with value 0 are set to 1022. The plots show that with increasing CapMem value, the relative as well as the absolute difference decreases. The maximum relative difference is around 90 %, but only in the case of 127 neurons with the same value as neuron 0.



(a) With multiplication enabled: relative difference in τ_{mem} with increasing number of cells with the same value as the cell for neuron 0 for τ_{mem}. Order of the curves with respect to the CapMem value and the trend of the curves is very similar to Figure 3.6b. The error bars for a CapMem value of 464 and 1000 were between 500 % and 1000 %, therefore the results were not plotted here. They might have been outside of the functional range.

(b) With division enabled: relative difference in τ_{mem} with increasing number of cells with the same value as the cell for neuron 0 for τ_{mem}. Excluding the results for a CapMem value of 1, the relative differences are ordered in the same way as in Figure 3.6b with respect to the CapMem values. The shape of the curves is different to the measurements without leak division. But the trend, that the absolute value of the relative difference increases and that the difference is negative does not change.

Figure 3.7: Same measurements as in Figure 3.6b but with leak multiplication/ division enabled and on chip W63F3.

The same plots are generated with either multiplication or division enabled. Figure 3.7 shows the results. The trend of the relative difference with respect to the number of neurons with the same parameter as well as the order of the difference with respect to the CapMem values is the same for the measurements with division or multiplication enabled as for the measurements with division and multiplication disabled except for a few exceptions.

As described above and shown in Figure 3.4, the relevant range for the calibration database in the plots where the x-axis shows the number of cells with the same digital parameter as neuron 0, is approximately between 0 and 20. For all the measurements (with multiplication enabled, with division enabled, as well as with multiplication and division disabled) the relative difference in range never exceeds 20 % for all tested CapMem values.

It is possible to change the settings of the ramp that generates the voltages and currents

in the CapMem for one quadrant, such that the ramp is slower, which can minimize the crosstalk effect. These changes (16441 and 16627) are not merged in the current version of calix. With this slower ramp the measurement from Figure 3.5a is repeated. Figure 3.8 shows that the crosstalk effect is minimized, however, the measured value for τ_{mem} is not the same as with the faster ramp.

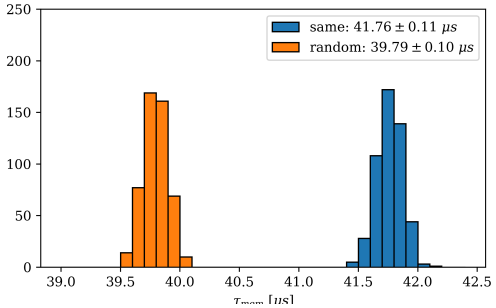


Figure 3.8: Same measurement as in Figure 3.5a on the same chip W63F3 but with the slower ramp (changesets 16441 and 16627). The shift due to crosstalk is smaller, but the measured value differs significantly from the value measured with the faster ramp.

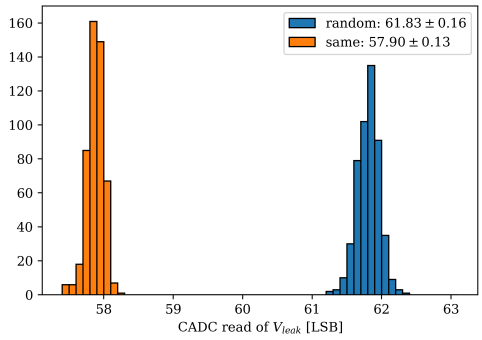
3.2.2 Leak potential

All the measurements in Section 3.2.1 are repeated for the leak potential.

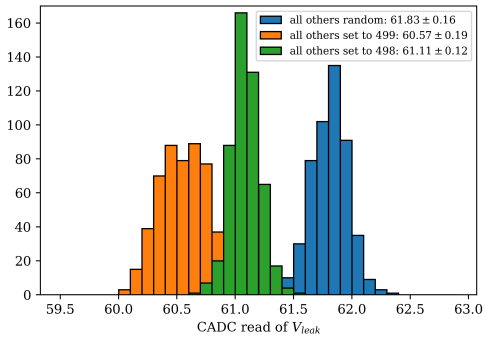
The first measurement is to apply the default calibration, then set all CapMem values in the row for V_{leak} in a quadrant to the same value (500) and measure V_{leak} of a chosen neuron. This is compared to the result when all CapMem values in the row for V_{leak} except for the value of the chosen neuron are set to a random value between 0 and 1022, excluding 500, while the value for the chosen neuron is set to 500. Figure 3.9a shows the result for neuron 0. This measurement is also done for neuron 31, 63 and 127 in order to check for a dependency of the crosstalk on the neurons position. For the tested neurons no significant difference was observed.

