Independent Noise Working Group

Wind Turbine Amplitude Modulation & Planning Control Study

Work Package 8.1
Appendices

Review of WSP/Parsons Brinckerhoff and Institute of Acoustics Amplitude Modulation Studies

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Objective:

To review the wind turbine amplitude modulation reports of WSP/Parsons Brinckerhoff and the Institute of Acoustics amplitude modulation working group and then to make appropriate recommendations to government.

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INWG critique of Institute of Acoustics Amplitude Modulation Working Group final report

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INWG critique of Institute of Acoustics Amplitude Modulation Working Group final report:

'A method for rating amplitude modulation in wind turbine noise'

Note: These comments and observations are referenced as per the sections of the Institute of Acoustics report

Executive Summary

Para 0.1.2 states the intent to regulate AM only from new wind turbine developments. There being no intention to regulate AM from the large number of existing wind turbines causing noise complaints.

Para 0.3.1 rules out any intention of measuring noise indoors despite the fact that most AM complaints relate to wind turbine noise experienced inside homes.

Introduction

Para 1.1.1 claims that the working group (AMWG) '*includes academics, representatives from wind farm developers and local authorities and acoustic consultants who have worked for developers, local authorities and objector groups*' as a demonstration of their impartiality. This is clearly misleading as all AMWG members are either directly or indirectly associated with the wind industry supply chain with the obvious conflict of interest.

At para 1.1.3 the authors lead the reader to understand that AM was first identified during 2002 to 2004 by Fritz van den Berg. This is misleading as AM was described in detail during the 1980s by NASA in the USA and later by others but has been ignored by the wind industry until recently.

AM Definition

At para 2.1.2 this definition is challenged where it claims AM is restricted to a frequency related to blade passing frequency. There are reports of AM also being related to blade and tower resonant frequencies. These resonant frequencies are close to but not exactly the same as the variable blade passing frequency. Also noise signatures become confused when there is more than one turbine due to them operating independently and at different speeds.

Para 2.1.5 repeats the intention stated at para 0.3.1 not to measure noise indoors.

Appendix A - January 2017

Outcome of Consultation Responses & Selection of Metric

The consultation responses have been glossed over with no serious attempt to answer the many consultation response criticisms. Also the arguments favouring the selection of the hybrid method at para 3.1.5 are brief and unsubstantiated.

Reference method

Overview of method

At Para 4.2.5 the 3rd bullet identifies that that the fundamental plus the next two harmonics are selected. There must be doubt that this is sufficient for the complex AM waveforms typically experienced. It is suggested higher harmonics should be included in the analysis to ensure most of the waveform power is captured.

Para 4.2.3 assumes the modulation occurs at blade passing frequency. This leads to concern where the modulation is not occurring at the blade passing frequency of a particular turbine. This may be due to the AM being the result of blade or tower resonance or the result of multiple turbines operating at slightly different speeds. The report does not seem to recognise the multi-turbine AM effect.

Para 4.2.9, Figure 4.2.1 identifies that the data is filtered into 3 bands, 50-200, 100-400 and 200-800 Hz. This is a change and improvement from the previous proposal where only 200-800 Hz was examined. This should overcome the previous objection that everything less than 200 Hz or 100 Hz was ignored however; frequencies below 50Hz are still ignored.

Para 4.3.9 argues against making audio recordings due to the large data storage requirement. This seems to be a weak argument given the relatively low cost for data storage. Audio recordings are considered essential for confirming the occurrence and severity of AM.

At para 4.4.4 and 4.4.5 there is concern that requiring at least 50% valid samples during each 10 minute period will exclude sporadic but intrusive nuisance AM. Listening to audio recordings will readily enable the presence or not of AM to be confirmed.

At para 4.4.10 the report essentially recommends the application of an AM penalty to be applied to the ETSU noise limits. This method was proposed in the ReUK report and subsequently shown to fail to control AM in even the worst cases.

Concern at para 4.7.4 'Analysis parameters' and elsewhere that use of $L_5 - L_{95}$ over 10 secs will miss some of the higher peaks due to the averaging effect.

It is believed that excluding the indicative method as at para 4.8.13 when AM is being assessed against a limit as may be specified in a planning condition will make it much more difficult to enforce the control of nuisance AM.

Appendix A - January 2017

Instrumentation

On-line AM measurement

Para 5.3.1 and 5.3.2 Given the widespread disagreement on how to measure and calculate AM, we are long way from an automatic AM measuring instrument that would give confidence to both practitioners, local authorities and those affected by AM.

Sound level logging equipment

Para 5.4.7 specifies the lower limit of instrument linearity of 25dB(A). This is far too high as night time noise levels in rural locations can be lower than 20dB(A). The measurement 'floor' of the specified sound level meters will ensure that in quiet rural locations the measurement will under record the true peak to trough of AM under these conditions. This is particularly important under low wind speed conditions when AM peak to trough is known to exceed 11dB.

Contrary to para 5.5.1, audio records are essential when investigating AM noise complaints and demonstrating compliance with AM limits. The need for audio recordings is however, confirmed at para 6.1.3. An obvious conflict within the report as to whether the authors are recommending for or against audio recordings.

Evaluation of method against adopted success criteria

Para 7.1.3 Reality: The report provides no evidence of the results of trials on real wind turbine noise data. Without thorough testing on real noise data the success criteria listed cannot be claimed to have been achieved. It is essential that the AMWG methodology is thoroughly tested using real turbine noise data.

Para 7.1.5 proposes the AMWG method only applies to free-field external measurements. In reality nuisance AM is usually experienced inside buildings so should be measured wherever the AM nuisance is experienced.

The AMWG terms of reference (appendix A) and scope of work (appendix B) has been reviewed and commented upon by the INWG at their AM report, work package 8 dated 27 July 2015. These criticisms are still valid after the release of the AMWG final report one year later.

After reviewing the AMWG report, the INWG conclusions from work package 8 still apply, "*This chronology of the activities by the IoA shows that its NWG and specialist subgroup the AMWG devoted to the study of excess amplitude modulation have consistently operated for the benefit of the onshore wind industry in the UK and to the detriment of local communities hosting wind turbines. This is also arguably against both the IoA code of ethics and that of the Engineering Council. The effect has been to both obfuscate and hide problems related to wind turbine noise assessment from government and from the Planning Inspectorate. Whether or not this behaviour is carried forward into the future remains to be seen (July 2015)*".

Appendix C: IOA AMWG responses to consultation document

The report claims 20 consultation responses were received although only 19 were published with the AMWG report. See summary table below. Of these responses, author names were withheld from 4 responses. Since all four of these responses were supportive of the AMWG proposals it can reasonably be assumed these response authors are 'close' to the AMWG and require anonymity to avoid embarrassment.

Out of the 19 responses, 11 are generally supportive of the AMWG proposals. Of these 11 supportive responses, 10 are from identified wind industry supply chain organisations plus one local authority representative. 5 other responses were critical or highly critical of the AMWG proposals. 3 responses are considered neutral with 2 or these 3 relating to peripheral issues only, (wind shields and standards).

The AMWG has only provided a selective summary of responses allowing them to 'cherry pick' topics and avoid addressing the many inconvenient criticisms made by responders' including the conflicts of interest by the AMWG members.

Appendix A - January 2017

Summary of AMWG Consultation Responses

Page	Author	Organisation	Wind industry supply chain	Critical of AMWG	Comments
1	Chris Jordan	Mid & East Antrim BC	No	No	Generally supportive of the AMWG proposals
8	Name withheld	Name withheld	unknown	No	Generally supportive of the AMWG proposals
31	Name withheld	Name withheld	unknown	No	Generally supportive of the AMWG proposals
43	Jon Cooper	Resonate Acoustics, Australia	Yes	No	Generally supportive of the AMWG proposals
52	Carlo Di Napoli	Pöyry Finland Oy	unknown	Neutral	Prefers time series method
62	Duncan Stigwood	MAS Environmental	No	Yes	Comments relating mainly to data analysis
71	Sarah Large	MAS Environmental	No	Yes	Highly critical in multiple areas
81	Dick Bowdler	Dick Bowdler	Yes	No	Surprisingly few comments
89	INWG	INWG	No	Yes	Highly critical in multiple areas
100	John Yelland	John Yelland	No	Yes	Highly critical in multiple areas
111	Name withheld	Name withheld	unknown	No	Generally supportive of the AMWG proposals
119	Dave McLaughlin	SgurrEnergy	Yes	No	Generally supportive of the AMWG proposals
127	Name withheld	Name withheld	unknown	No	Generally supportive of the AMWG proposals
135	Matthew Cassidy	RES	Yes	No	Generally supportive of the AMWG proposals
144	Claire McKeown	SSE Renewables	Yes	No	Generally supportive of the AMWG proposals
152	Tom Levet	Hayes McKenzie Partnership	Yes	No	Coments re analysis, freq range, harmonics etc
162	Lee Moroney	REF	No	Yes	Highly critical in multiple areas
175	Richard Tyler	AVI Ltd	Yes	Neutral	Concerns re windshields only
176	Susan Dowson	National Physical Laboratory	No	Neutral	Minor comments regarding standards only

Appendix B

INWG critique of WSP/Parsons Brinckerhoff AM paper, Inter.noise 2016

Appendix B - December 2016

INWG critique of WSP / Parsons Brinckerhoff paper 'A review of research into the human response to amplitude-modulated wind turbine noise and development of a planning control method'

Comments and observations

These comments follow the format of the WSP/Parsons Brinckerhoff paper dated August 2016 and include the same section references.

Introduction

The author's statement '*the extent of the issue is not fully understood*' would appear to be an attempt to continue with the mystery of amplitude modulation (AM) while ignoring the large number of technical publication and scientific evidence that explain the phenomenon in considerable detail.

The author then goes on to downplay the significance of AM again ignoring the large body of evidence to the contrary.

The author's statement '*The emergence of a form of AM that could be audible at long distance and with a lower frequency character*' implies that AM is something that has only recently arisen. This ignores the large body of evidence and understanding of AM from as far back as the 1980's as documented in the INWG report work package 2.1.

However the author has agreed for the need to control AM if only at new wind farms.

Project Overview

Aims

The declared statement regarding a suitable control method is that '*this could take the form of a rating penalty system, similar in concept to existing approaches to quantifying acoustic characteristics in wind turbine and environmental noise*' leads the reader to conclude the authors were producing their report to justify an already determined and convenient control methodology before examining the scientific facts.

Review of Evidence

The authors claim to have considered the INWG reports. However, we need to review the full PB report in order to comment further.

Potential for Bias

A recognition of the potential but no detail of how they dealt with it.

Appendix B - December 2016

Outcomes

Discussion

An admission of a 2dB (peak to trough) threshold of perception of AM and that adverse impacts increase during the night-time and the statement "*The evidence reviewed supports the proposed use of a penalty regime for AM in WTN"*.

Proposed Planning Control

Planning Context

The statement '*The AM control has only been designed for use with new planning applications; applicability for use in Statutory Nuisance investigations on existing wind turbine sites, where the legal regime is different (and outside the research scope), has not been considered*' demonstrates the futility of this report when we have large numbers of existing wind turbines causing AM noise related complaints and realistically only a few new wind turbines are now likely to be built if the current Government policy continues.

Key Elements

The author continues the wind industry misinformation regarding the predictability of AM with the statement '*the likely occurrence cannot be reliably predicted at the planning stage with the current state of the art*' whereas there is sufficient evidence as detailed in the INWG reports that AM can be reliably predicted for all wind turbines.

The author clearly endorses the IoA AMWG hybrid time and frequency domain method for rating AM despite any evidence that this method has been tested with real data.

The author then proposes essentially the same penalty approach proposed in the discredited 2013 ReUK AM study. This method proposes adding a sliding penalty to the ETSU rated time averaged noise level. This provides for a 3dB penalty at a 3dB AM modulation depth (MD) rising only 2dB (to 5dB) at 10dB MD and greater. (An attempt to justify the 3dB threshold has been made in the report but not for the other values) The main difference to the previously proposed RUK method is to include an additional penalty during the night being the difference between the day and night limits. There is no recognition that AM can and should be treated independently and separately from the ETSU time averaged noise levels.

The author does recognise that the AM penalty may not breach the ETSU limit during the night time without the additional penalty. However, since complaint causing AM typically occurs when background noise levels are low it is considered highly unlikely even with the additional penalty that the ETSU noise limit would ever be breeched and the AM control triggered. The authors clearly have not tested their proposal and only independent testing with confirm.

The author then goes on to state that even if the control is triggered it is down to 'professional judgment' to trigger enforcement and then proposes a 2 to 5 year testing programme for a number of sites from planning approval being granted.

Appendix C

INWG critique of WSP/PB report titled 'Wind turbine AM review'

Appendix C – December 2016

INWG critique of WSP / Parsons Brinckerhoff report 'Wind Turbine AM Review'

Comments and observations

The review and report into wind turbine amplitude modulation (AM) dated August 2016 was prepared by WSP/ Parsons Brinckerhoff under a contract to the Department of Energy and Climate Change (DECC). Since the contract was awarded, DECC has been absorbed into the new government Department for Business, Energy & Industrial Strategy (DBEIS). The report was released by DBEIS onto their website on 25 October 2016.

The report consists of two parts, a Phase 1 report and a Phase 2 report. Phase 1 sets out the contractors approach and methodology for the review. Phase 2 describes the review and findings including recommendations for elements of a planning condition for controlling excessive AM.

These INWG comments follow the format of the WSP/Parsons Brinckerhoff reports and include the same section references for ease of cross referencing.

Phase 1 Report – 15 pages plus appendices, a total of 29 pages

The phase 1 report sets out the approach and methodology for the review. This document describes what would appear to be a professional approach with the exception of the apparent greater weight to be given to evidence from the RenewableUK (ReUK) report released during 2013.

Introduction

Para 1.1.4 defines the objective of the review as: '*The objective of this project is to review the current evidence on the human response to AM, the factors that contribute to human response (such as level, intermittency, frequency of occurrence, time of day, etc.), and make a recommendation to Government on how to decide what AM controls could be implemented, and the likely impact of that decision in relation to current Government planning policy, and potential health effects*'.

Study Aims Para 1.2

Items 1 and 3 would seem to give special priority from the very beginning of the review to the ReUK AM study published December 2013.

Methodology

Proposed approach Para 2.1.1 under Phase 2 would also seem to give special priority to the ReUK work at the 1st and 3rd bullet items.

Appendix C – December 2016

Project Timeline at Para 2.8.1
It is noted that the updated project program indicates the final report should have been released by 12 Feb 2016. The actual release date was during August 2016 and no explanation for the delay is given.

Phase 2 Report – 88 pages plus appendices, a total of 117 pages

Production Team

This page identifies the three members of the WSP/PB internal research team and the three independent external reviewers. Additionally, the report indicates that DECC commissioned three peer reviewers although their identities, qualifications and affiliations are not provided. (The identities of the three peer reviewers have since been provided by the WSP/PB authors at the IoA seminar held on 7 December 2016.)

Non-Technical Summary

The review confirms that there is sufficient robust evidence that excessive AM leads to increased annoyance from wind turbine noise and should be controlled using suitable planning conditions. The non-technical summary is otherwise not very informative.

Executive Summary

At page 2, 4th para it should be noted that the acoustic descriptor $L_{A90,\ 10min}$ is the sound level exceeded for 90% of the time and averaged over 10 minutes. Although this is a suitable acoustic descriptor for measuring steady noise levels such as road traffic noise it will not identify intermittent sound or wind turbine amplitude modulation. Also the continued use of ETSU-R-97 (ETSU) has been widely criticised and is discussed in detail in INWG work package 10 (INWG WP10 was not reviewed by WSP/PB) with the strong recommendation that ETSU be replaced with a procedure based on the principals of BS4142:2014.

At page 3 the conclusions from the Category 1 studies confirm the experiences of those complaining of wind turbine noise. That wind turbine like sounds known as amplitude modulation are more annoying than similar noise levels without modulation. Also a confirmation that the perception level for AM is around 2dB modulation depth (peak to trough) with increasing modulation depth associated with increasing annoyance.

These conclusions are supported by the Category 2 papers reviewed including the association of wind turbine noise related annoyance with increased risks of sleep disturbance and stress. Additionally, the annoyance increases during normal resting periods during the late evening, night-time and early morning.

At page 4 the report notes that the prevalence of unacceptable AM has not been evaluated as part of the study. This would appear to be a critical failure of the WSP/PB study.

The report also claims that AM cannot be predicted at the planning stage such that the default position for a decision maker should be to apply an AM planning condition unless

there is good reason not to. The review also concludes that: '*where there are high levels of AM, the adverse effects could be significant. On this basis a control for AM is required*.'

The report claims to have reviewed three existing methods of control; the Den Brook condition, The ReUK sample condition and BS4142:2014. However, the prominence given to the ReUK study in the Phase 1 report and elsewhere would indicate that there was an intention from the very beginning of the review to adopt the ReUK proposals.

The WSP/PB proposals for a penalty scheme outlined at page 5 will be critiqued separately. Additionally, there is an acknowledgement by the authors at the 5th listed item of the increased sensitivity to noise annoyance during the night-time.

Introduction

The AM study and report mentioned at Para 1.1.6 and conducted by the IoA AMWG is critiqued separately by the INWG.

Evidence Review Methodology

At Para 2.3.2 it is noted that only the internal research team reviewed the category 2 papers. As a result the independent external examiners will have likely been unaware of most of the evidence claimed to have been reviewed.

At Para 2.3.5 it is noted that generally only papers released since 2000 have been considered.

Para 2.3.10 states that the 1st draft of the review was completed on 16 March 2016.

Stakeholder Responses

Confirmation at Para 3.1.1 that the papers (reports) from the INWG study have been considered.

Category 1 Papers - Conclusions

The main conclusions from the laboratory and field test environments at Para 3.2.46 include:

- '*Increasing overall time-averaged levels of AM WTN-like sounds showed a strong and significant association with increasing ratings of annoyance'*.
- *'The onset of fluctuation sensation for a modulating WTN-like sound appeared to be in the region of around 2 dB modulation depth'*.

Category 2 Papers

Human Response to Wind Turbine Noise Exposure (Health Effects)

Para 3.3.85 discusses the health related literature reviewed by WSP/PB. It states that 30 papers were considered with just 10 papers shown at Para 3.3.86 having been reviewed for their study. In contrast the review conducted by Hanning for the INWG work package 3.2 considered over 100 papers and reports.

The conclusions at Para 3.3.87 show: '*There is strong evidence to show that exposure to WTN can cause increased annoyance amongst exposed populations'*. The report then goes on to speculate and focus on the numerous non-acoustic factors that potentially could be contributing to the annoyance that some people feel but offers no supporting evidence. This would appear to be a subtle attempt to shift the blame for noise complaints from the source of the noise to the attitude of the complainant.

Then at Para 3.3.88 the report claims '*that at the current time there is insufficient evidence to indicate that the AM component in WTN at typical exposure levels directly causes any significant adverse effects beyond increased annoyance'*. This contradicts the WSP/PB statement at the executive summary at page 3: '*The Category 2 papers reviewed in section 3.3 provide supporting evidence that there is a potential association between WTN-related annoyance and increased risks of sleep disturbance and stress*'.

The above claim at Para 3.3.88 also contradicts the findings of Hanning at INWG work package 3.2. This though is perhaps unsurprising given the limited and selective nature of the evidence reviewed by WSP/PB as shown above. Para 3.3.88 would appear to be an attempt by WSP/PB to close off any further debate concerning the health effects of WTN.

The WSP/PB comments at Para 3.3.90 would appear to be a poorly argued attempt by the authors to dismiss any evidence concerning the health effects of WTN. These issues are commented on further at Paras 3.3.136 to 3.3.138 concerning INWG work package 3.2.

Wind Farm Publications Produced by an Independent Noise Working Group

Work Package 1: The fundamentals of amplitude modulation of wind turbine noise (Yelland, 2015)

The WSP/PB report is initially positive regarding the technicalities of AM as described in WP1 but then becomes dismissive and negative when faced with criticisms especially of ETSU and the ReUK report. No constructive attempt has been made by the WSP/PB authors to rebut the scientific evidence presented in WP1.

Work Package 2.1: Review of reference literature (Cox, 2015)

At Paras 3.3.114 to 3.3.122 the WSP/PB authors have selectively chosen a small number of areas from WP2.1 for negative criticism. They provide a distorted view of the work package ignoring the body of evidence, much of it inconvenient to the WSP/PB authors as presented in the literature and summarised in the work package.

An example of this misrepresentation is illustrated by the comments at Para 3.3.119 dismissing the INWG conclusions regarding ETSU. However, unlike the WSP/PB author opinions, the INWG conclusions are based on reviews of literature by others including Bowdler, July 2015 and the Northern Ireland Assembly (NIA) report, January 2015. The extensive and thorough NIA report was especially critical of ETSU making the recommendation to '*review the use of the ETSU-R-97 guidelines on an urgent basis*'. Significantly the NIA report has not been included in the WSP/PB literature review despite being highly relevant to the AM study requested by DECC. The WSP/PB authors will be fully

aware that replacing ETSU as recommended in the NIA report would completely undermine their own report conclusions and recommendations.

Work Package 2.2: AM Evidence Review (Large, 2015)

The WSP/PB authors are highly dismissive of this work package and make no mention of the extensive volume of noise data presented by Large as evidence of AM. There still seems to be a reluctance by the WSP/PB authors to accept that AM is not rare, that it is being generated by the majority if not all wind turbines and that under certain meteorological conditions adverse AM can occur for long periods of time.

Work Package 3.1: Study of noise and AM complaints received by local planning authorities in England (Sherman, 2015)

Once again the WSP/PB authors are dismissive of this work package despite the survey limitations being highlighted by Sherman. WP3.1 is the most comprehensive survey of this type to date and despite its limitations served to confirm and highlight that wind turbine noise complaints are much more widespread than the wind industry has admitted. These findings disprove the findings of the widely criticised 'Salford report', (Research into Aerodynamic Modulation of Wind Turbine Noise, University of Salford July 2007) where it was claimed that incidences of AM were rare and stated '*The low incidence of AM and the low numbers of people adversely affected make it difficult to justify further research funding*'.

The INWG survey also highlighted the inconsistent approaches by local authorities across the country in dealing with wind turbine noise complaints due to the lack of useful guidance. Additionally, local authorities expressed the need for guidance that works for and protects communities regarding operating wind farms.

Work Package 3.2: Excessive amplitude modulation, wind turbine noise, sleep and health (Hanning, 2015)

The WSP/PB authors have ignored the findings and conclusions presented by Hanning having reduced the 47 page WP3.2 down to less than half of a page of misleading comment. They have reproduced their own version of what is claimed to be Henning's conclusions. It is suggested that this is an attempt by the WSP/PB authors to keep the health effects arising from WTN and criticism of ETSU out of their report. It being more convenient to claim that excessive AM is confined to causing annoyance only.

An example of this misrepresentation by WSP/PB is the first listed conclusion at Para 3.3.137 that claims to quote Hanning as stating, '*Current setback distances for wind turbines recommended by ETSU are not safe for health*'. Whereas the actual conclusion by Hanning from WP3.2 Para 5.73 states, '*It is abundantly clear that wind turbine noise adversely effects sleep and health at the setback distances and noise levels permitted in the UK by ETSU. There is no reliable evidence at all that wind turbines are safe at these distances and noise levels, not a single study. In contrast there is an increasing volume of studies outlined here to the contrary*'.

The WSP/PB critique consists merely of opinion with their conclusions echoing the WP3.2 conclusions while downplaying the significance. This difference of opinions may be partly due to the very limited selection of health related literature has been reviewed by WSP/PB with just 10 papers and reports reviewed in contrast to the over 100 reviewed by Hanning for WP 3.2. It should be noted that Hanning is a leading sleep expert in his own right and suitably qualified to evaluate the relevant literature. However, the WSP/PB authors have gone some way to admitting that wind turbines do adversely affect sleep. This in itself is another significant admission from the wind industry.