Next, all other CapMem values for V_{leak} in the quadrant are set to 499 or 498. Figure 3.9b shows the result and that these settings also lead to a shift of the measured V_{leak}.

Then, the number of cells that are set to the same value as the cell of neuron 0 in the row for V_{leak} is varied and different CapMem values for V_{leak} of neuron 0 are tested. In Figure 3.10 the relative difference in CADC read of V_{leak} is plotted as a function of the number of cells that are set to the same value as the cell for neuron 0 in the row of V_{leak}. In contrast to τ_{mem}, the relative difference does not increase with decreasing CapMem values but rather first moves to larger negative differences and then moves upwards and ends with a positive difference. The results for a value of 800 might look different because of edge



(a) Distributions of the measured V_{leak} (over 500 trials) for neuron 0 for two settings of the remaining neurons in the first quadrant. The case "same" means that all CapMem values for V_{leak} in the first quadrant are set to the same digital value 500, "random" means that the CapMem value for V_{leak} of neuron 0 is set to 500 and all others in the first quadrant are set to a random value between 0 and 1022, excluding 500. The mean value of V_{leak} shifts by 4 LSB.



(b) Distributions of the measured V_{leak} (over 500 trials) for neuron 0 for three settings of the remaining neurons in the first quadrant. The CapMem value of V_{leak} for neuron 0 is set to 500, while all other neurons in the first quadrant are either set to 499 or 498 or to a random value between 0 and 1022, excluding 500. For both cases (all others to 498 or 499) a shift of the mean can be observed.

Figure 3.9: Trial-to-trial distributions of V_{leak} of neuron 0 on chip W63F3, while the setting of all other neurons in the first quadrant is changed.

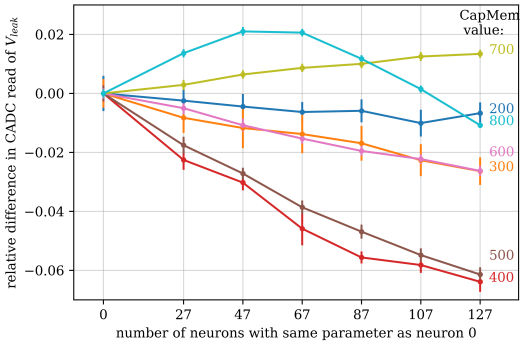


Figure 3.10: Relative difference in CADC read of V_{leak} as a function of the number of cells with the same value as the cell of neuron 0 for V_{leak}. The numbers indicate the CapMem value of neuron 0. For all CapMem values of neuron 0, excluding 800, the absolute value of the difference seems to increase monotonically with increasing number of shared parameters. From a value of 200 to 400 the absolute value of the slope increases and the slope is negative. Then, the slope increases from a value of 400 to 700, the slope of the curve for 700 is positive. The results for a CapMem value of 800 first increases and then decreases.

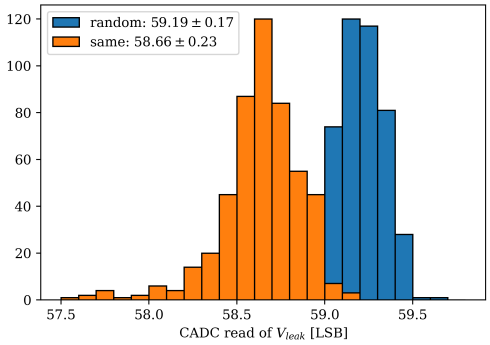


Figure 3.11: Same measurement as in Figure 3.9a but with the slower ramp. The shift due to crosstalk is smaller, but the measured value differs significantly from the value measured with the faster ramp.

effects. In the relevant range from 0 to 20, the relative difference does not exceed 2 %, which is an order of magnitude smaller than the difference in τ_{mem} in this region.

As for the membrane time constant, the crosstalk effect is measured with the slower ramp (changesets 16441 and 16627). Figure 3.11 shows that the shift of the CADC read of V_{leak} is smaller than for the fast ramp, but again, the mean value of V_{leak} with the slower ramp does not equal the measured value with the faster ramp.