The adverse effects of WTN on sleep have also been demonstrated in a recent paper; Smith et al (September 2016) Physiological effects of wind turbine noise on sleep that concludes, '*Physiological measurements indicate that nights with low frequency band amplitude modulation and LAEq,8h=45 dB, slightly open window (LAEq,8h=33 dB indoors) impacted sleep the most. In particular, amplitude modulation and the presence of beating were important constituents of the wind turbine noise contributing to sleep disruption*'. These findings support the conclusions reached by Hanning at WP3.2 and demolish the theoretical basis behind the AM control scheme advocated by WSP/PB in that simply reducing the overall noise level will alleviate the problems associated with AM.

Work Package 4: Den Brook (Hulme, 2015)

The WSP/PB authors have not presented any significant objections at Paras 3.3.139 to 3.3.143 to this work package but have misrepresented the situation regarding the Den Brook AM planning condition. Concern is heightened by the commentary beginning with a footnote [42] clearly miscomprehending and so misrepresenting events surrounding the Den Brook AM conditions. Three iterations are incorrectly stated to have taken place with a 'final' AM condition erroneously said to be in the form of an "amendment" by the wind farm's developer.

The reality, however, is that the extant AM conditions in fact remain precisely as drafted and imposed by the Government Inspector on his granting of planning approval for the Den Brook wind farm in 2009. Neighbourhood legal challenges since have resulted in important clarifications and ratification of the AM noise conditions by the Court of Appeal. To amend the conditions as suggested at both b) and c) of the footnote would of course be unlawful as no section 73 planning application for such has been progressed through to a conclusion.

A requirement of the conditions has however been discharged and resulted in measures being introduced arguably designed by the applicant to significantly water down the AM noise control parameters that were specifically set for planning permission to be awarded. Whereas, the sole conclusions drawn and outlined by the WSP/PB authors' mirror only unsubstantiated assertions of unenforceability. Moreover, that the Court of Appeal's crucial clarification and unequivocal ratification of the AM conditions appears to have escaped any attention from the WSP/PB authors suggesting a perhaps less than thorough or objective review.

Nonetheless, the WSP/PB review reasonably concludes that the process outlined in Work Package 4 was "*conflictual*" at times. However, to state that the issues generate high levels

of emotion might be more appropriately defined in terms of ongoing, deep and widespread concern.

Work Package 5: Towards a draft AM condition (Large, 2015)

The WSP/PB authors have mostly commented positively to WP5 but have glossed over much of the 161 pages. However the concluding Para 3.3.158 is misleading. The WSP/PB authors misquote WP5 as recommending that ETSU is one of two methods for assessing and controlling excessive AM. WP5 is clear at para 1.10 that it recommends that ETSU should only be used where noise from the wind farm is steady, benign and anonymous; this being when AM is at very low levels. For the assessment and control of excessive AM then WP5 recommends that BS4142:2014 be used and at para 11.6 states '*Where there are generic wind farm noise complaints, including noise level, noise character etc, BS4142 should be used as a stand-alone assessment independent of any other assessment, for example ETSU-R-97 compliance'*.

Work Package 6.1 (inc. 6.1A): Legal issues: the control of excessive amplitude modulation from wind turbines (Cowen, 2015)

The WSP/PB authors' state WP6.1 is a carefully written legal review and make no objections to the conclusions reached. This includes the need for a suitable AM planning condition to be imposed in every planning condition for a wind turbine unless there are clear reasons to show that it is unnecessary.

Work Package 6.2: Control of AM noise without an AM planning condition using Statutory Nuisance (Gray, 2015)

The WSP/PB authors state that a '*reasonable case is made here'* and seem to agree with the conclusions reached including that Statutory Nuisance law is ineffective and that only an AM planning condition could be effective in controlling excessive AM.

Work Package 8: Review of Institute of Acoustics amplitude modulation study and methodology (Cox, 2015)

The WSP/PB authors dodge the evidence presented at WP8 concerning conflicts of interest by simply stating at Para 3.3.178 that it is outside the scope of their review. The WSP/PB authors then ignore the bulk of WP8 confining their comments to para 49 concerning the AMWG consultation that is reproduced as seven bullet items at Para 3.3.179 stating '*this is a useful critique of the IoA AMWG consultation that is of direct relevance*'. The following Para 3.3.180 then attempts unsuccessfully to respond to just three of the bullet items.

Work Package 9: The Cotton Farm monitor experience (Gray, 2015)

The WSP/PB authors make minimal comment regarding WP9 and at Para 3.3.186 indicate that WP9 is not of relevance to their study for DECC. At Para 3.3.183 there is a cautious note regarding an opportunity to undertake dose-response analysis from the Cotton Farm data. This contrasts with the statement by the WSP/PB presenter at the August 2016 Internoise conference at Hamburg when this report was presented. The WSP/PB presenter in response to a question from the audience denied knowledge of any extensive AM noise data available in the UK. However, it is well known in the industry that data has been collected from Cotton Farm for almost four years.

Institute of Acoustics Method for Rating AM

Para 3.5.1 states that a draft of the final report 'A method rating amplitude modulation in wind turbine noise' was made available to the WSP/PB project team during January 2016. However, the report was not released by the IoA until August 2016. This begs the question as to why the IoA report was held back for so long.

The WSP/PB authors then describe in just over one page details taken from the IoA AMWG report. There is no attempt to critique or question any aspect of the proposed measurement methodology including the most obvious being the lack of testing with real turbine noise data. The INWG have critiqued the IoA AMWG report separately.

Factors Affecting Development of a Planning Condition

The INWG believe that at Para 4.1.5 the last bullet item should also state that if the level of AM cannot be reduced using engineering methods then the AM control method may require the turbine to be shut down during breach conditions. The WSP/PB authors have avoided mentioning that in order to mitigate against excessive AM, turbines will need to be stopped during the conditions that excessive AM occurs.

Other Potential Planning Condition Methods

Para 4.4.2 is where the WSP/PB authors argue against and summarily dismiss the use of the BS4142:2014 method to control AM. The claim that BS4142 has not been tested in the field is weak when compared to the slightly modified version of the ReUK penalty method as is being proposed by WSP/PB. There is no evidence the WSP/PB scheme has been tested at all whereas the very similar ReUK penalty method has been tested by INWG and shown to fail to protect against even the most extreme cases of AM as described at INWG WP5. BS4142:2014 is the latest UK standard for noise assessments for all types of industrial noise that could and should include wind turbine noise.

Threshold of Excessive AM

Para 4.5.4 makes the statement '*modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3 dB(A) (peak to trough)… if there are more than two hard, reflective surfaces then the increase in modulation depth may be as much as +/- 6 dB(A) (peak to trough)*'. Introducing the effects of hard reflecting surfaces is irrelevant since ETSU requires measurements to be taken in free field conditions and away from hard reflecting surfaces. This paragraph would appear to be an attempt by the WSP/PB authors towards justifying an increase from 3dB to 6dB for what is considered normal AM and hence the threshold of what is to be considered as excessive.

At Para 4.5.5 the WSP/PB authors makes a serious misrepresentation of INWG WP5 when they quote '*If the Den Brook condition (a peak to trough method) were to be treated as a simple metric or trigger value a higher peak to trough value in the region of 6dB would need to be used*'.

What INWG WP5 actually states is '*If the Den Brook condition, or criteria, is to be used as a trigger value, i.e. one or two exceedances indicative of a breach, then the peak to trough*

level value needs to be increased from 3dB(A) to around 6dB(A). However, it is recommended that the Den Brook condition is not used as a simple trigger value'. The WSP/PB statement conveniently ignores the detail of how the Den Brook condition is structured and is again seen as an attempt to justify an increase from 3dB to 6dB of what is considered to be normal AM.

Para 4.5.6 would appear to be an attempt to downplay the significance of AM and that excessive AM is an infrequent event for the 78-80m hub height turbines installed in recent years.

At Para 4.5.7 the WSP/PB authors question the current ETSU noise limits and makes a case for the limits to be reviewed. It also highlights that the aims of the NPPF in England today are to avoid noise giving rise to significant adverse impacts.

At Para 4.5.10 the WSP/PB authors consolidate their shift of what they want to be considered normal AM from 3dB to 6dB peak to trough. This quite clearly conflicts with ETSU where the normal modulation depth referred to at page 68 is '*This modulation of blade noise may result in a variation of the overall A-weighted noise level by as much as 3dB(A) (peak to trough) when measured close to a wind turbine. As distance from the wind turbine/wind farm increases, this depth of modulation would be expected to decrease….*'. Close to the turbine is usually considered to be up to 50m so the modulation anticipated by ETSU at typical residential distances of greater than 400m would be in the order of 1-2dB or less and unlikely to be audible.

Additionally, the reconstructed Time-Series Modulation Depth from the IoA AMWG measurement metric is defined differently and is not the same as modulation depth defined in ETSU-R-97. The proposed IoA AMWG measurement metric is an averaged value of mathematically manipulated signals, each of which is then assessed in terms of a comparison between L5 and L95, and is then further averaged across multiple 10-min samples using the L10 percentile measure.

Control Scheme for AM

Para 4.5.21 is where the switch from a real AM using the ETSU definition of peak-to-trough to the IoA synthesised and averaged value metric occurs. (The INWG comment separately on the shortcomings of this proposed metric.) The proposed AM level penalty regime from WSP/PB has thus, perhaps even mistakenly used dissimilar amplitude modulation metrics as a basis for the suggested AM penalty regime. Para 4.5.21 also introduces the concept of introducing a penalty to the overall average noise level via the ETSU assessment during periods of unacceptable AM with the purported aim to reduce noise levels back into compliance.

Para 4.5.22 indicates there are two potential methods for reducing AM but recognises that these methods are new, not proven and will not be available to every model of turbine. The INWG suggest that any AM planning condition should be designed to assume there will be no engineering solution and that it may be necessary to stop turbines during the conditions when excessive AM occurs.

The authors are also basing their proposed AM condition on the claimed findings from two papers, von Hünerbein et al. (2015) and Lee et al. (2011) that reducing absolute noise levels will reduce annoyance from AM. Both these papers relate to small scale laboratory studies and at Paras 3.2.7 and 3.2.8 the WSP/PB authors express reservations with the laboratory study conducted by Lee et al. Importantly there is no evidence of real world testing presented that such a method would work in practice with real WTN.

Para 4.5.23 then proposes essentially the same AM penalty scheme as proposed in the ReUK report from 2013. When previously tested by INWG with real turbine noise data this ReUK scheme was shown to fail to provide control even in the worst cases of AM. The minor changes now being proposed by WSP/PB to the original ReUK scheme are considered unlikely to make much difference. However, it is intended that INWG will later be testing the effectiveness of the proposed AM control scheme.

Para 4.5.24 provides more detail of the proposed penalty scheme. However, research by INWG has shown that almost always when nuisance AM occurs the overall decibel levels are well below limits by more than the penalty proposed which means it will often or nearly always be an ineffective provision. To explain this, the problem noise is measured by effectively assessing its troughs and not its peaks. As a result these troughs are well below the limits when this AM type of noise occurs and the headroom to the limit means any penalty will almost never lead to the noise being considered excessive. The control will rarely if ever be effective. In contrast, BS4142:2014 as discussed at INWG WP5 para 9.49 '*attributes a penalty for noise character and then combines assessment of noise character and noise level to be judged relative to the background sound environment. This provides a context based approach and includes combined assessment of noise level and noise character*'.

Para 4.5.27 sets out what WSP/PB propose the resulting action imposed on the operator during periods of AM should achieve. These are shown as either point a) **or** point b). INWG believe that only point a) is relevant as this ensures excessive AM is prevented irrespective of the overall noise level. Point b) would effectively provide the wind turbine operator with a 'get-out clause' to continue operating and generating any level of AM providing the overall average noise level remains within the ETSU limits.

Para 4.5.30 highlights the untested nature of the WSP/PB proposals and proposes a 2 to 5 year testing programme. This is promoting a continuation of the wind industry strategy of obfuscation and delay.

Operational Impacts and Mitigation

This section covered by Paras 4.6.2 to 4.6.5 highlights the loss of revenue as being main concern of wind turbine operators.

Conclusions

All these points have been covered above.

Appendix D

INWG Comments on planning condition proposals by the IoA and WSP/PB

Appendix D

INDEPENDENT NOISE WORKING GROUP

REPORT OF THE IOA AMPLITUDE MODULATION WORKING GROUP

AND REPORT OF PERKINS ET AL

COMMENTS ON PLANNING CONDITION PROPOSALS

Richard Cowen LLB

Background

1) These comments are supplemental to the INWG Work Package 6.1 which addressed the way a condition to control Excess Amplitude Modulation (EAM) had been addressed since the Den Brook condition was considered by the Court of Appeal. In short, WP6.1 shows that for a considerable period of time, any condition to control AM was resisted by the Wind Industry as it was claimed it was not lawful and this claim had been followed by many decision makers.

2) WP6.1 also considered other methods such as Nuisance in its various forms for controlling EAM and concluded that these create many problems. It concluded that the only realistically acceptable way to address this problem if planning permission is granted for a wind farm or single turbine is to include a suitably worded condition to control EAM.

3) INWG produced a number of Work Packages as the Institute of Acoustics Noise Working Group had established a sub Group, the Amplitude Modulation Working Group, to consider this subject following an admission from the wind industry that EAM was a bigger problem than had previously been admitted. INWG wished to monitor the AMWG and consider any report it may produce for government.

4) The IoA AMWG has now produced its report following its study of the EAM issue and this has been followed by a report from Richard Perkins of Parsons Brinckerhoff, the firm who had won a contract from the former DECC to report to the government on this issue. The purpose of these comments is to consider what both reports say (if anything) about a planning condition to control EAM.

Scope of AMWG Report

5) As far as a planning condition is concerned, there are perhaps 2 points in the AMWG Report of interest

a) Appendix A is entitled “Terms of Reference”. These relate to practical issues rather than legal ones such as the need for or drafting of a planning condition. On page 50 however, it does state

“It is expected that the working group’s activities will be of relevance to:
i. Acoustic consultants
ii. Local authorities;
iii. Developers
iv. Academics carrying out research on wind turbine noise
v. Turbine manufacturers
vi. The general public living close to wind turbines.”

As far as point vi. is concerned, it does not differentiate between those already living close to wind turbines and those who may live close to them in the future. It is presumed therefore that this provision is meant to relate to **all** people living close to turbines, whether already constructed or to be constructed in the future.

b) Appendix B is entitled “Scope of Work”. This gives one Goal, at page 54, as

> “Provided in the format to allow straightforward inclusion in ‘standard’ forms of planning conditions for wind turbines [subject to thresholds or penalties set by others]”

6) The body of the AMWG Report does not mention planning conditions or any other remedy for people living close to existing wind turbines. It deals only with methods of assessing EAM. That is outside the scope of these particular comments.

The Perkins Report

7) The bulk of this Report also addresses practical issues and so is outside the scope of these comments. However, it does also consider the issue of planning conditions in Section 4.

8) Paragraph 4.5.1 states that the control has been designed purely for new applications and that Statutory Nuisance issues relating to existing wind farms has not been considered as it is outside the research scope.[1] INWG is most concerned about this. WP6.1 shows the steps that have been taken to avoid a suitable planning condition to control EAM in the past and considers it is not

[1] Since this Report, there have been suggestions that the suggested controls can be applied in Nuisance (including Statutory Nuisance) cases but this needs to be clearly stated if it is now the Industry’s current position.

acceptable for the IoA AMWG to ignore this issue. This is especially so if INWG's interpretation of the Terms of Reference is correct (see paragraph 5a above).

9) As far as paragraph 5b above is concerned, the Perkins Report does not provide a format that is straightforward for inclusion in a "standard" form of planning condition although a form of wording is given in paragraph 4.5.31. These comments do not consider the adequacy or otherwise of the methods outlined in the Reports, merely that there is no form of words in the Perkins Report for inclusion, say, as a Guidance Note to a suitably worded Planning Condition. If there is to be in Standard Format, INWG believes it should be clearly stated as such in the Perkins Report.

10) INWG is also concerned about the Perkins Report's suggestion that such a planning condition should be included in a planning permission[2]. The Report refers to the 6 tests for the validity of a planning condition, arguments that have been used extensively in the past to say that an EAM condition would be unlawful as, it was claimed, the phenomenon was rare and unpredictable and it was an unreasonable constraint on developers to include such a condition. While the Report suggests that a condition should always be imposed, we note paragraph 4.5.31 where it is said "Legal advice would need to be sought to ensure any proposed condition meets the NPPF 'six tests' requirements):" We must question the reason for this – ultimately is there a possibility that there will in fact be "no change" from the present situation?

11) Paragraph 4.2 of the Perkins Report is noted. This states that EAM is unpredictable at the planning stage and so "control would by necessity be instigated by complaints (i.e. a "reactive" control)".

12) Any planning condition will only be subject to enforcement if it is breached, which is "reactive" control. It is not clear what is meant by this comment. Given the hostility to a planning condition in the past, does this mean that the Report is suggesting that planning controls only come into effect if there is a complaint?

13) INWG believes that the Perkins Report must be clarified to say either that a planning condition must be imposed as standard (unless there are very good reasons why one should not be imposed e.g. because the nearest dwelling is a considerable distance away) or clarify just when it is saying that a planning condition should be imposed. Given the history relating to this form of condition, INWG believes it is absolutely essential that this is clarified.

[2] See the Recommendation in the Non-Technical Summary

Appendix D

Conclusion

14) INWG remains of the view that a planning condition is now required in **all** planning certificates issued at any time in the future unless there are sound reasons for not doing so. It represents that the Perkins Report should explicitly require this.

15) INWG is also most concerned that the Perkins Report specifically does not cover existing wind farms, especially when any condition to control EAM has so vigorously been opposed by the wind industry in the past.

16) These comments do not address the adequacy of the methods proposed in the AMWG or Perkins Reports for measuring EAM or the proposals to remedy problems that may arise from EAM. That is for other members of INWG to consider. Nor do these comments address the actual wording of any proposed condition. They merely address the vexed question as to when a condition to control EAM should be imposed in a planning certificate and question why existing wind farms have not been considered in the AMWG and Perkins Reports, notwithstanding the comments made in paragraph 4a above.

29 December 2016.

Appendix E

INWG press release 5 October 2016

Informative – 5th October 2016

Independent Noise Working Group

Wind Turbine Noise Amplitude Modulation (AM) and its Control:

Concerns have been raised with Members of Parliament including The Rt. Hon Greg Clark MP Secretary of State in the Department for Business Energy & Industrial Strategy regarding the recent report and recommendations produced for Government by WSP / Parsons Brinckerhoff (WSP/PB) on the subject of wind turbine noise amplitude modulation (AM) and its control.

In making their position absolutely clear, INWG recommends that Government do not implement either the IoA or the WSP/PB report recommendations.

Moreover, INWG believes that it is now essential for a suitably worded condition to properly protect residents from the impacts of EAM to be drafted and included in every new planning permission issued in the future. It can no longer be claimed that such would not meet the tests for a planning condition and so leave residents vulnerable to this common form of nuisance without any planning control. Although WSP/PB refer to a condition in their document, it remains unclear under which circumstances one should be imposed.

Background:

The contract for the AM study and report was awarded by the former DECC to WSP/PB during early summer 2015, shortly after the election and before the new Government ministers had become familiarised to their new roles at DECC.

The INWG subsequently met with the then Energy Minister Andrea Leadsom MP on 13 October 2015 where INWG representatives presented the findings and recommendations from their fourteen-month duration AM study. This included, amongst others, the recommendation that BS4142:2014 be used for the assessment and control of AM. The INWG also presented their concerns at that time regarding conflict of interest issues surrounding the Institute of Acoustics (IoA) wind turbine noise working groups and WSP/PB. The Energy Minister offered to provide INWG with the final WSP/PB report when submitted to DECC. The INWG has now reviewed a paper presented by WSP/PB at the Internoise conference on 23 August 2016 summarising their AM report to Government.

The INWG also has concerns regarding the report produced by the IoA on wind turbine AM measurement released on 9 Aug 2016 and forming an integral part of the WSP / PB report to Government. Since these two reports are produced by the same small group of closely connected acousticians largely from the wind industry supply chain, the INWG concerns below relate to both reports.

Summary of INWG concerns:

- The methodologies being proposed by WSP/PB and the IoA for measurement and control of AM are very similar to the methodologies proposed in the RenewableUK AM report from 2013. RenewableUK being the wind energy industry lobby organisation. The RenewableUK

report was subsequently heavily criticised and on testing by the INWG the proposed control methodology failed to protect against even the worst cases of AM. These methodologies also rely on the now discredited and undermined ETSU-R-97 guidelines for assessment of wind turbine noise. It should also be noted that the authors of the RenewableUK report were from the same small group of wind industry supply chain acousticians responsible for the two recent reports and most formal noise assessment guidance to Government over the last two decades.

- The control methodologies being proposed by WSP/PB have not been tested on real wind turbine noise data. The INWG plan to conduct such tests later this year when available resources permit.

- The WSP/PB report ignores much inconvenient scientific literature and evidence, thus summarily and unreasonably dismissing the use of BS4142:2014. The INWG found in their 2014/15 AM study that this latest version of BS4142 to be a most effective methodology for the control of wind turbine noise AM when tested with real wind turbine noise data. It should be noted that BS4142:2014 was developed by academics independent of the wind industry for assessing all types of industrial noise sources.

- The WSP/PB report and control recommendations are specifically for future wind turbines only and explicitly exclude existing wind turbines. Both the WSP/PB and IoA reports downplay the significance of AM from existing turbines. This leaves a large number of people living near wind turbines currently suffering from AM without adequate protection and local authorities no closer to a solution.

- Local communities are expressing their concerns regarding the lack of independence of the IoA with behaviour more akin to an industry trade body than an independent academic institution. The conflict of interest issue is covered in detail in the INWG 2014/15 AM study. In a letter[1] dated 7 August 2014 and obtained under a Freedom of Information request, W. Egan the then President of the IoA urged E Davy the then Secretary of State at DECC to adopt a penalty system for AM and in the penultimate paragraph states:

  "The incidence of AM is reported to be increasing the number of complaints from onshore wind farms, and a number of nuisance cases are understood to be currently being progressed through the courts. Without a Government steer on the matter of AM, it is likely that Judges may accept a lower threshold of acceptance than current Government support for on-shore may suggest, which could restrict the roll-out of onshore wind in the UK."

  The INWG believe this is a clear attempt by the IoA to influence the independence of the judiciary for the benefit of the wind industry and further exemplifies the INWG's deep concerns.

[1] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/388706/Letter_to_Ed_Davey_MP_7_Aug_14.pdf

Testing of IoA AMWG proposed AM noise control methodology:

Tests using real AM recordings have yet to be completed. However, preliminary analysis by leading Australian wind farm acoustic experts and INWG consultants, L Huson & Associates Pty Ltd., using only the test data supplied by the IoA AMWG already reveals substantial flaws.

For example, in situations where a wind farm is adjusting to frequently changing wind conditions (and each turbine may be turning at different speeds) the frequency range suggested in the IoA AMWG analysis process may not accommodate the speed range from all of the turbines and will produce false negatives.

It is probably the changes in wind conditions across a wind turbine that causes blade instability which gives rise to larger levels of amplitude modulation. When this is the case, then the IoA AMWG amplitude modulation metric will significantly underestimate the amplitude modulation in the input data and be a poor indicator of noise nuisance in the community.

In addition to testing the WSP/PB proposed AM control methodology, the INWG will be reviewing and producing a detailed critique of the WSP/PB and IoA AM reports.

The INWG has requested Government to provide a copy of the full WSP/PB report to enable a more detailed review to be conducted.

END

<u>Who are the Independent Noise Working Group?</u>

The Independent Noise Working Group (INWG) was formed during August 2014 to study wind turbine noise amplitude modulation (AM) in response to concerns surrounding the setting up by the Institute of Acoustics (IoA) of an amplitude modulation working group (AMWG). The principal objective of the INWG study is to protect communities and wind turbine neighbours from amplitude modulation, challenging the IoA where appropriate.

The INWG is sponsored by Chris Heaton-Harris MP (Con., Daventry) and the National Alliance of Wind farm Action Groups (NAWAG) and consists of a diverse group of concerned individuals, experts and non-experts. The group takes an independent and holistic view of the current wind turbine noise AM problem avoiding the constrained wind industry approach adopted by the IoA AMWG. The INWG multi-disciplinary team is independent of the wind industry supply chain with expertise including:

- Acoustics
- Physics

- Meteorology
- Statistics and data analysis
- Health and sleep
- Environmental health (LPA)
- Legal and planning

A highly detailed report was released during the summer and autumn of 2015 which along with supporting presentations made to Energy Minister Andrea Leadsom MP on 13 October 2015 and to the IoA at their annual conference on 15 October 2015 can be downloaded at; https://www.heatonharris.com/reports-publications

Appendix F

Preliminary review of IoA approved wind farm AM analysis programme, L Huson & Associates

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LHUSON & ASSOCIATES
Consultant Scientists in Acoustics

Bev Gray (by email to: bev@gray1.org.uk)

28 September 2016

Re: Preliminary review of IoA approved wind farm Amplitude Modulation analysis program

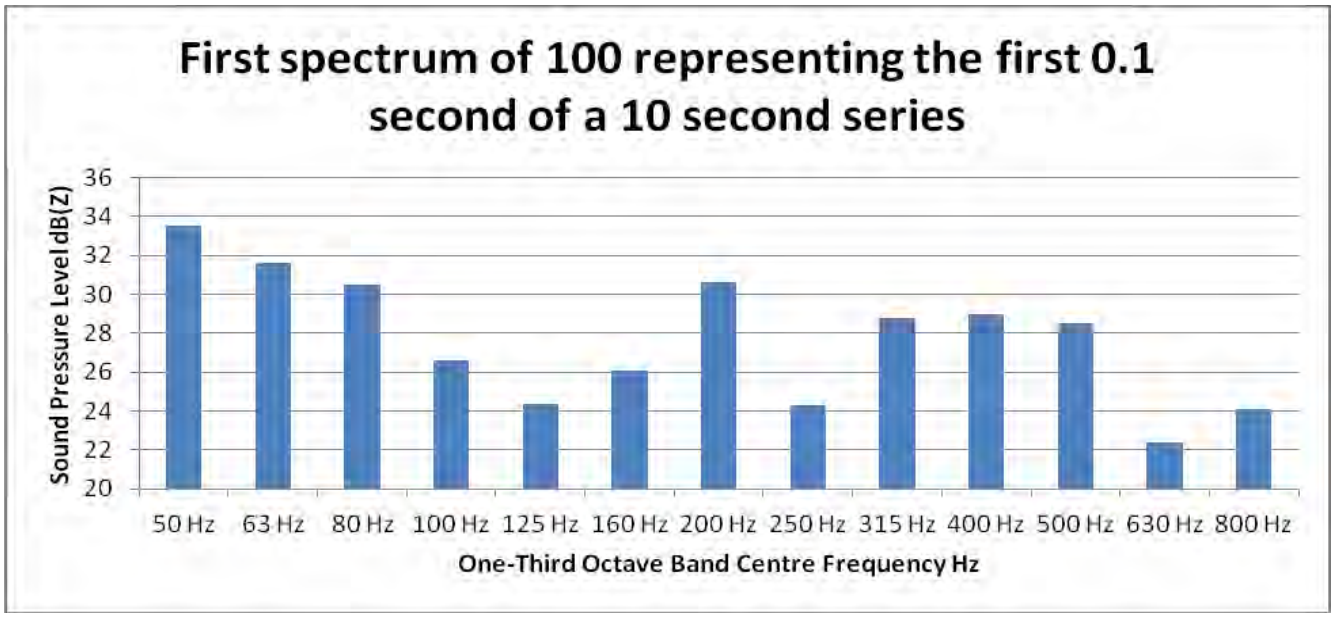
Dear Bev

The IoA AMWG hybrid method was supposed to be transparent and easily understood. Unfortunately, the Python code they provided has taken all of the graphics presentations out, leaving only a simple output to a CSV type file showing only numbers.

I have modified the IoA supplied program to show in graphic form what the analysis process does to the original amplitude modulated (AM) sound levels observed near operating wind turbines. The IoA program has not been altered but has been enhanced (as presumably the pre-release program would have been) to include graphic output.

The IoA have provided sample sound level data in a spreadsheet form that has taken one-third octave band sound level data obtained at a rate of one unweighted one-third octave band spectrum every 100ms (0.1 second) or 10 times per second for a time of 10 seconds. This yields 100 spectrum samples, each containing one-third octave band values from 50 Hz to 800 Hz.

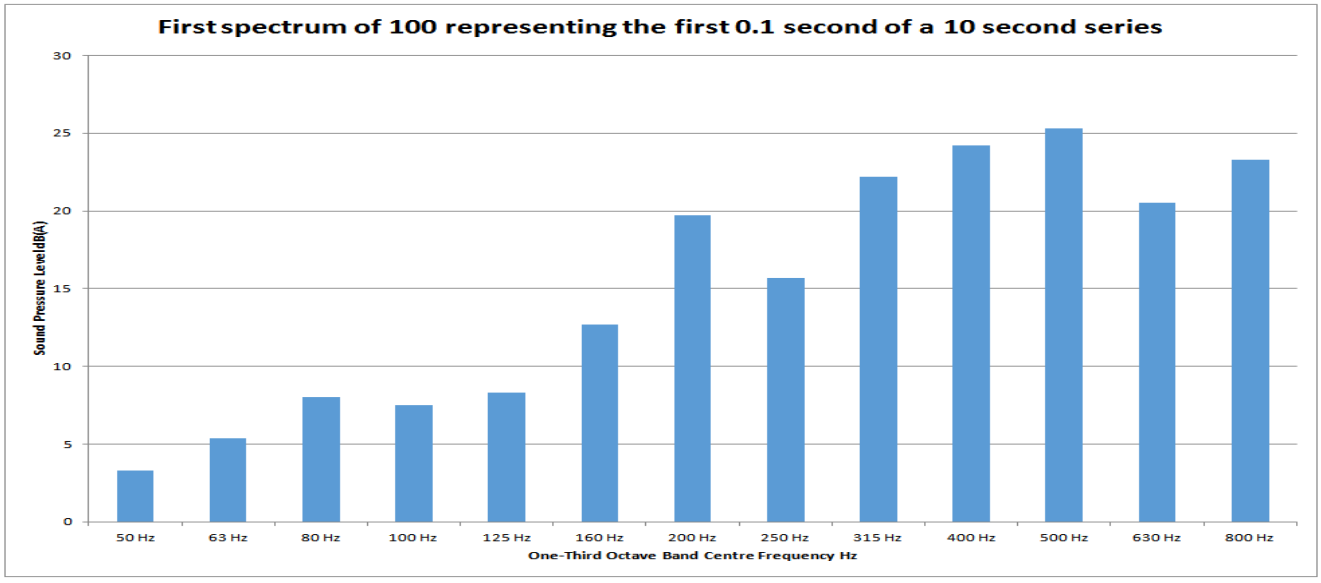
A single spectrum from the first of 100 spectrum values supplied as test data by the IoA is shown below. The y-scale amplitude is unweighted or Z-weighted (Zero weighted).



The unweighted spectrum samples are then converted to A-weighted spectrum samples as shown in the following figure.

Association of Australian Acoustical Consultants

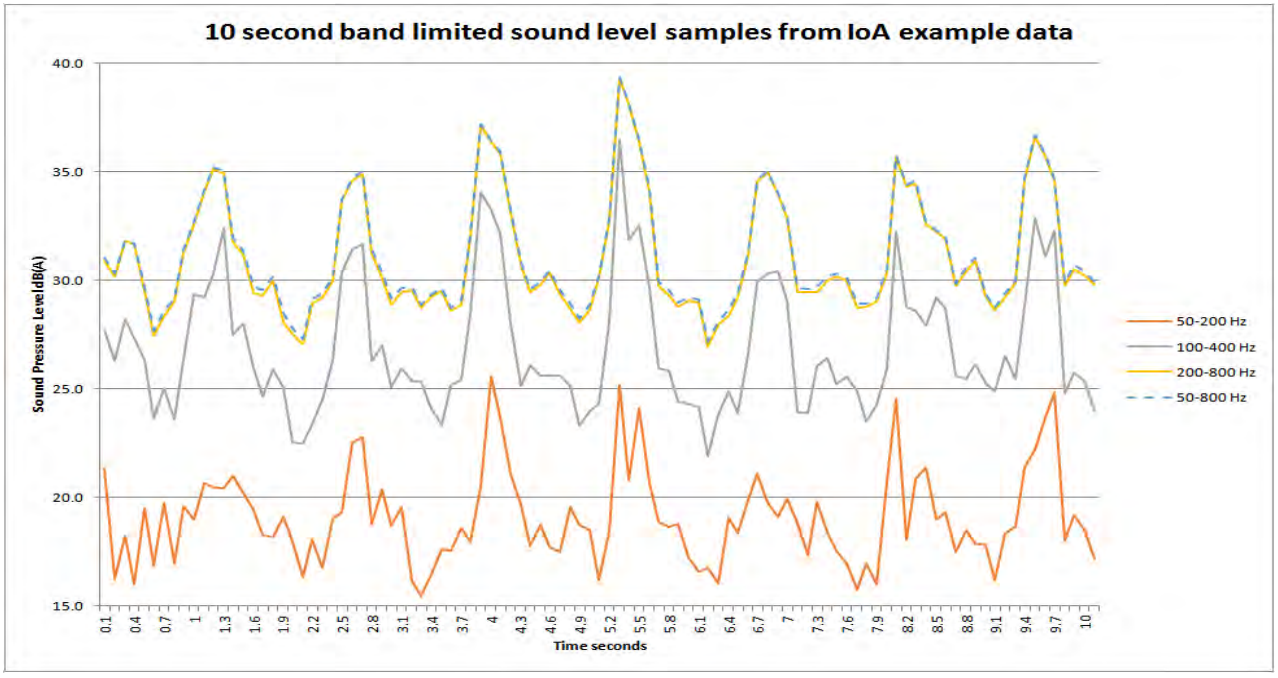
ANC ACOUSTICS & NOISE CONSULTANTS



The one-third octave band output from a typical sound level meter would generally cover the full audible frequency range from 20 Hz to 20,000 Hz but only the limited range from 50 Hz to 800 Hz is suggested by the IoA AMWG to be appropriate to the amplitude modulated sound from a wind turbine. I disagree with this assumption since measurements at the Cape Bridgewater wind farm in Australia show that the MM82 turbines at that location produce amplitude modulated sound emissions in the 32 Hz one-third octave band which would be excluded from the analysis.

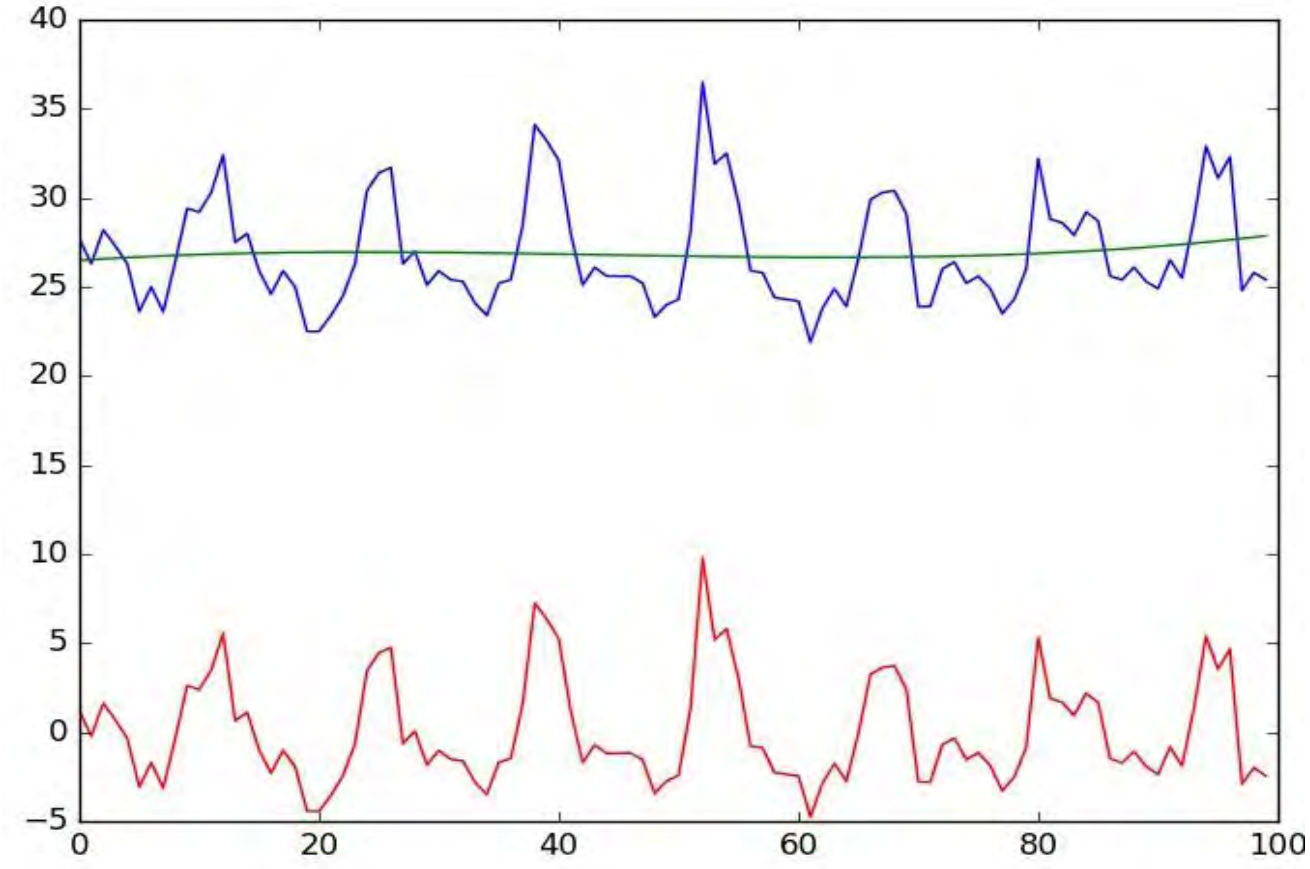
The IoA AMWG then recommend producing average sound levels from specific groups of each one-third octave band spectrum (taken in 0.1 second intervals) in the ranges of 50 to 200 Hz, 100 to 400 Hz and 200 to 800 Hz. This is done by logarithmically averaging the spectrum values at 50, 63, 80, 100, 125, 160 and 200 Hz to produce a single sound level band limited to 50 to 200 Hz, and likewise for the 100 to 400 Hz range and 200 to 80 Hz range for each 0.1 second spectrum.

The IoA AMWG test data is then a 100 point series of sound levels in three different frequency bands covering 10 seconds titled: sample-50_200Hz.txt; sample-100_400Hz.txt, and; sample-200_800Hz.txt as shown below:



The overall A-weighted sound level from 50 Hz to 800 Hz has also been included for comparison.
The IoA hybrid AM assessment method starts with a given waveform such as those in the previous chart and converts the time signal into a frequency representation using the Fourier transform. However, a Fourier transform requires the input data to resemble a waveform that oscillates about a zero value. The IoA method achieves this by offsetting the input time signal with an average trend line through the input data.

The result from an analysis on the 100 to 400 Hz sample data is shown below with the green line being a 3rd order polynomial trend line fit to the original data (in blue) and the resultant de-trended data in red.

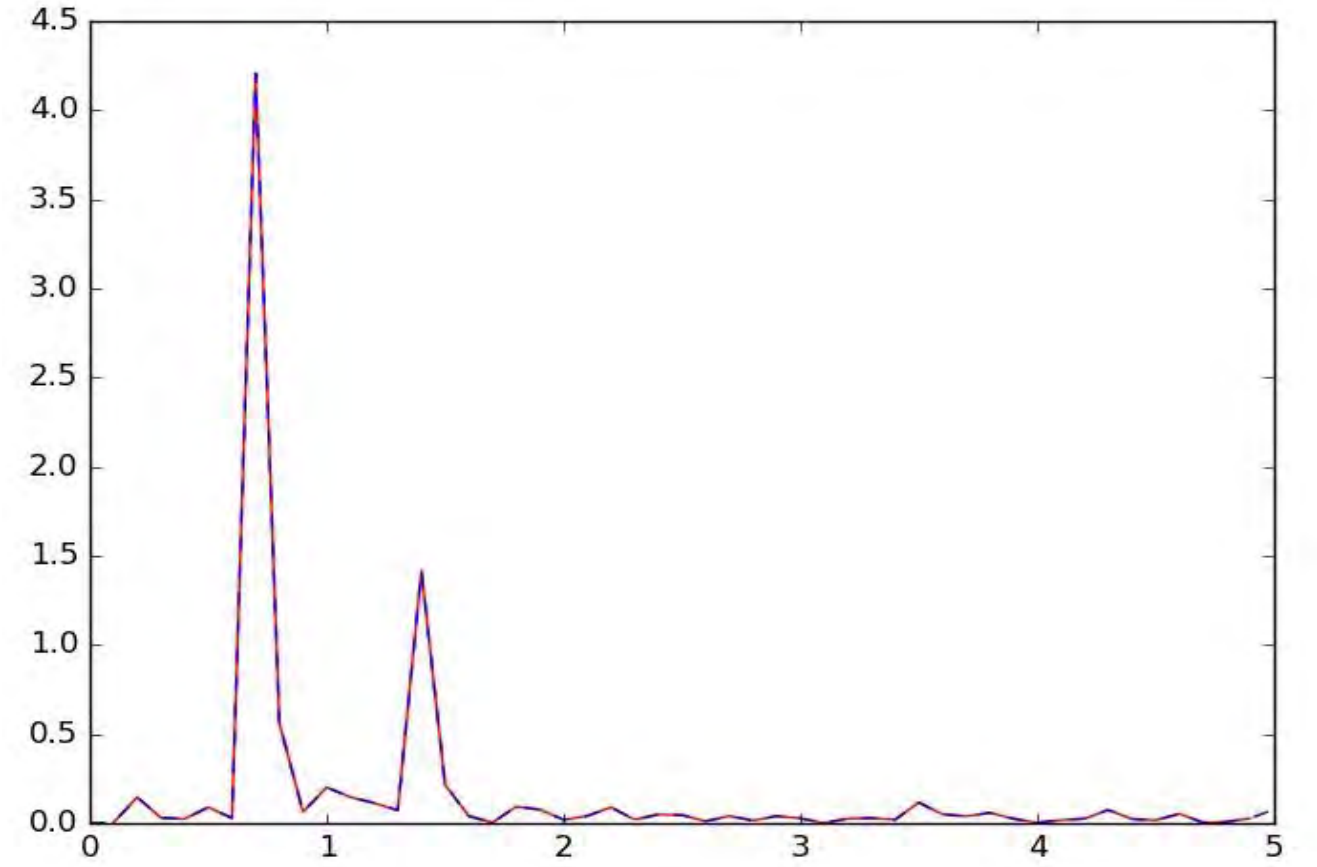


X-axis shows time as a sample number in 0.1 second intervals (10 second total). Y-axis is sound level in dB.

Two things are worth noting from this chart is that a 3rd order polynomial trend curve has two inflexions (one positive hump and one negative hump), as it must, and that the de-trending process does not cause the start and end of the resulting red curve to start and end at 0dB. The implications of using a 3rd order polynomial trend curve is that this may not be the best trend option for all input data and can cause unacceptable distortion in the de-trended signal.

The implication of there being a non-zero dB start and end to the de-trended signal is that a step discontinuity at the beginning and end of the signal, which is then passed to a Fourier analysis will cause the spectrum result to have an artificially high 'background' spectrum. This can be important when the analysis later tests for prominence of the blade pass frequency peaks and can result in a false negative result.

There are a number of Fourier transform methods that can be used and we have chosen an alternative method to compare against the one chosen by the IoA AMWG. The result is shown below with the IoA Discrete Fourier transform method in red being compared to an alternative method in dashed blue. A Fourier transform result can be presented as a power spectrum or a power spectrum density. The IoA hybrid method shows the result as a power spectrum.



X-axis is frequency in Hz. Y-axis is the power spectrum result.

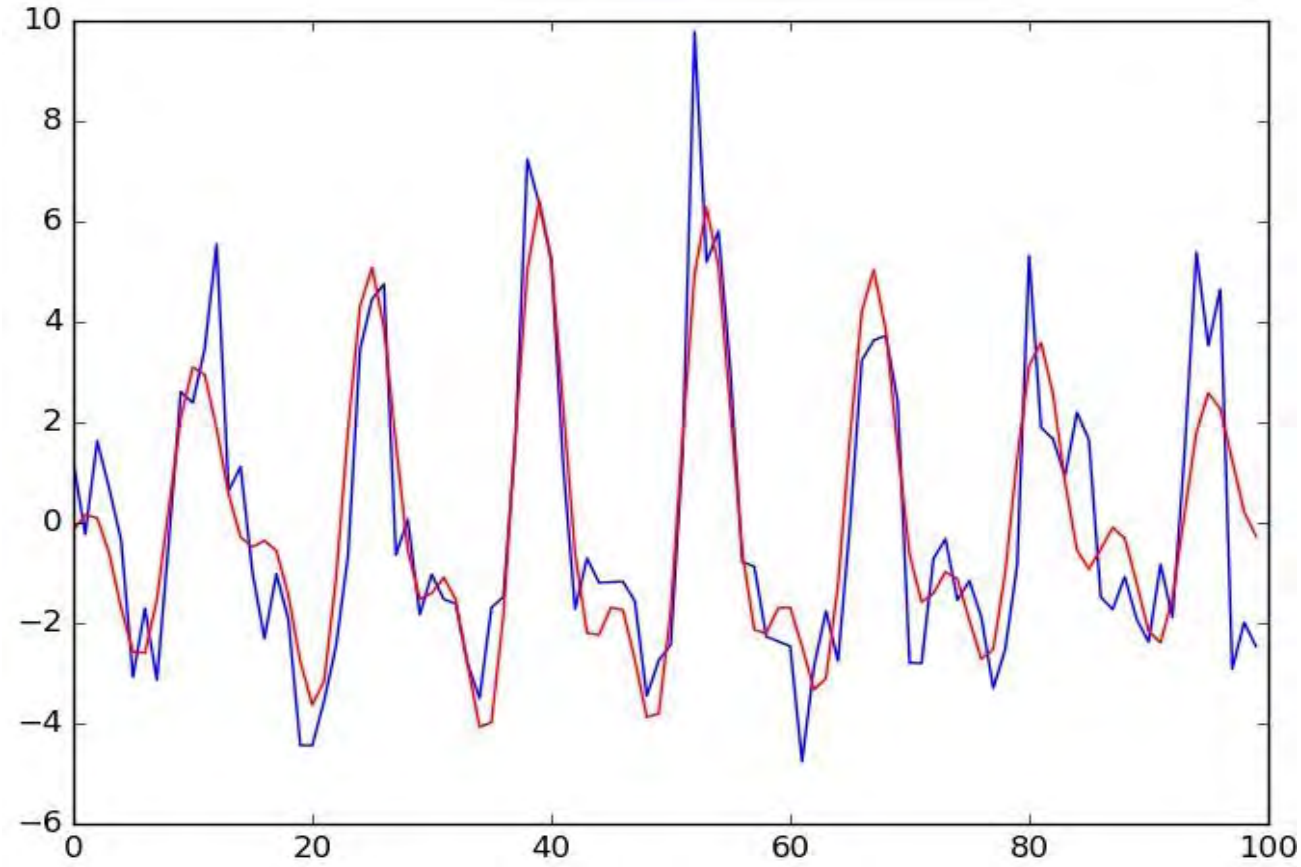
The IoA chosen Discrete Fourier transform method provides identical results to the alternative periodogram method. It is worth noting that the resolution of the spectrum result is only 0.1 Hz (50 data points representing a 5 Hz frequency span) and that the next part of the hybrid method uses the peak values from the spectrum result to reconstitute the input AM signal. When the frequency of the input signal lies between two frequency spectrum bins (each data point is called a bin containing power within a 0.1 Hz frequency width) the resulting peak is reduced with the power being shared by two adjacent bins.