4 Discussion

To sum up, in Section 3.1 the current calix calibration was evaluated. In the mean over all neurons no systematic deviation of the model parameters after calibration from the calibration targets was found for the membrane time constant and the leak potential. The measurement-to-measurement and neuron-to-neuron standard deviation was measured as a function of the target value. The neuron-to-neuron standard deviation was always larger than the measurement-to-measurement standard deviation. The behaviour of the standard deviation as a function of the target was not the same for the membrane time constant and the leak potential. These results and the scripts that were used for measuring can be used later to compare the current calibration to the results from the parameter transformation model.

In Section 3.2 the CapMem crosstalk effect of the current CapMem implementation was measured in order to evaluate the feasibility of the parameter transformation model. The range of interest for the number of CapMem cells with the same value was found to be from 0 to 20 cells. First, the case, where all cells in one row of one quadrant are set to the same digital parameter, was measured, to have an estimation of the crosstalk effect in a bad case. There was maximum shift of $-75\,\%$ in τ_{mem} and a maximum shift of $-6\,\%$ in V_{leak}. We also investigated the behaviour when all other cells in one row in one quadrant were set to digital values close to the value of the measured neuron. A shift in V_{leak} and τ_{mem} was observed for values one and two below the value of the chosen neuron. The shift for two below was smaller than the shift for one below. This was only investigated for one CapMem value of the chosen neuron, for a more fundamental statement (i.e. independent of the CapMem value of the chosen neuron) more measurements would need to be done.

Another measurement that was only done for one CapMem value of the chosen neuron, was to not only test for one or two values below, but for all settings of the cells of the row of τ_{mem} where all neurons, except for the measured neuron, have the same value. This measurement was only performed with a small number of measurement trials, which means that for a certain result one would need to do more measurement. For this quick sweep no other values were found where a shift of τ_{mem} of the chosen neuron was observed. The most interesting measurement for the parameter transformation model is the measurement where the number of cells with the same parameter was varied, because here the crosstalk effect can be evaluated in the relevant range of the number of cells with the same digital setting. For τ_{mem}, the relative difference in τ_{mem} never exceeded $20\,\%$ in the range from 0

to 20 cells with the same value. For V_{leak}, the relative difference stayed below 2 % in the relevant region. These results mean that the crosstalk effect is not strong enough to lead to the conclusion that the parameter transformation model is not feasible. In these results the effect of the CapMem values one and two below was not taken into account. Thus, an interesting measurement to investigate the crosstalk effect further, would be to set a certain number of cells to the same and a certain number to a value one or two below the value of the measured neuron. Furthermore, if one would be interested in the CapMem crosstalk and not in the effect of the crosstalk on the model parameter, one could measure the currents and voltages generated by the CapMem directly.

In summary, in this report, first steps were taken towards the implementation of the calibration database, by evaluating the current fixed-point calibration in order to have a comparison and by assessing that the current CapMem crosstalk problem does not hinder the implementation of the database.

5 Outlook

In this section the next steps towards the lookup-based parameter transformation model are shortly discussed.

First, the model parameters need to be measured as a function of the according CapMem values. For the measurements, it is important to take the crosstalk effect into account, i.e. to not measure a neuron while other neurons have the same CapMem value.

Then, thought needs to be put into which kind of functions will be fitted to the measurements. In addition to a fit function, we might want to find and store a functional range of the parameters. Another aspect regarding the fits is, that there might be dependencies between the different model parameters, that we want to model in the transformation, which means that one might need higher dimensional fit functions.

The next step is to develop a query interface and parameter representation. Some concepts could be adopted from the calibration database for BrainScaleS-1 [4]. A way to allow for dependencies between parameters needs to be worked out.

Lastly, the calibration from the database can be evaluated with the scripts used in Section 3.1 and compared to the results in Section 3.1.

All these steps will first be carried out for the leak potential and the membrane time constant (separately). Later, a transformation for all other model parameters will be developed, and dependencies between the parameters will need to be considered.

Acronyms

AdEx adaptive exponential integrate-and-fire

ASIC application-specific integrated circuit

BSS-2 BrainScaleS-2

CADC columnar analog-to-digital converters

CapMem capacitive memory

MADC membrane analog-to-digital converter

OTA operational transconductance amplifier

6 References

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