The IoA AMWG hybrid method only uses the bin containing the largest peaks and one bin either side of the peak. For the situation where the frequency of the AM in the input signal lies between two bins it is clear that some power from the blade pass frequency spans more than three bins and can be lost prior to reconstituting the input signal using an Inverse Fourier transform, which will result in a lower AM in the processed output. Furthermore, in such a situation the prominence test in the hybrid method can produce a false negative result since it compares the peak level to the level of the bins in the four adjoining bins (two either side of the three bins that are the peak bin and the two bins either side of the peak).

Tests on real AM recordings have yet to be completed and this preliminary review only considers the test data supplied by the IoA AMWG.

The following chart shows a comparison of the original input signal, after de-trending, in blue for the 100 to 400 Hz data and the reconstituted signal after being processed using the IoA hybrid method in red.

Notwithstanding any distortion that can be produced from the de-trending process, it is clear that the resulting AM has been reduced after processing with the hybrid method. Furthermore, the start and end of the processed signal has been forced by the mathematical processing (inverse Fourier transform) to start and end on zero dB.



X-axis shows time as a sample number in 0.1 second intervals (10 second total). Y-axis is sound level in dB.

Part of the hybrid method uses the comparison of statistical properties of the AM signal to produce an AM metric. The L5 and L95 statistical levels of the reconstituted input data are compared (L5 – L95). This is the difference between the upper 95 percent of the input signal compared to the lower 5 percent of the input signal.

We have modified the IoA program to report the L5-L95 result for the reconstituted signal and the input signal, prior to any de-trending or other processing. The program also reports if and when harmonics from the intermediate spectrum results are used in the reconstitution processing, as follows for the 100 to 400 Hz sample data.

> Calculating 10 second results...
> 2nd Harmonic has been included
> 3rd Harmonic has NOT been included
> Modulation depth L5-L95 of original data = 9.005
> Modulation depth L5-L95 of IoA transformed data = 8.38317578891
> Calculating 10 minute values...
> Writing results to file...
> Processing complete!

The metric suggested to be used to quantify modulation depth of AM is the difference between L5 and L95 statistics, which may be band limited, of a 10 second time trace from a sound level meter in dB(A).

The result shows that the modulation depth is lower after processing using the IoA AMWG hybrid method.

The modified Python program which produced all of the charts in this document, except for the first three that show the example input data, is available to anyone who may wish to investigate the IoA recommended hybrid method independently using real data.

The analysis shown above is for a single 10 second sample which would be but one of 60 similar analyses used in each 10 minute sample. The hybrid method assumes a limited blade pass frequency range in the analysis process.

For situations where a wind farm is adjusting to changes in wind conditions (and each turbine may be turning at different speeds) the frequency range suggested in the IoA AMWG analysis process may not accommodate the speed range from all of the turbines and will produce false negatives. It is probably the changes in wind conditions across a wind turbine that causes blade instability which gives rise to larger levels of amplitude modulation. If this is the case, then the IoA AMWG amplitude modulation metric will be a poor indicator of noise nuisance in the community.

From this preliminary investigation of the IoA AMWG recommended hybrid method, that is suggested to be used to quantify amplitude modulation in the Community, it is apparent that the metric can produce false negatives and provides underestimates of the amplitude modulation in the input data.

Unfortunately, the IoA hybrid method and the understanding of its technical deficiencies is clearly beyond the comprehension of the general Public and probably most local Council's environmental health officers.

Yours sincerely,

W Les Huson BSc(Hons) MSc CPhys MInstP MIoA MAAS MEIANZ

Appendix G

Testing of IoA AMWG hybrid methodology, L Huson & Associates

Email from Les Huson dated 11 October 2016

Subject: Testing IoA Hybrid Method

I have prepared two pdf files (63 pages each) showing the output from the IoA hybrid AM method for a real 10-minute AM sample from a two-turbine wind farm measured 700m away outside the nearest dwelling. The files are quite large so I have included the overall A-weighted file to this email and the 100Hz to 400Hz band limited file will follow in another email. In this 10-minute example the two turbines rotate at slightly different rates.

The first page shows the full A-weighted sound level over a 10-minute period. By eye, it is obvious that the peak to trough AM is about 6 to 10 dB. The major grid lines represent each 10-second sample each being represented sequentially in the following pages (page 2 is the first 10-second sample and page 61 is the 60th 10-second sample). Each of the 10-second samples show the 'original' data after de-trending and the final wave in red after going through the suggested IoA 'Fourier - inverse Fourier' processing.

It is very obvious that each processed result underestimates the peak to trough AM of the unprocessed AM trace in blue.

The suggested AM metric is the difference between two statistical values: the 95 percentile (L5, level exceeded for 5% of each 10-second sample) minus the 5 percentile value (L95, level exceeded for 95% of each 10-second sample). This AM metric does not reflect the actual peak to trough values of the samples - it was an approach suggested by researchers in Japan. I don't agree with it because of the averaging effect it has.

The last two pages show the output obtained from the IoA Python program for the 10-minute sample at Leonards Hill. I have added an extra column to the right which shows the L5-L95 value of the de-trended signal before manipulation through the Fourier- inverse Fourier processing. Again, it is obvious when comparing the unprocessed L5-L95 to the processed L5-L95 (10 sec AM rating (dB)) that the mathematical manipulation reduces the AM rating (L5-L95) by varying amounts.

The gaps in the table are caused by the extra test for prominence (data ignored if prominence < 4). I have plotted the original input data for these missing 10-second samples within the 60 charts.

A quote from J Bass in the Noise Bulletin article: "*You are effectively just using a method - a black box - to clean up an input time series that's not related to modulation*."

The attached files show that the 'black box' processing is artificially reducing the reported AM and would not capture the occasional 'whump / thump' because of the use of statistics in each 10-sec sample. The 10-minute AM rating value is the 10

percentile of the AM rating values in each 10-second block, meaning that a full minute of any very large AM results will be ignored.

The 10-minute IoA AM metric produced on these files would trigger an AM penalty of about 3.5 dB on the overall A-wt data and 3.8 dB for the 100Hz to 400 Hz band limited data using the WSP/PB proposed penalty scheme.

Les Huson

Email from Les Huson dated 10 January 2017

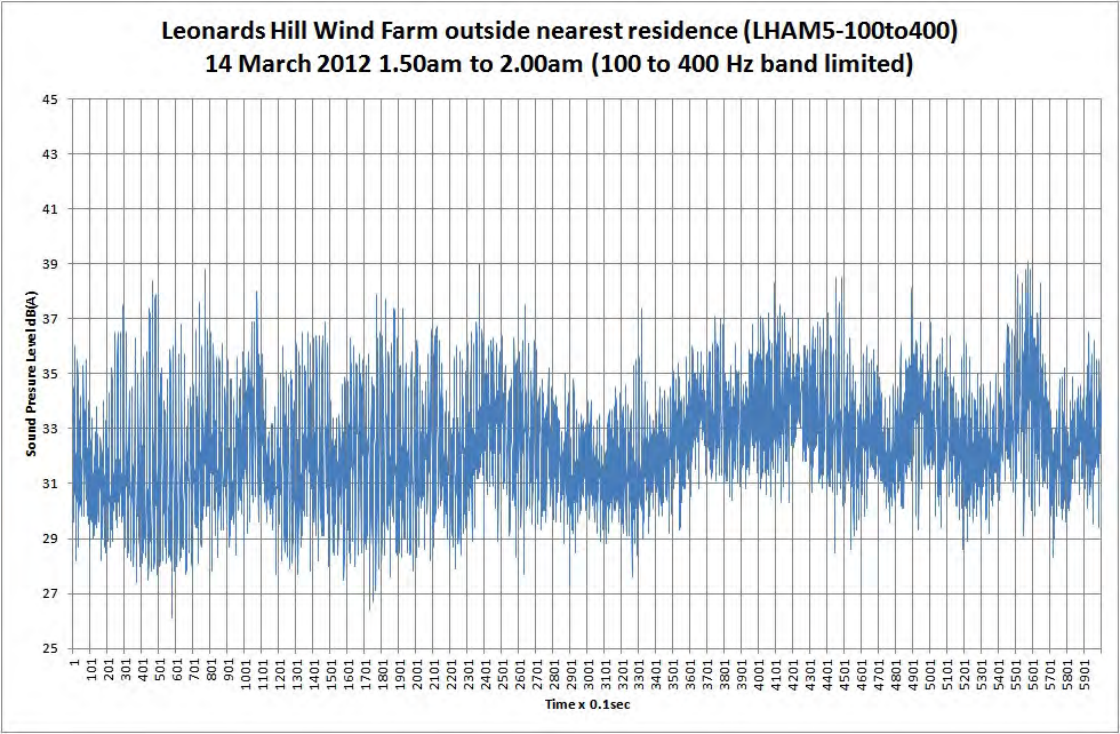
Subject: Testing IoA Hybrid Method

I have attached another similar analysis (a third set of 63 pages) that has the second chart showing how the L5-L95 levels underestimate real maximum peak to trough AM in 10-second samples. The chart is for the first sample, although others could be similarly analysed.

The last chart in the set shows how the Fourier processing reduces the L5-L95 levels from the original data to that after processing with the IoA method. This is a further diminution of the real AM experienced by people through poor or inappropriate signal processing.

The last chart shows the underestimate of (L5-L95) for each 10-sec sample in the data set. This underestimate is in addition to the underestimate of real peak to trough levels caused by using the statistical L5 and L95 comparison.

Les Huson


Leonards Hill Wind Farm outside nearest residence (LHAM5-100to400)
14 March 2012 1.50am to 2.00am (100 to 400 Hz band limited)
Sound Presure Level dB(A)
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41
39
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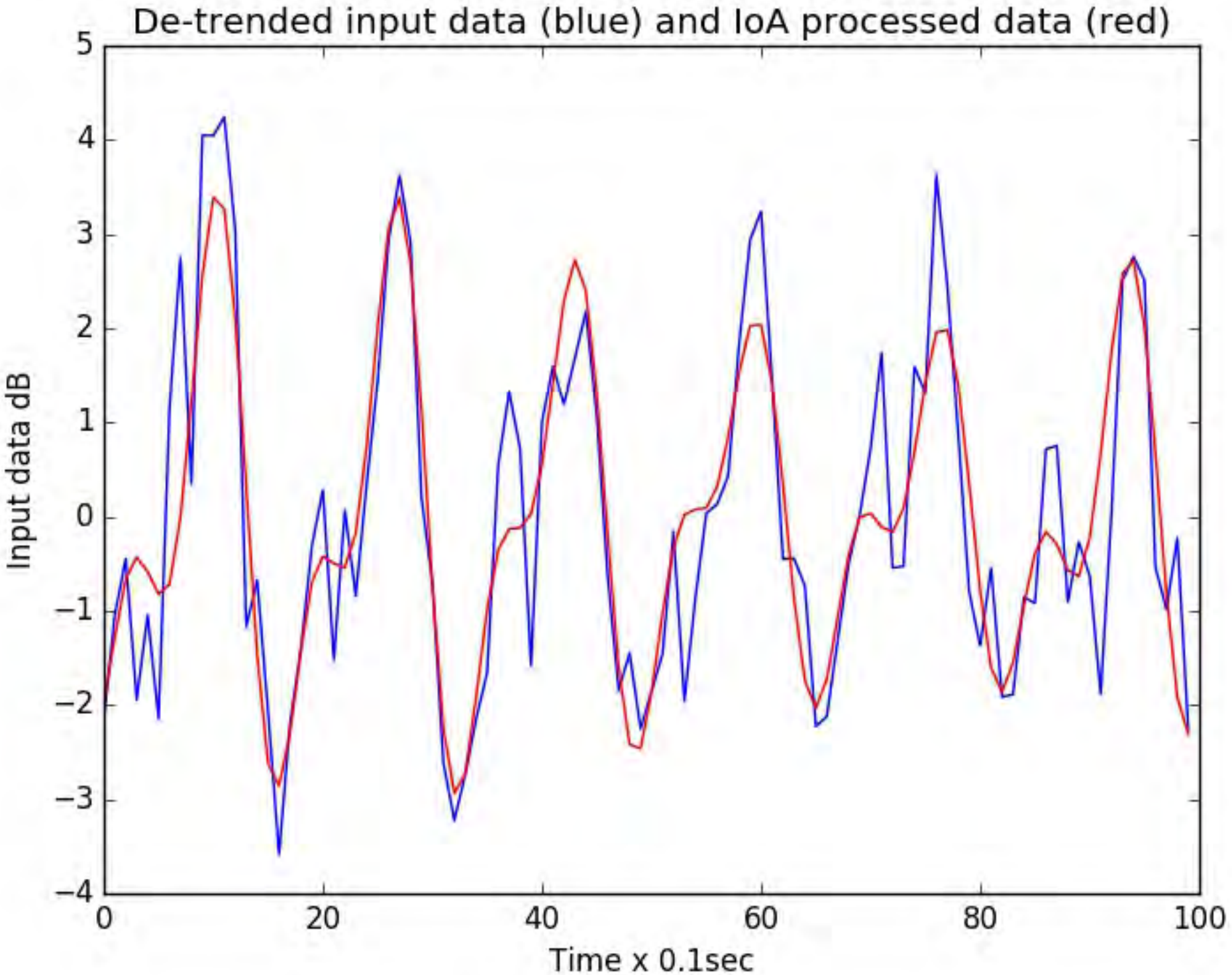
Time x 0.1sec


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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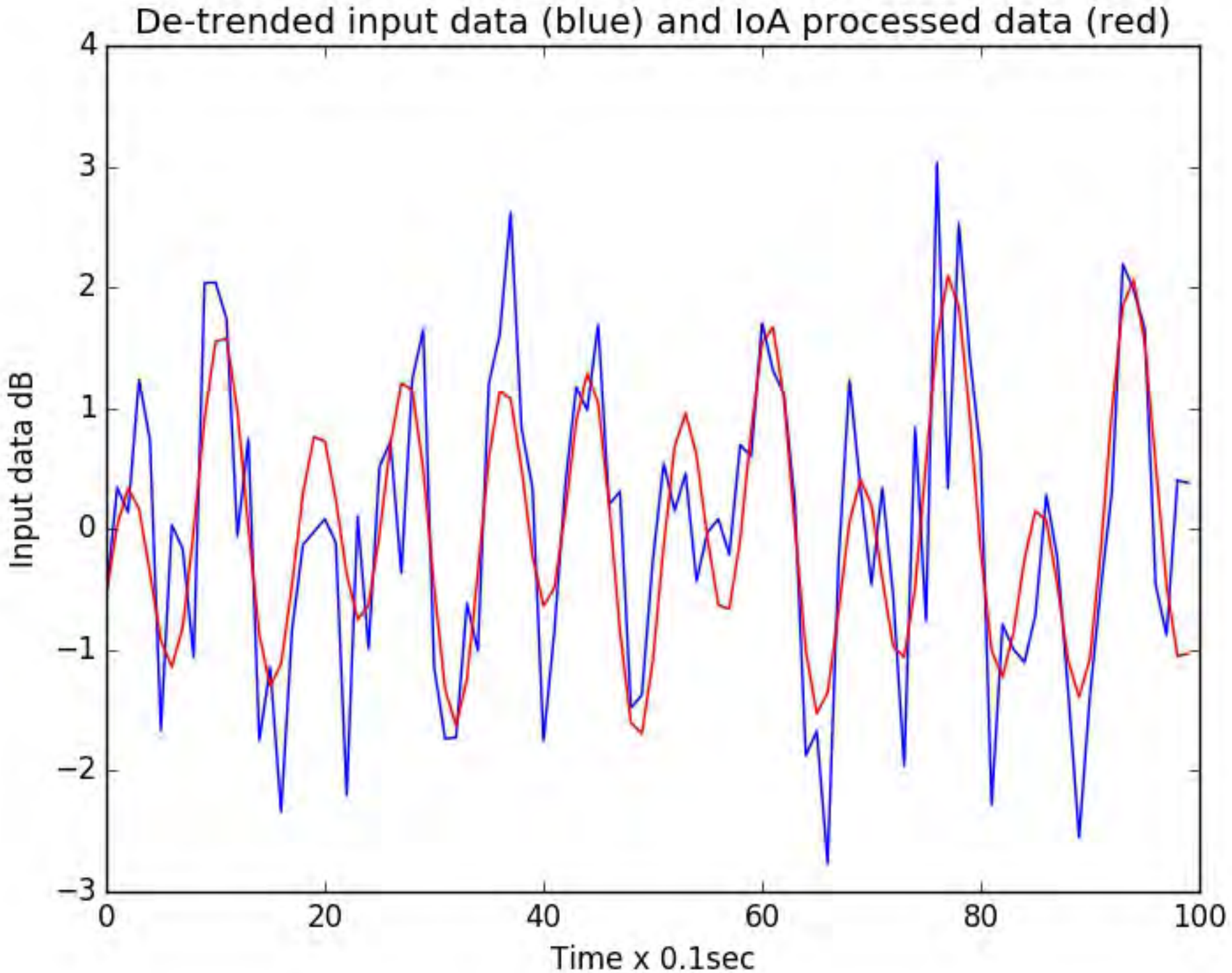
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Input data dB
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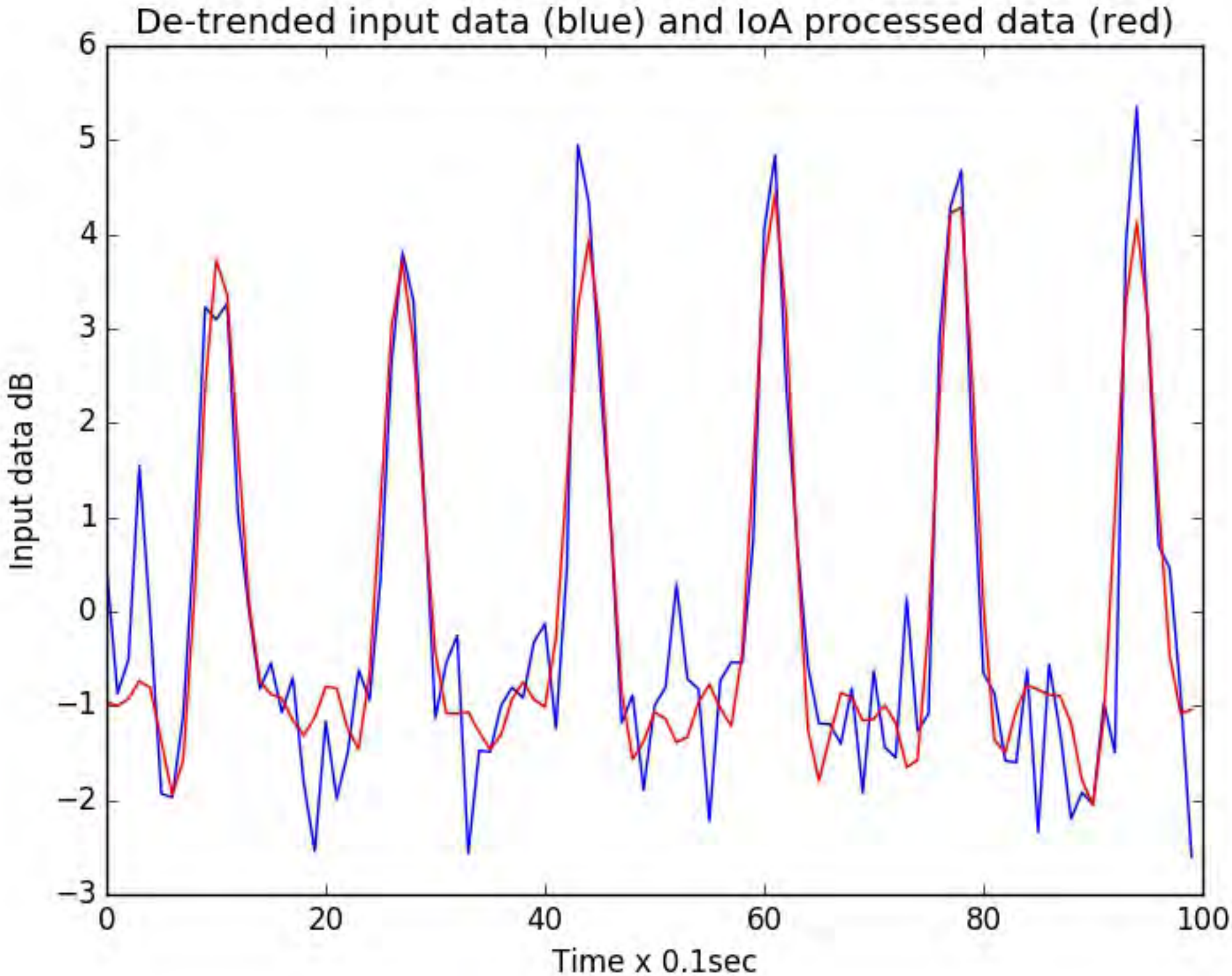
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Input data dB
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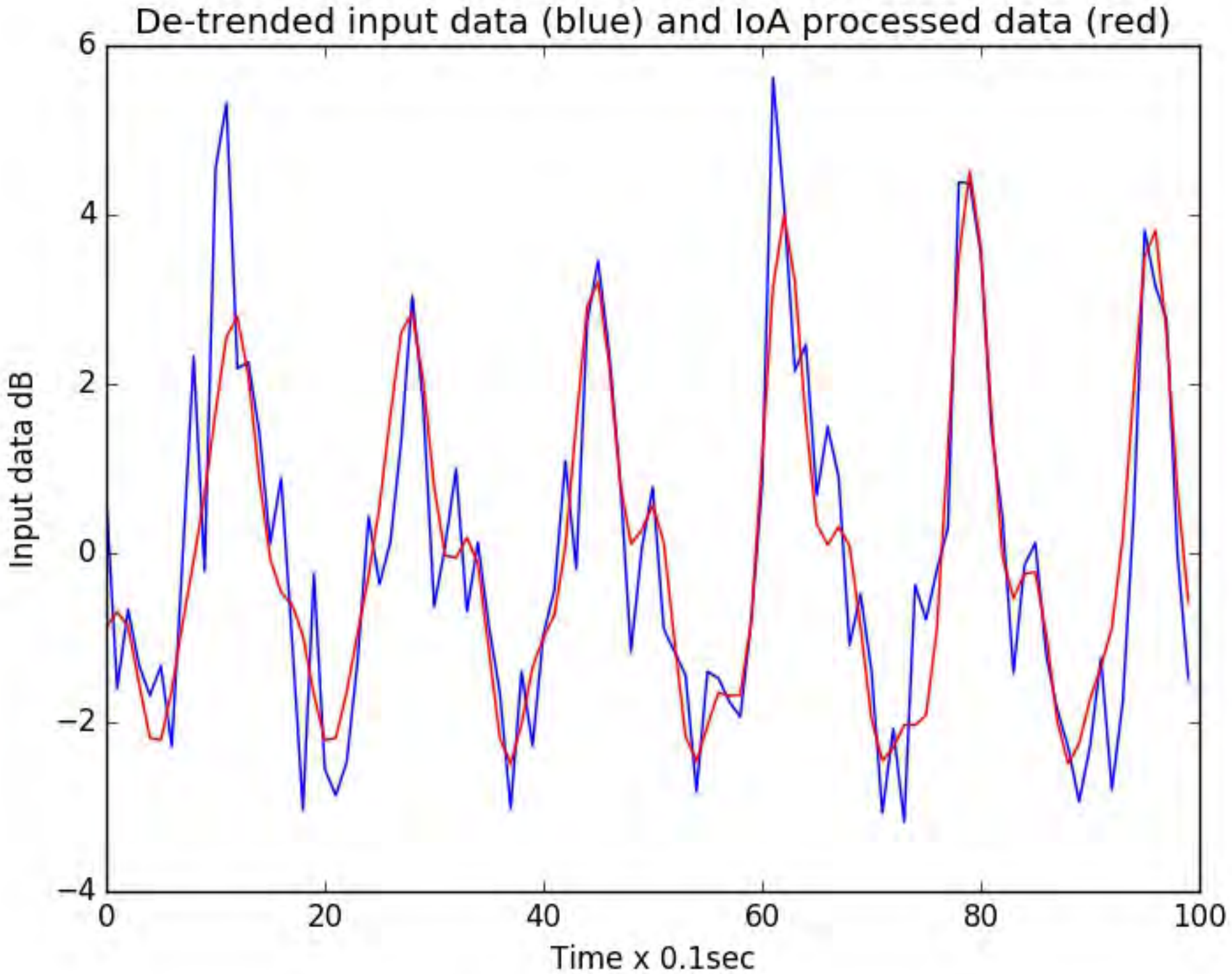
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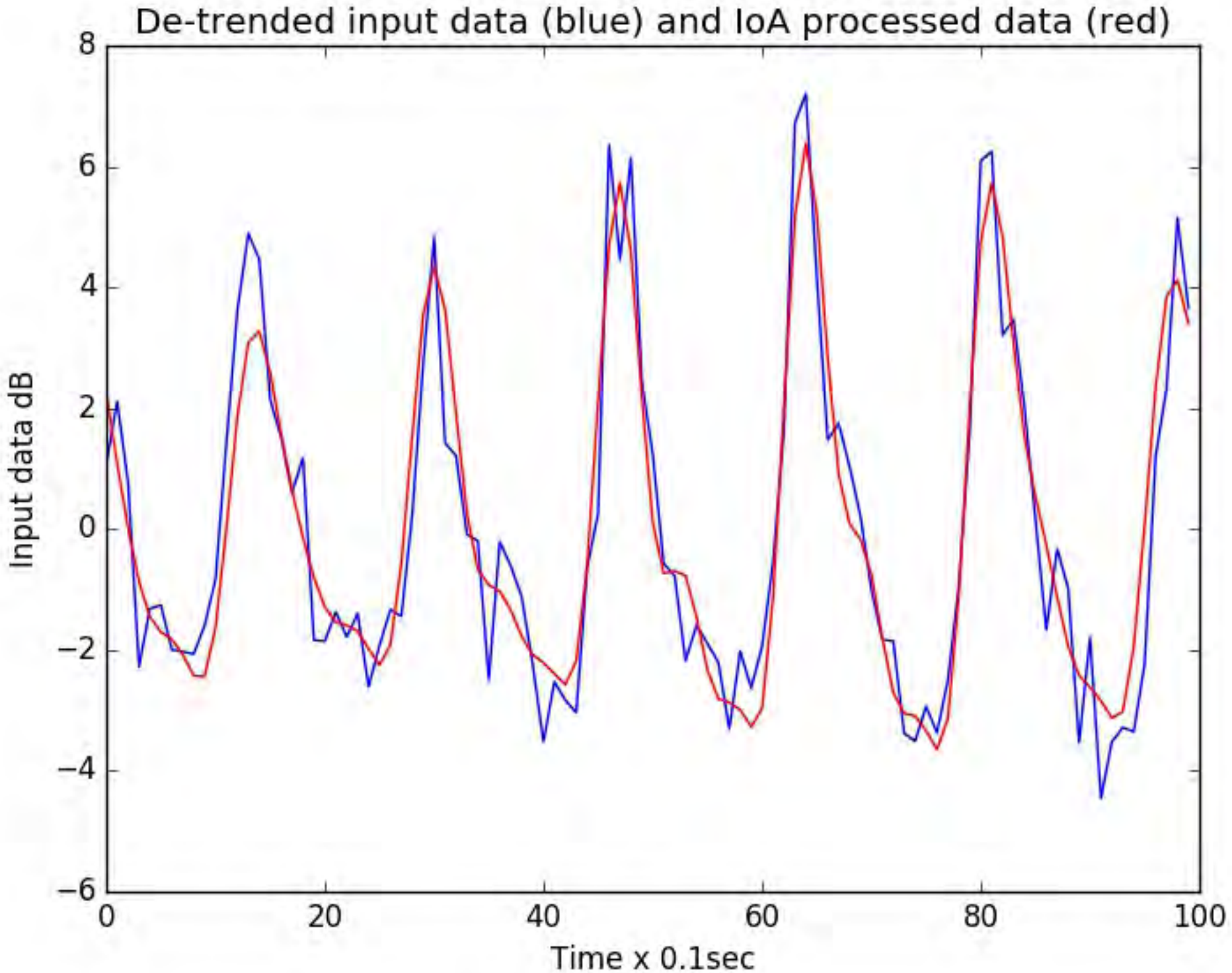
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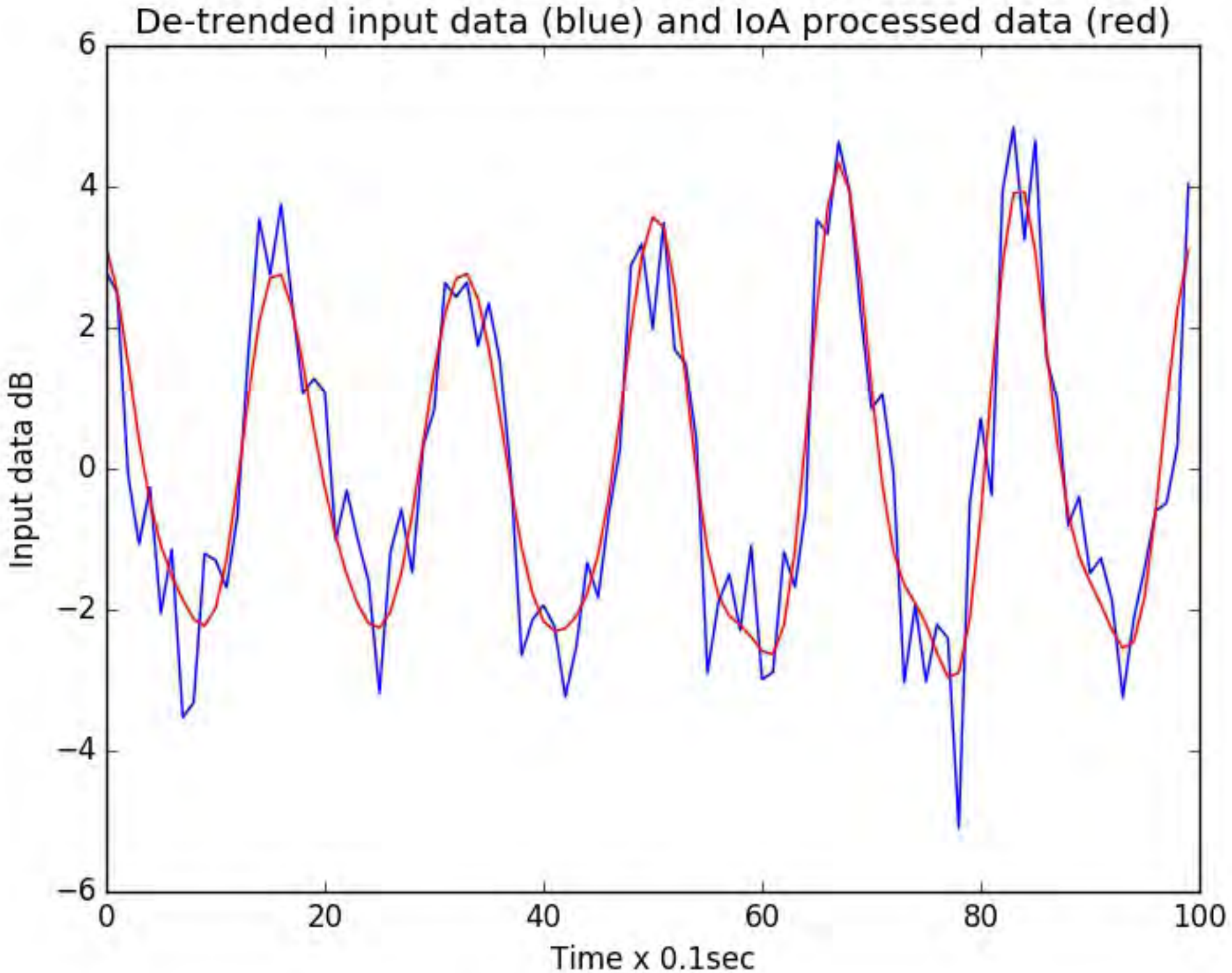
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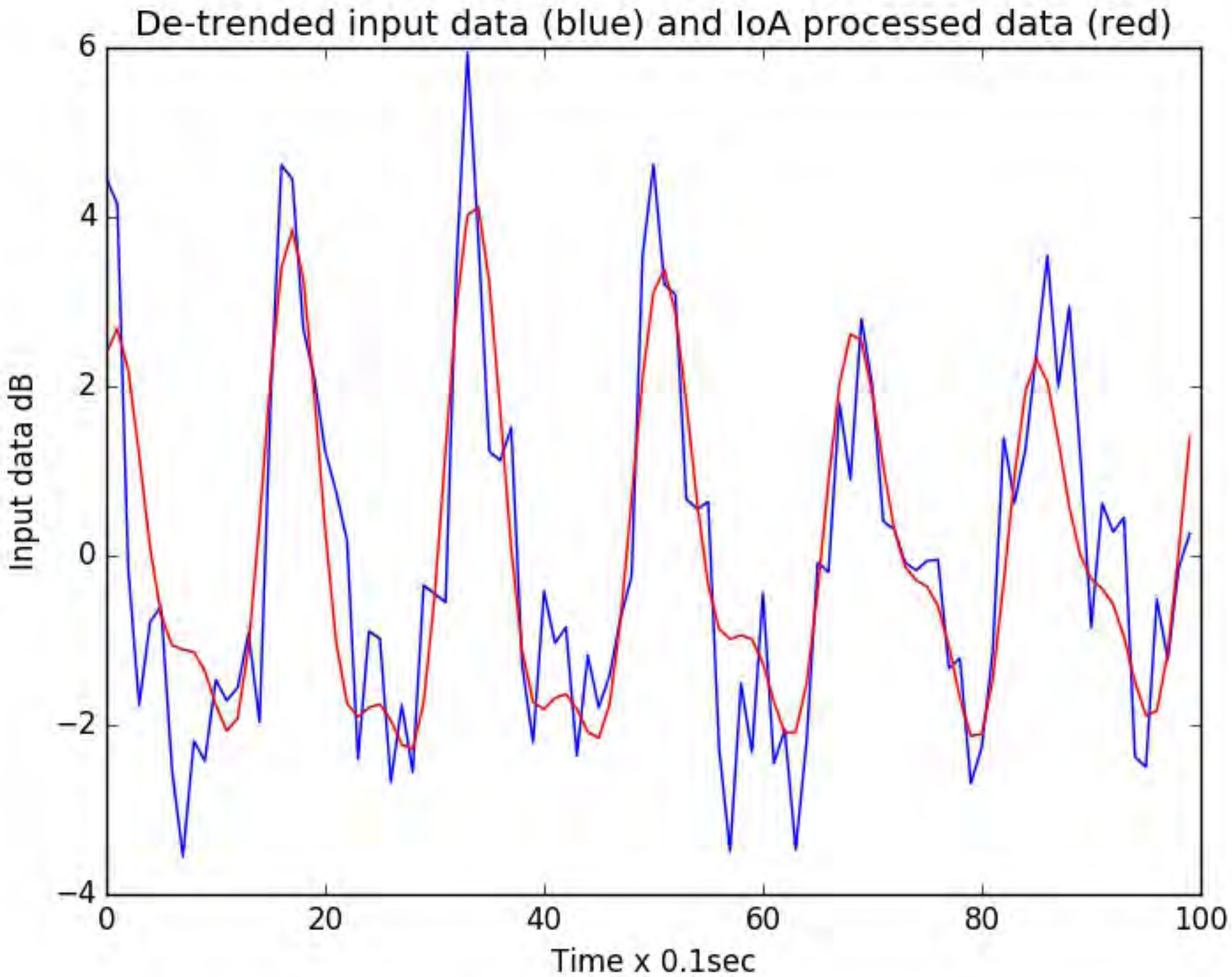
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Input data dB
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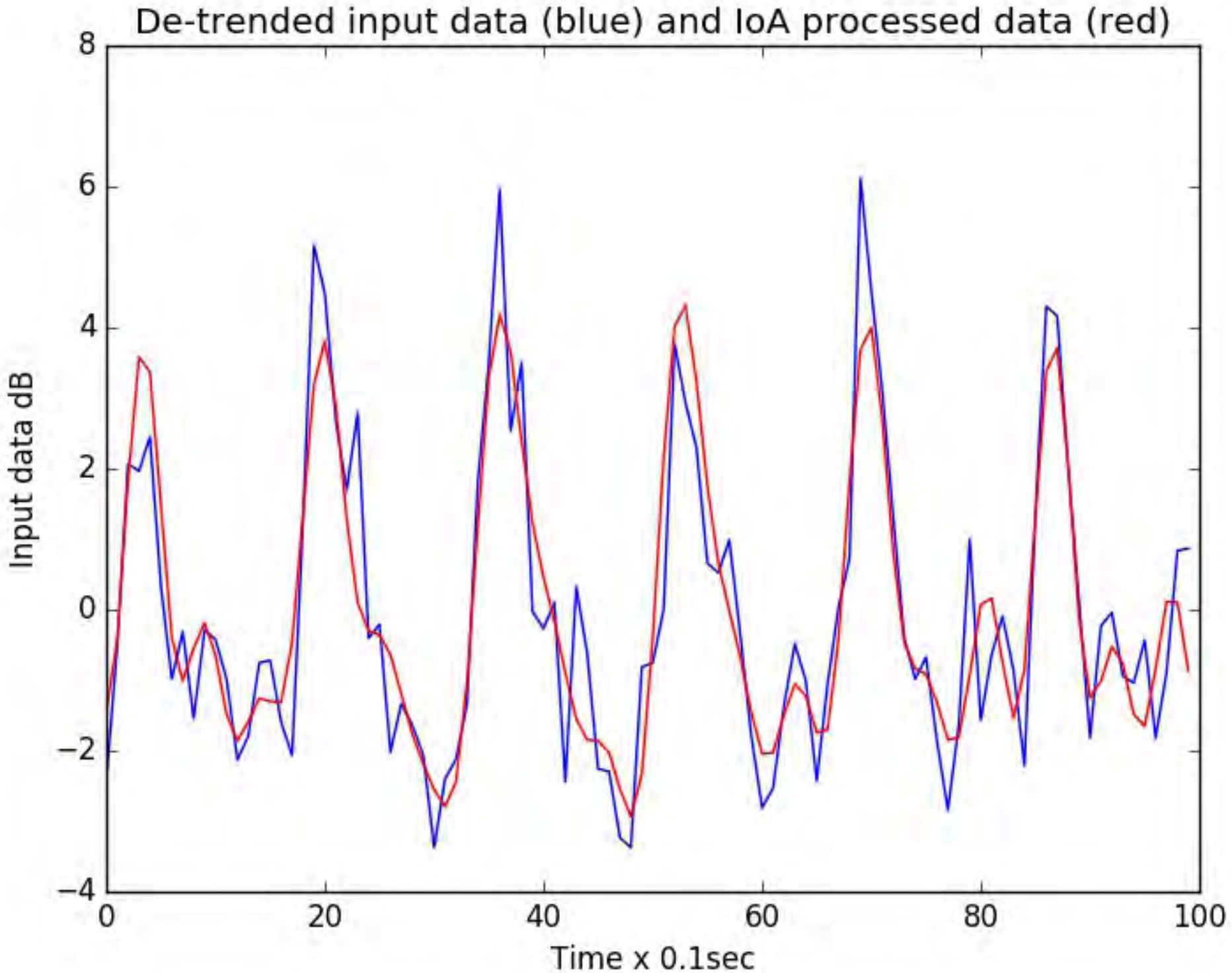
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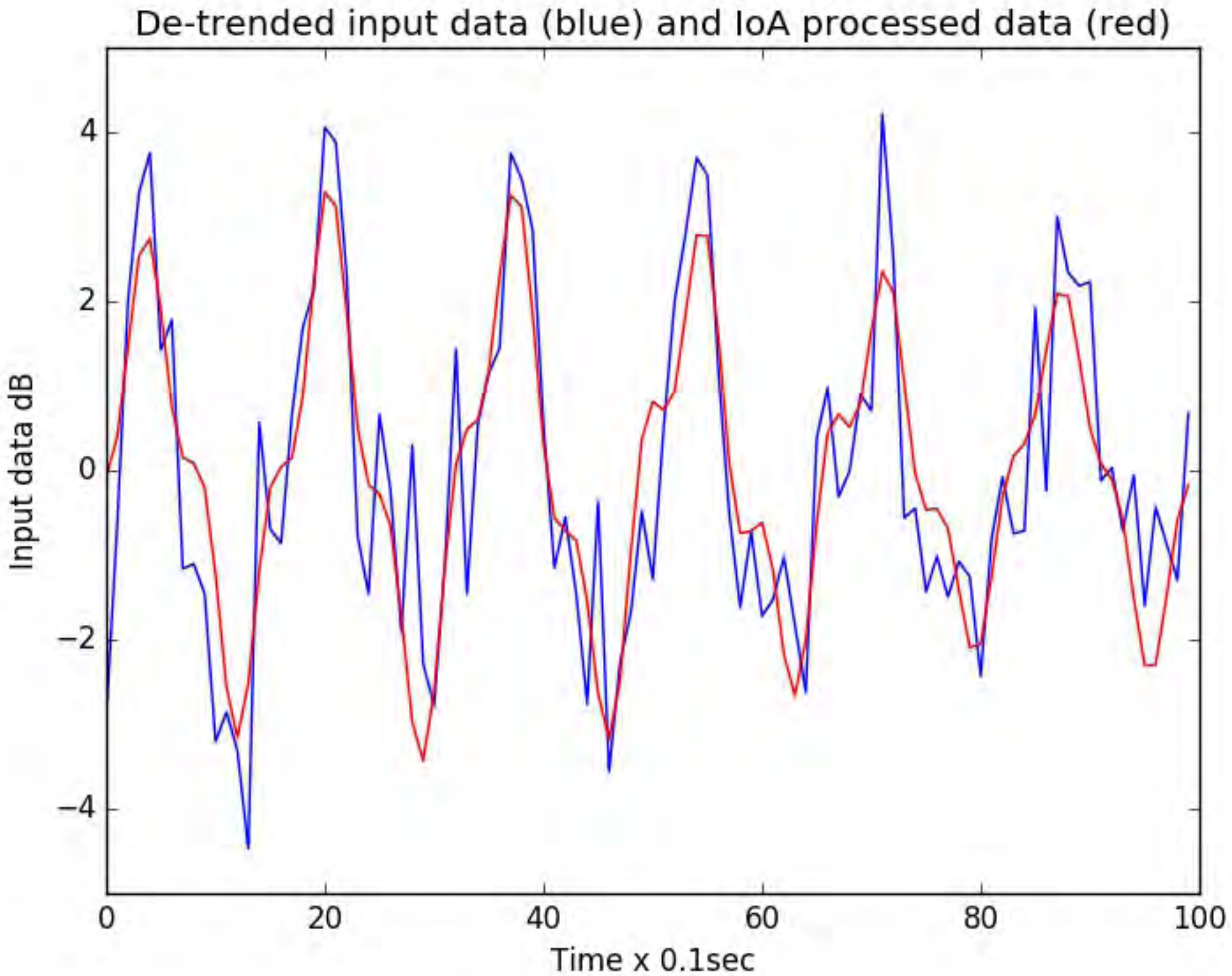
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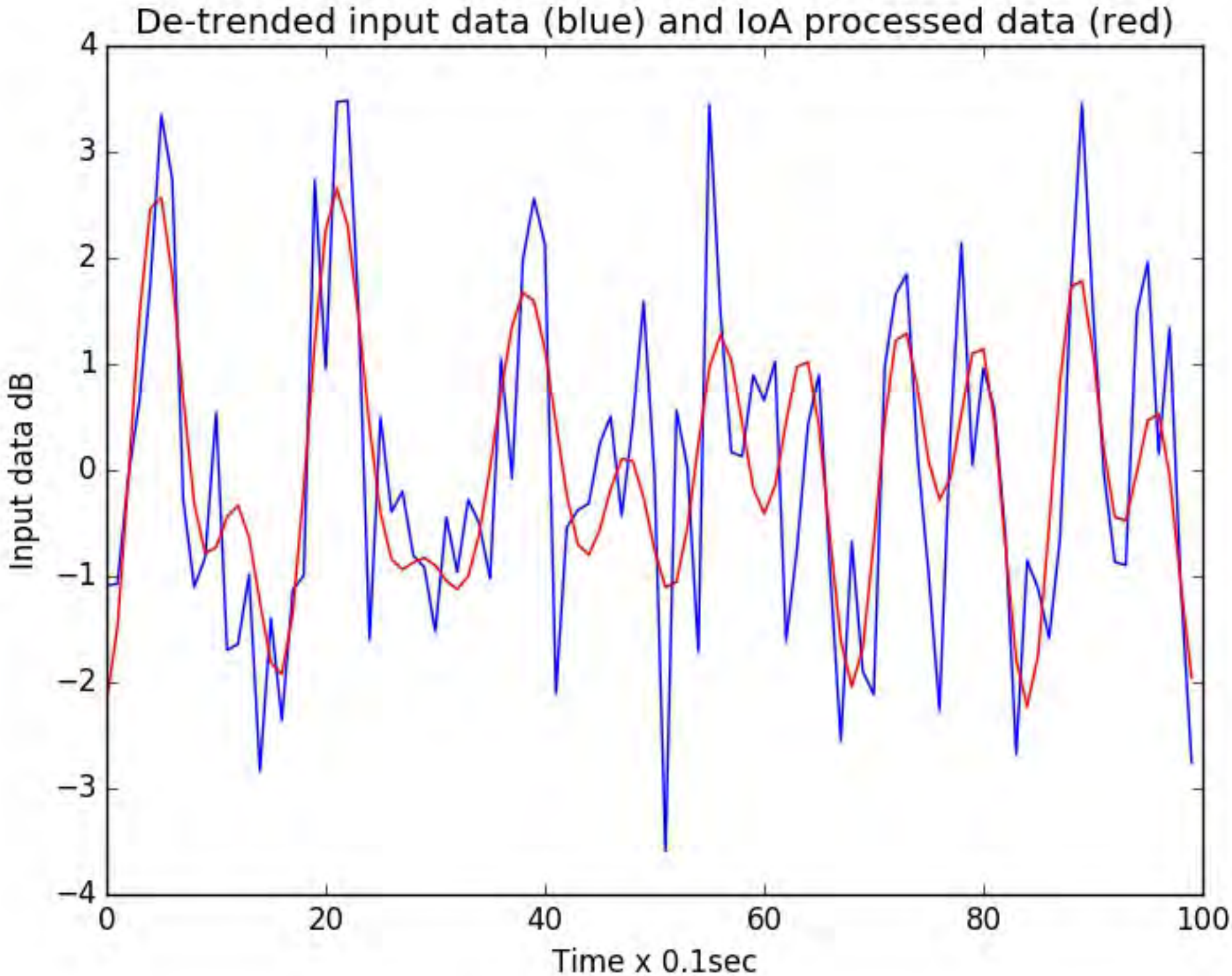
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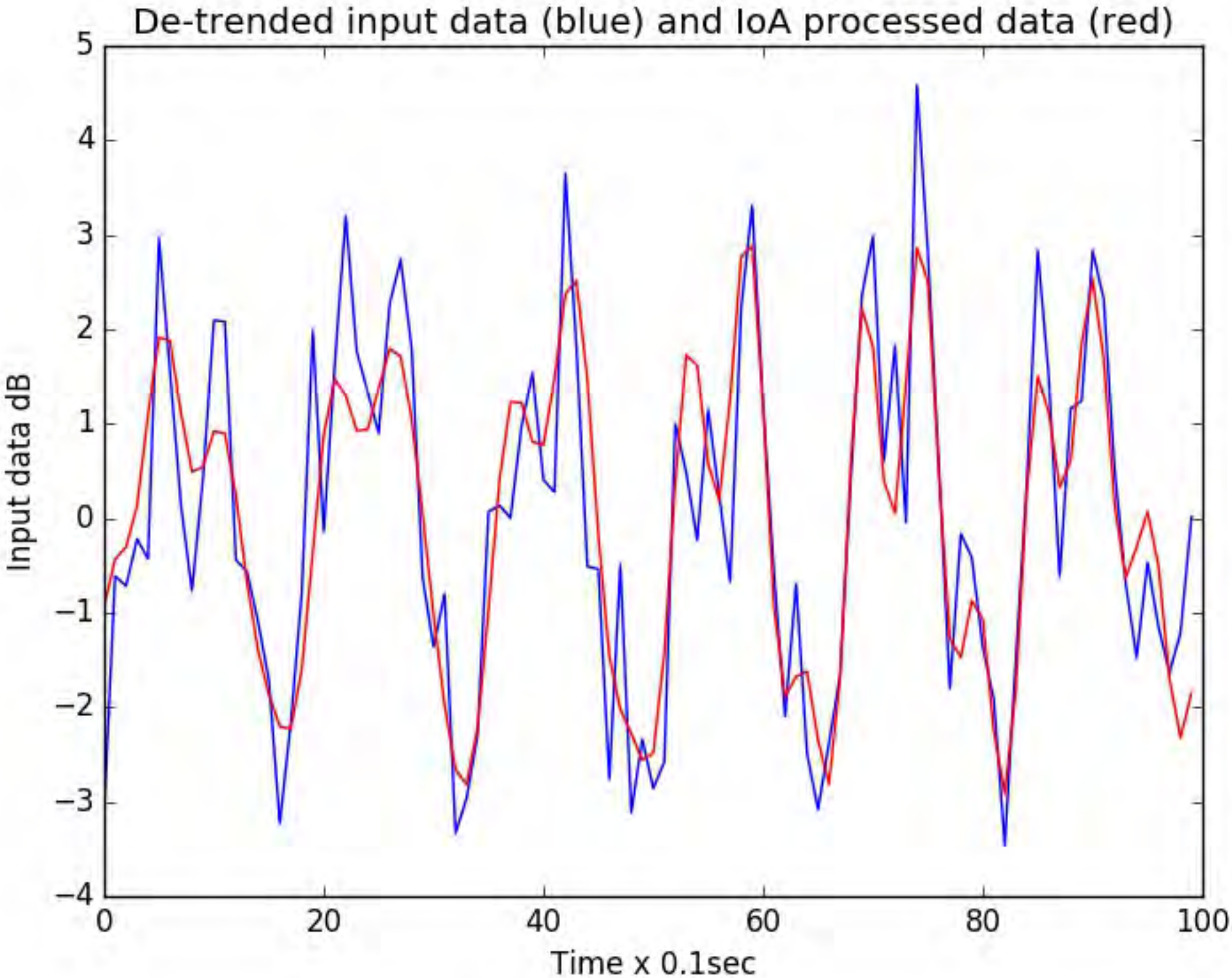
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Input data dB
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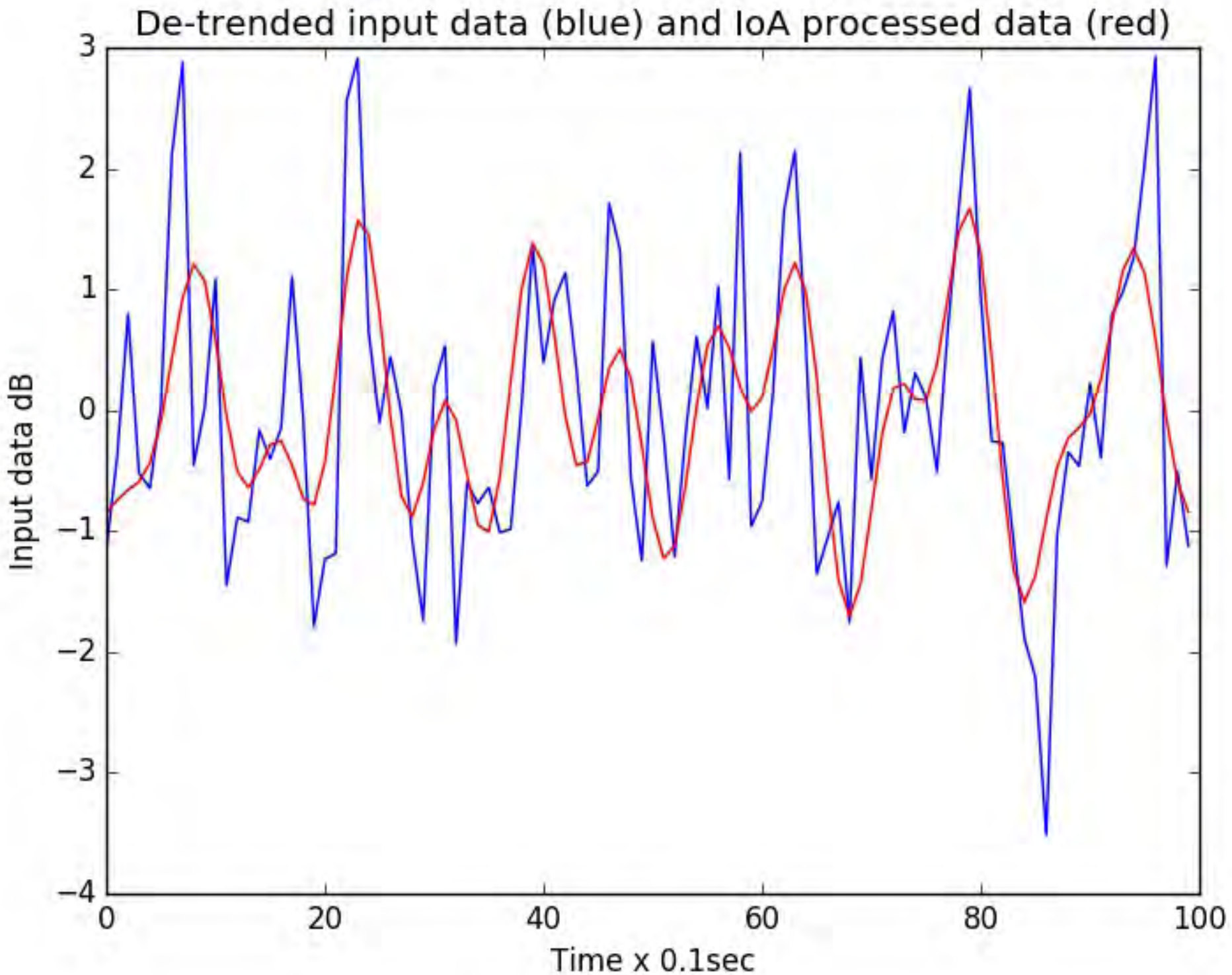
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Input data dB
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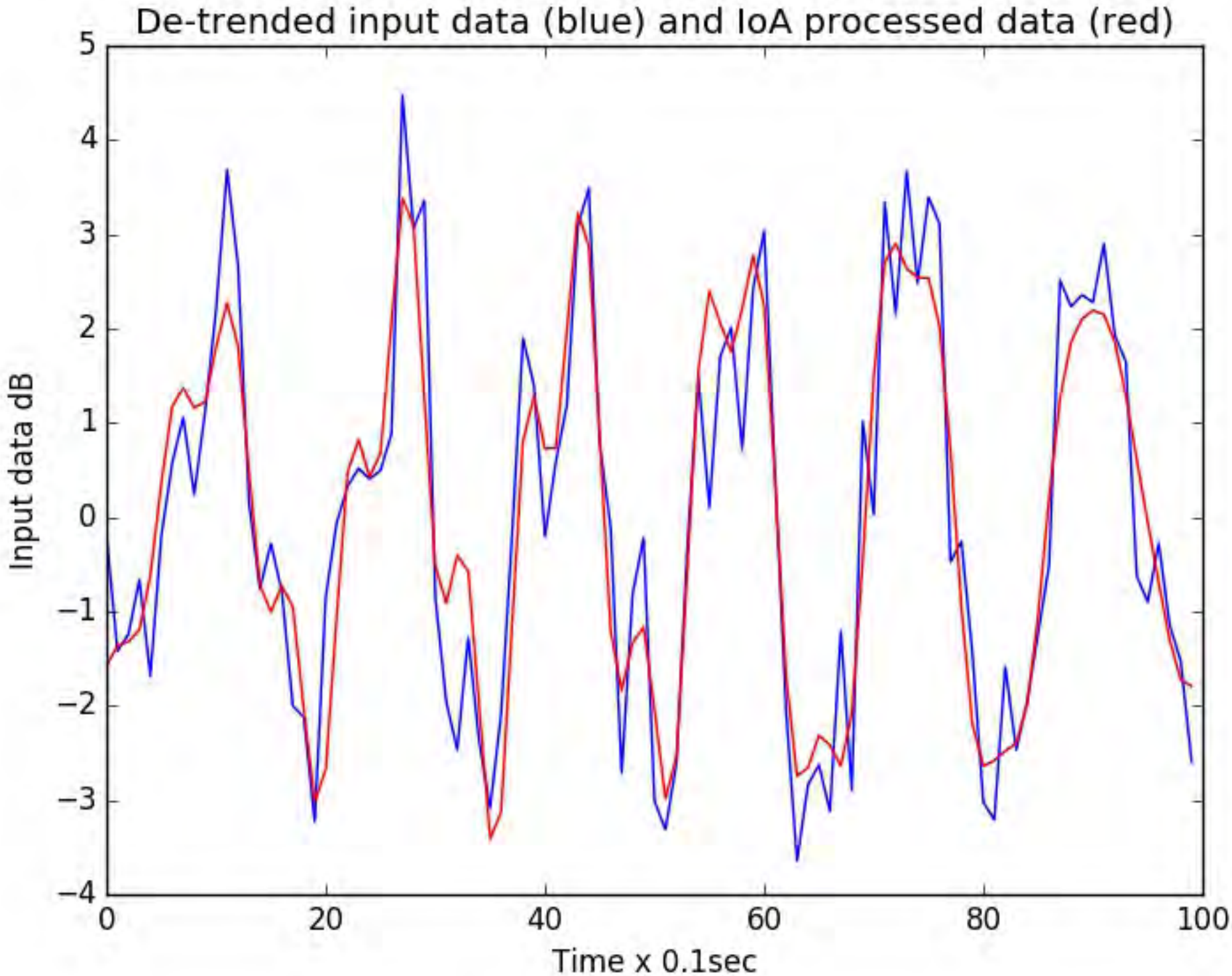
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Input data dB
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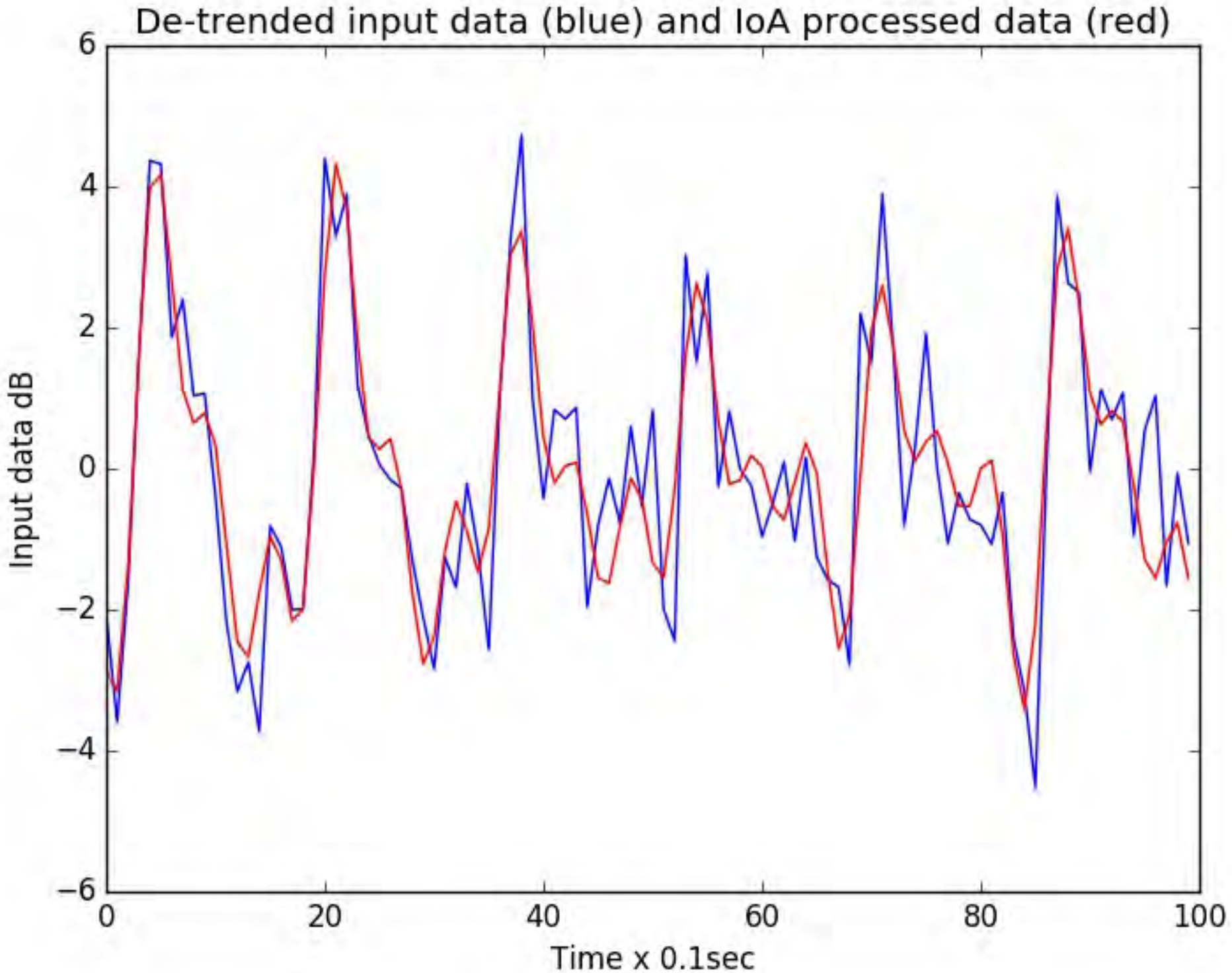
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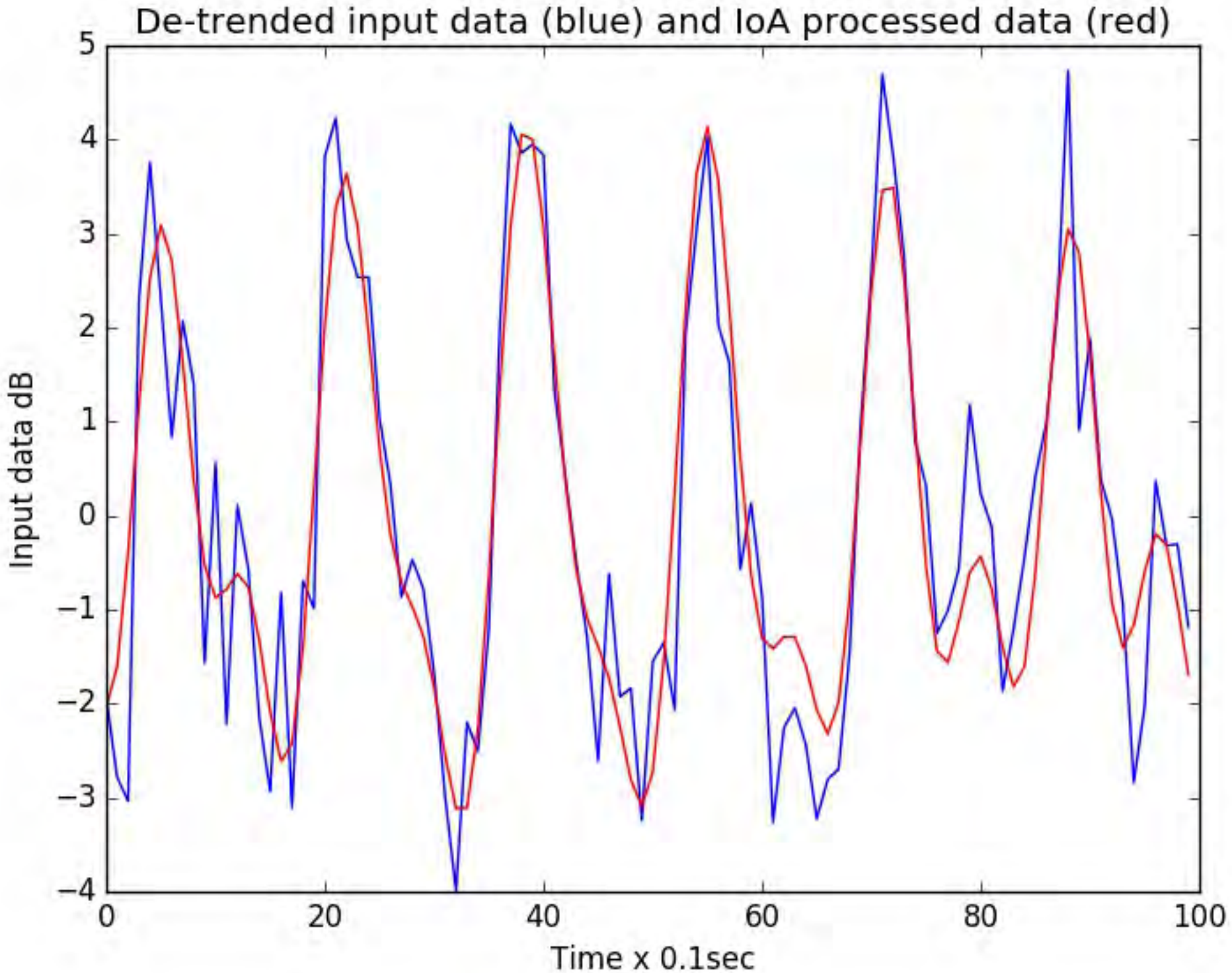
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Input data dB
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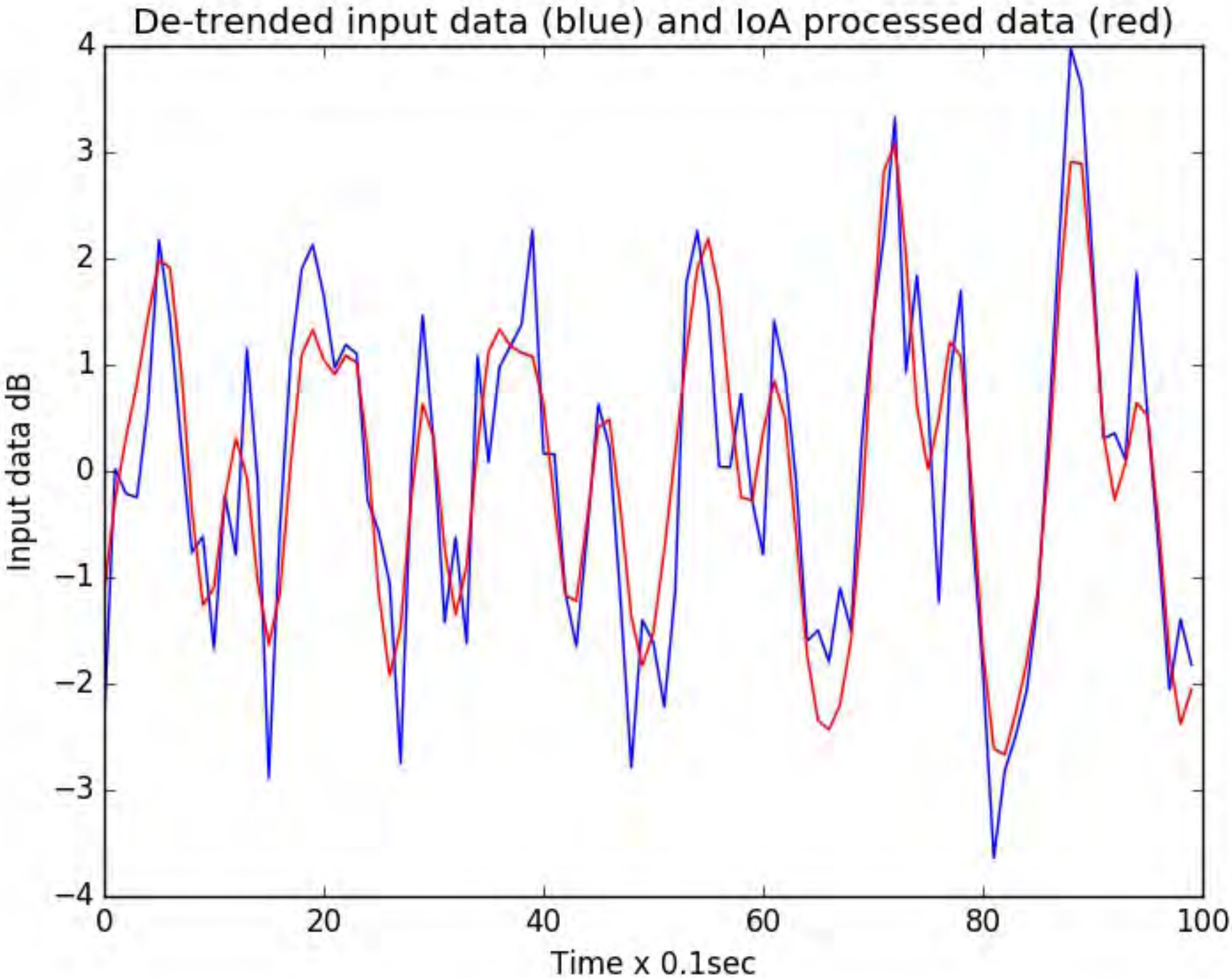
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Input data dB
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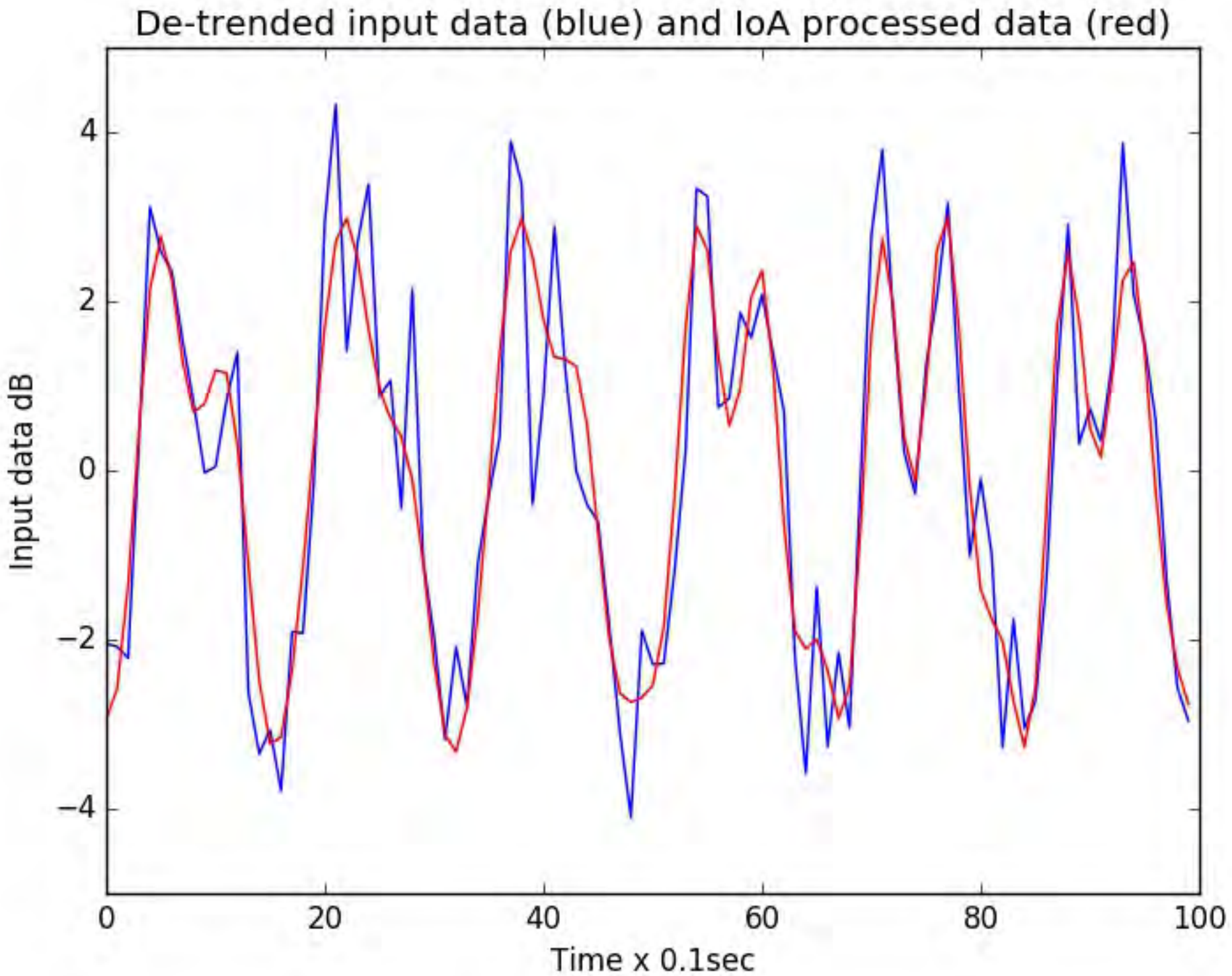
De-trended input data (blue) and IoA processed data (red)
Input data dB
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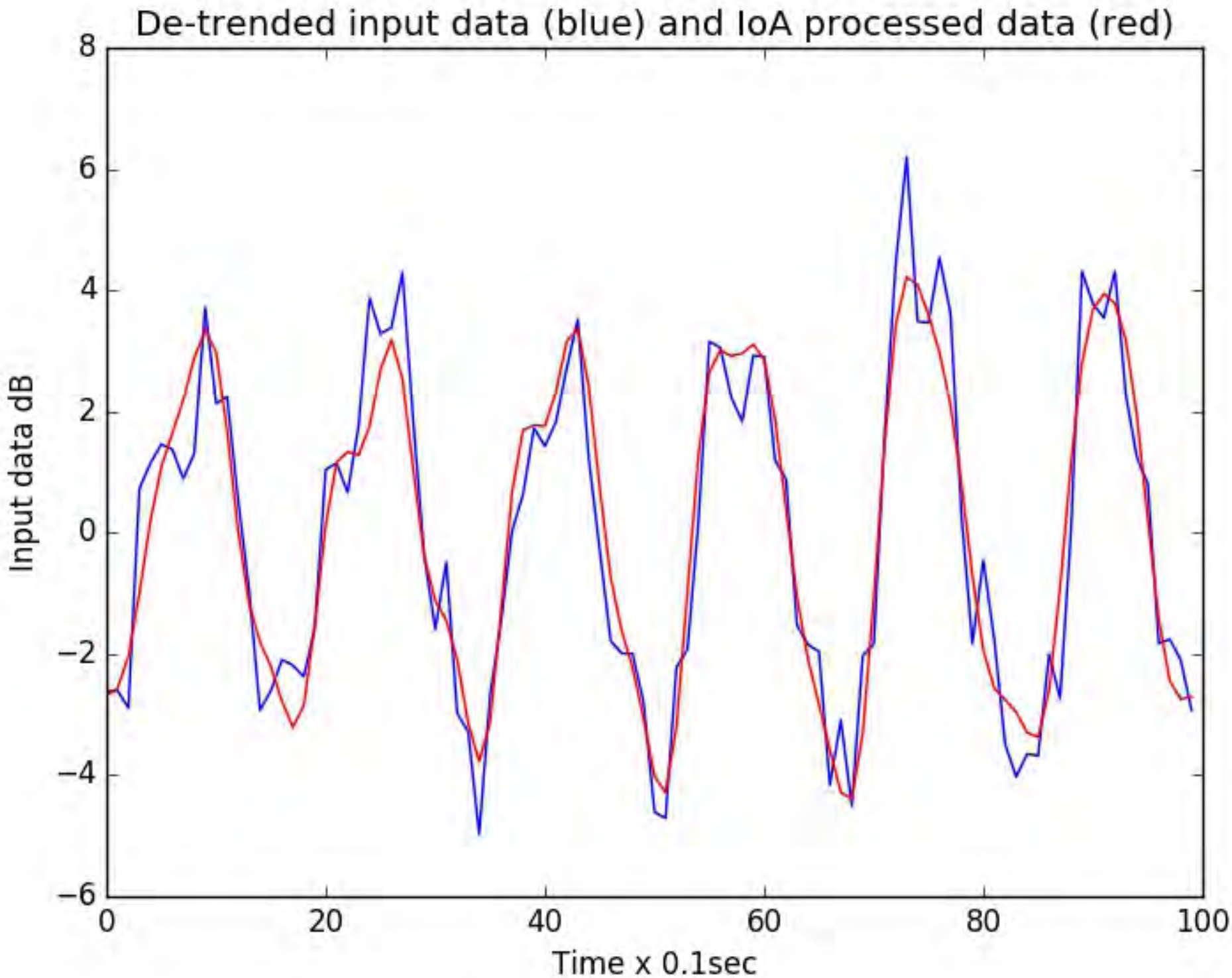
Time x 0.1sec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Input data dB
Time x 0.1sec
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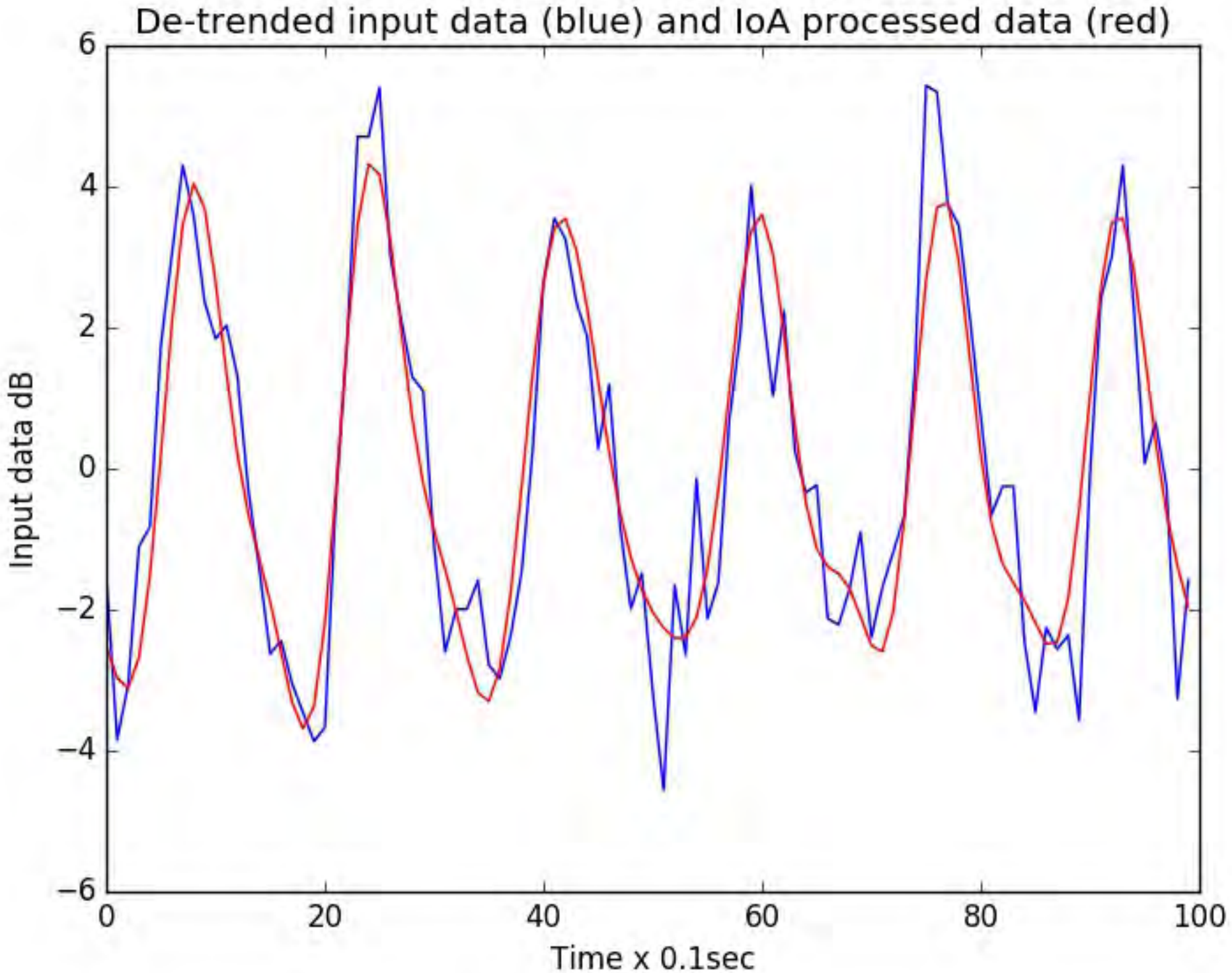
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Input data dB
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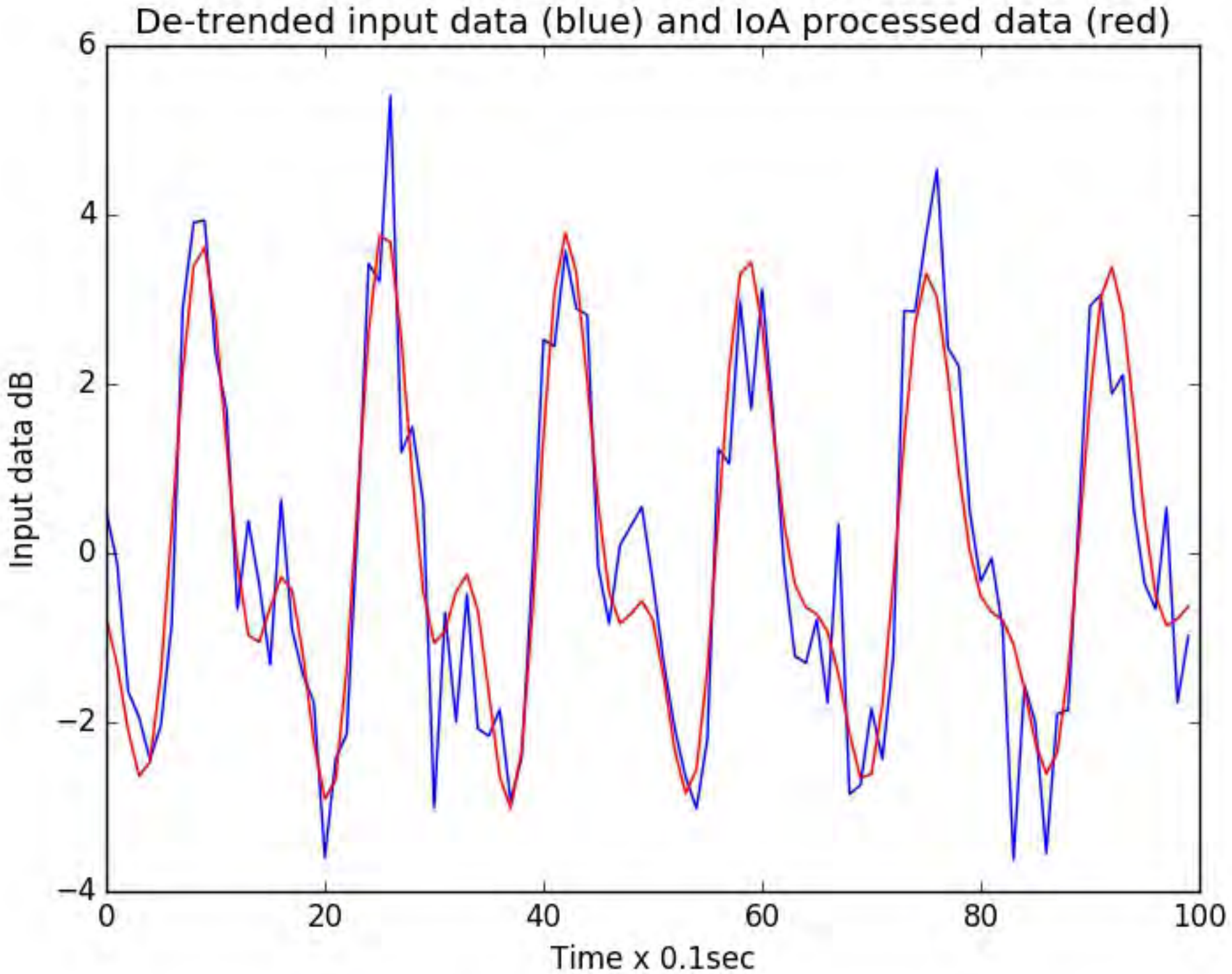
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Input data dB
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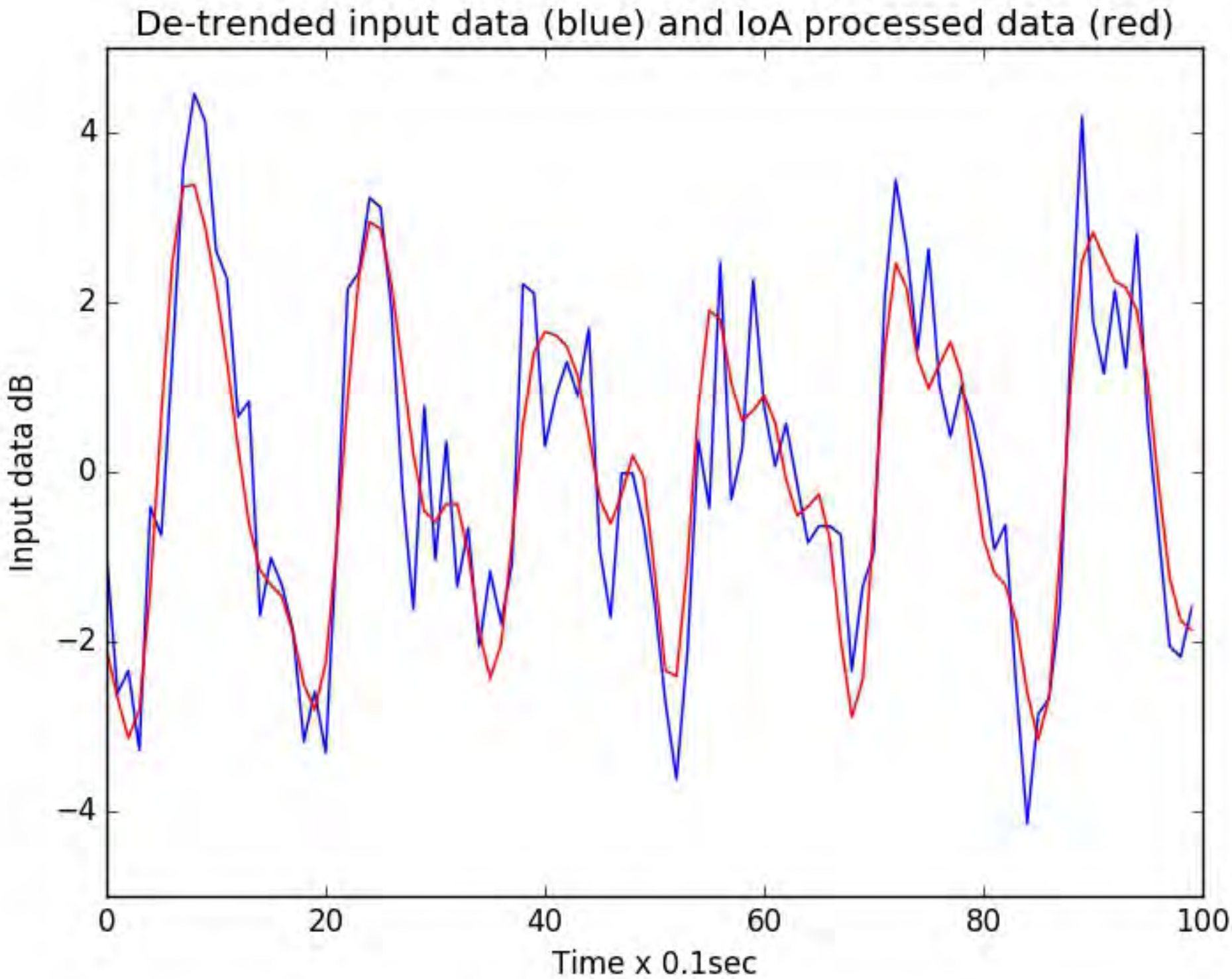
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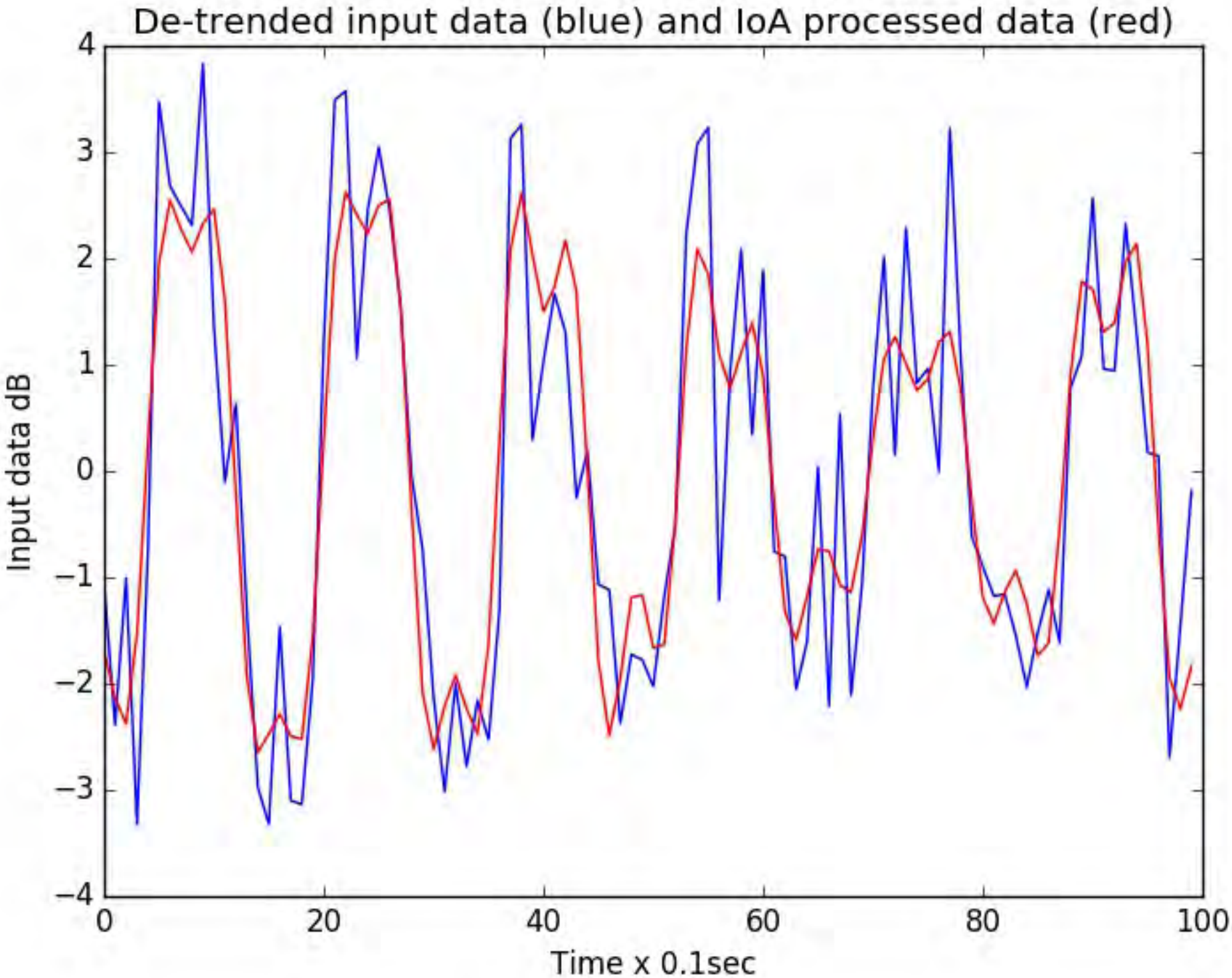
Time x 0.1sec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Input data dB
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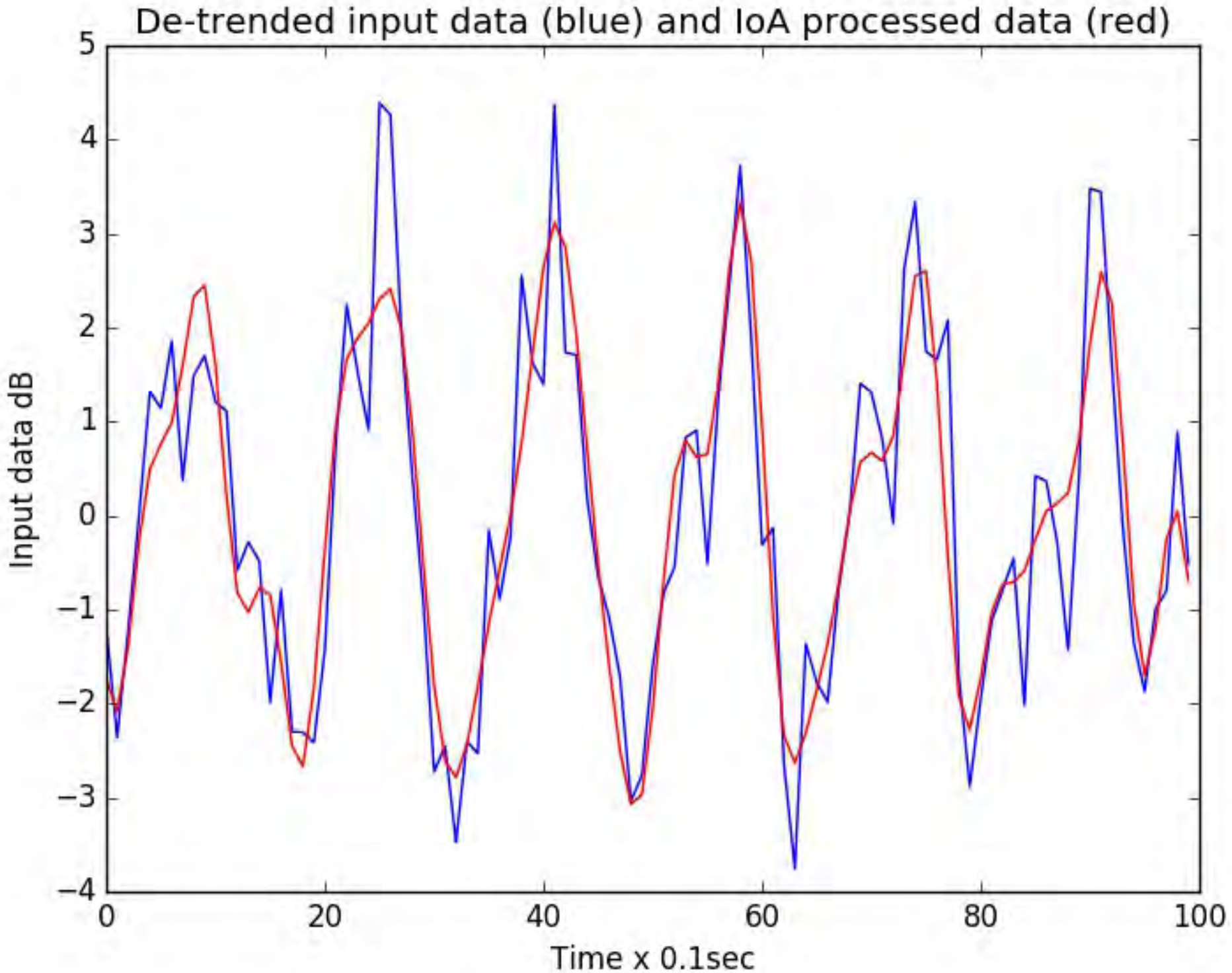
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Input data dB
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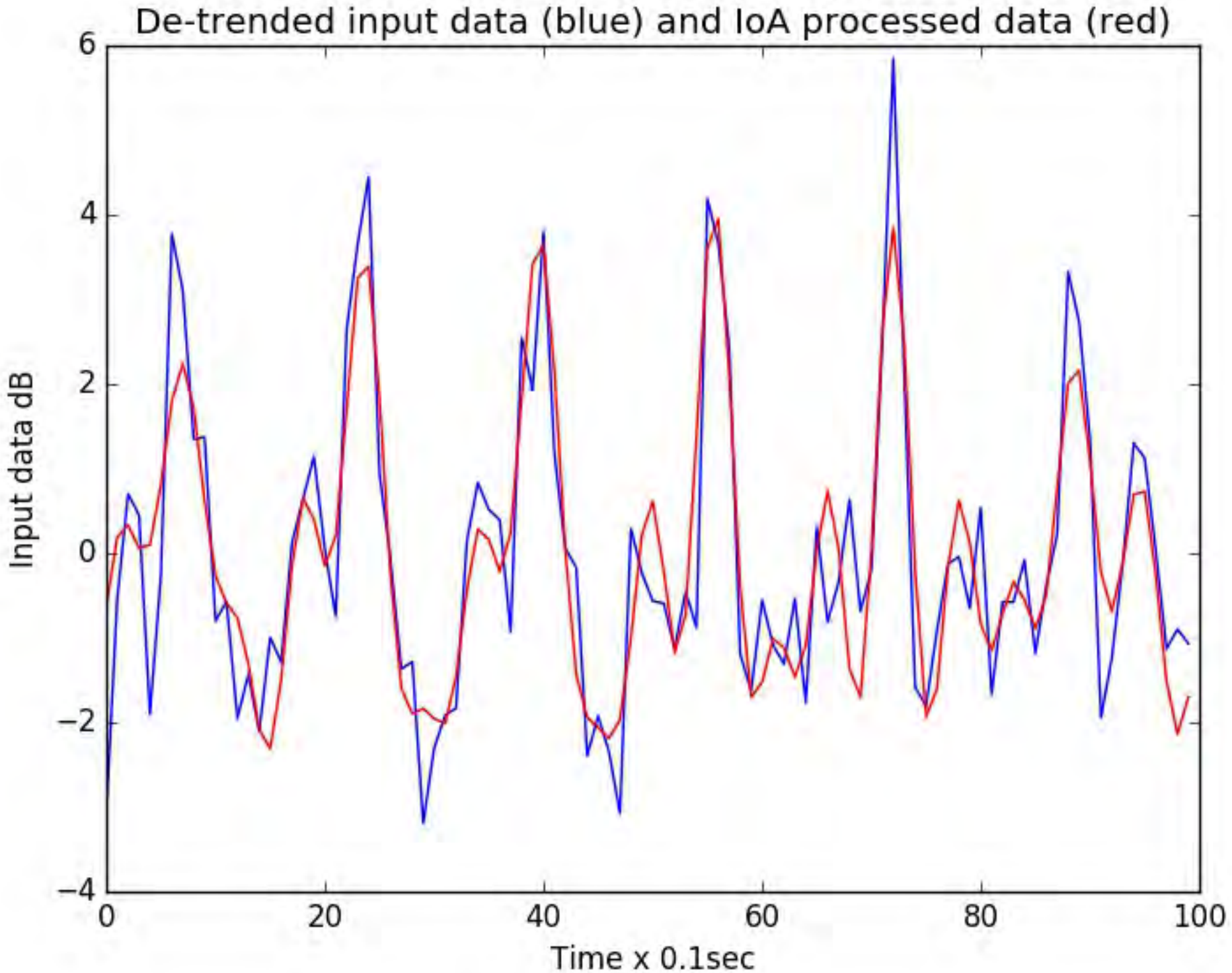
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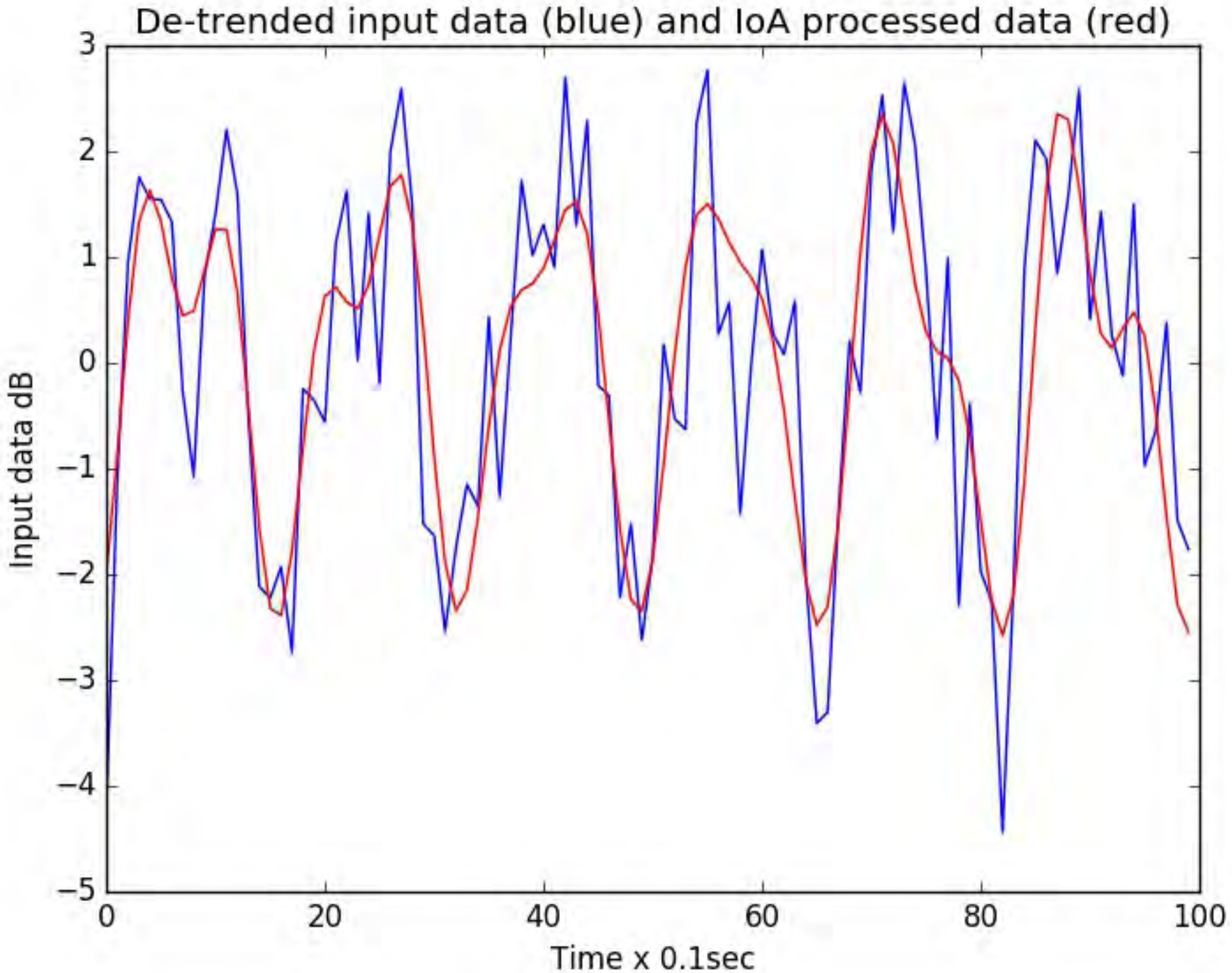
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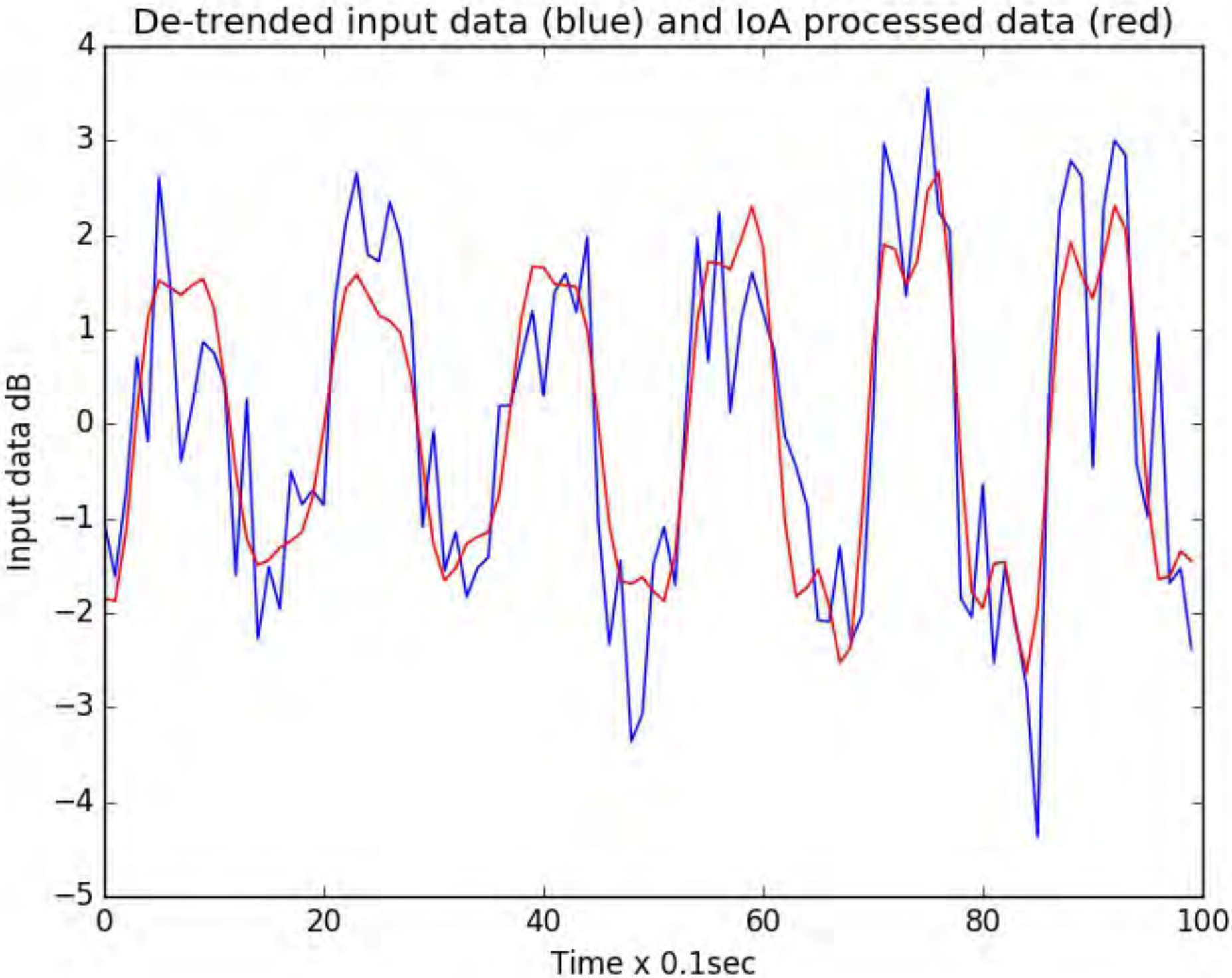
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Input data dB
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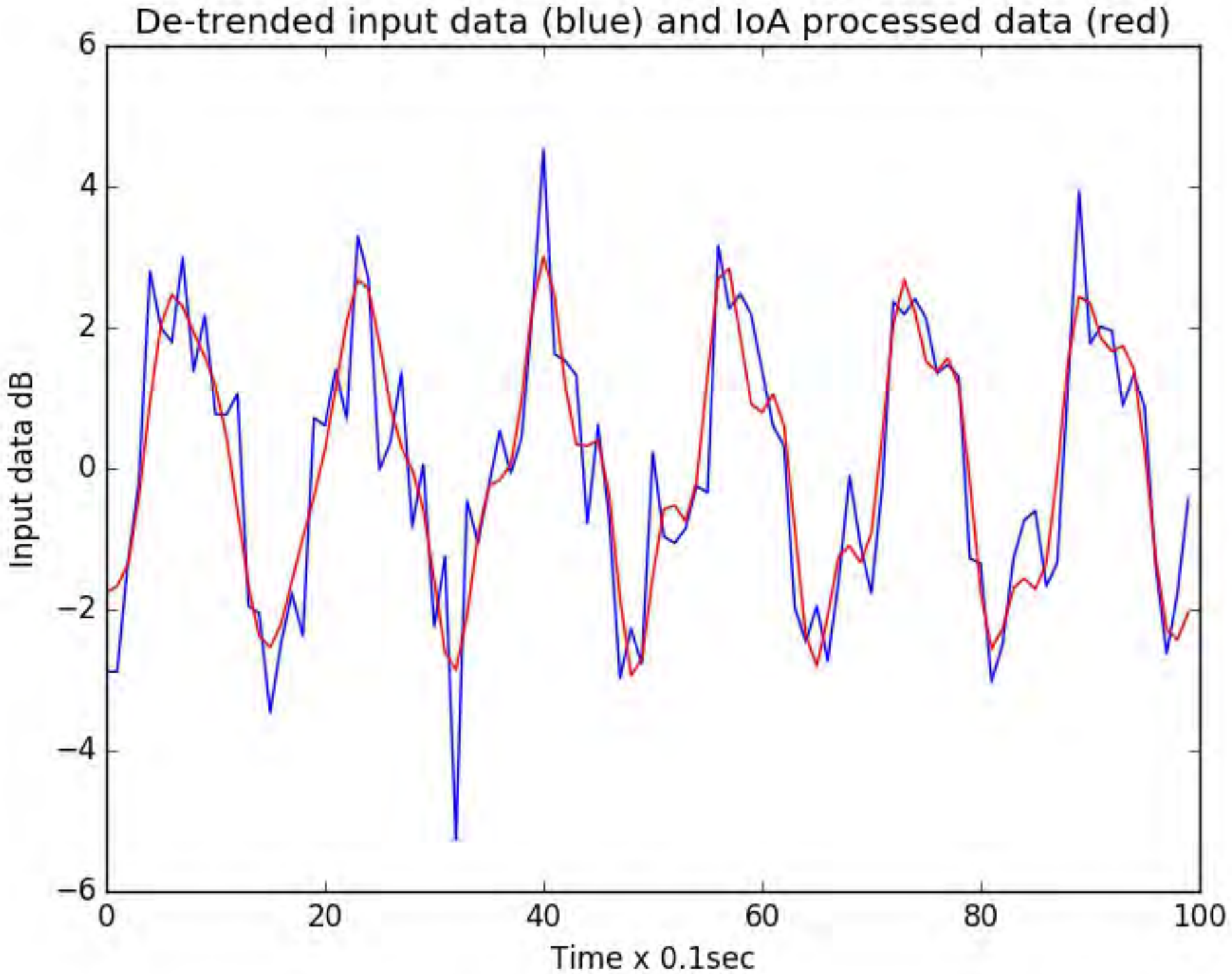
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Input data dB
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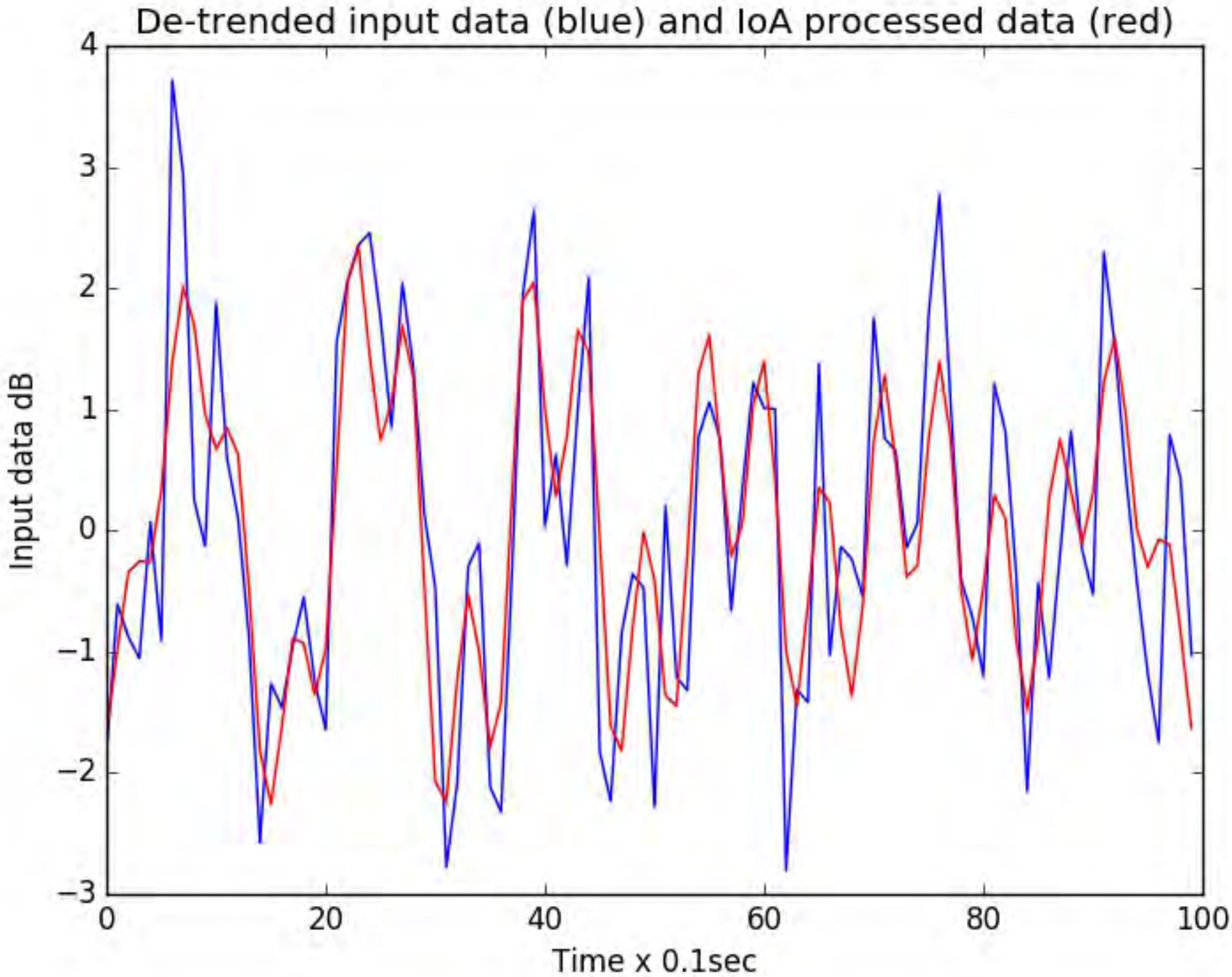
De-trended input data (blue) and IoA processed data (red)
Input data dB
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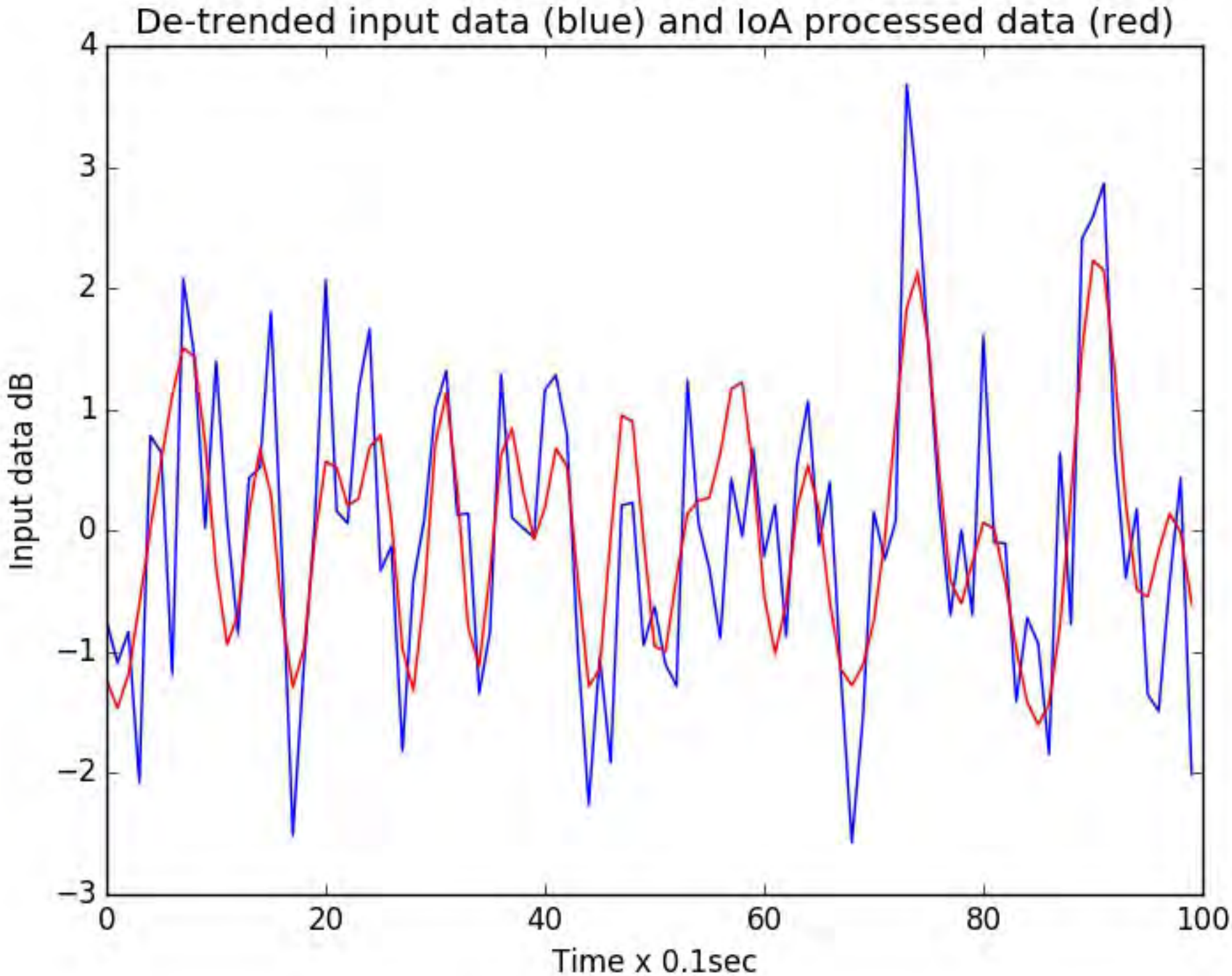
De-trended input data (blue) and IoA processed data (red)
Input data dB
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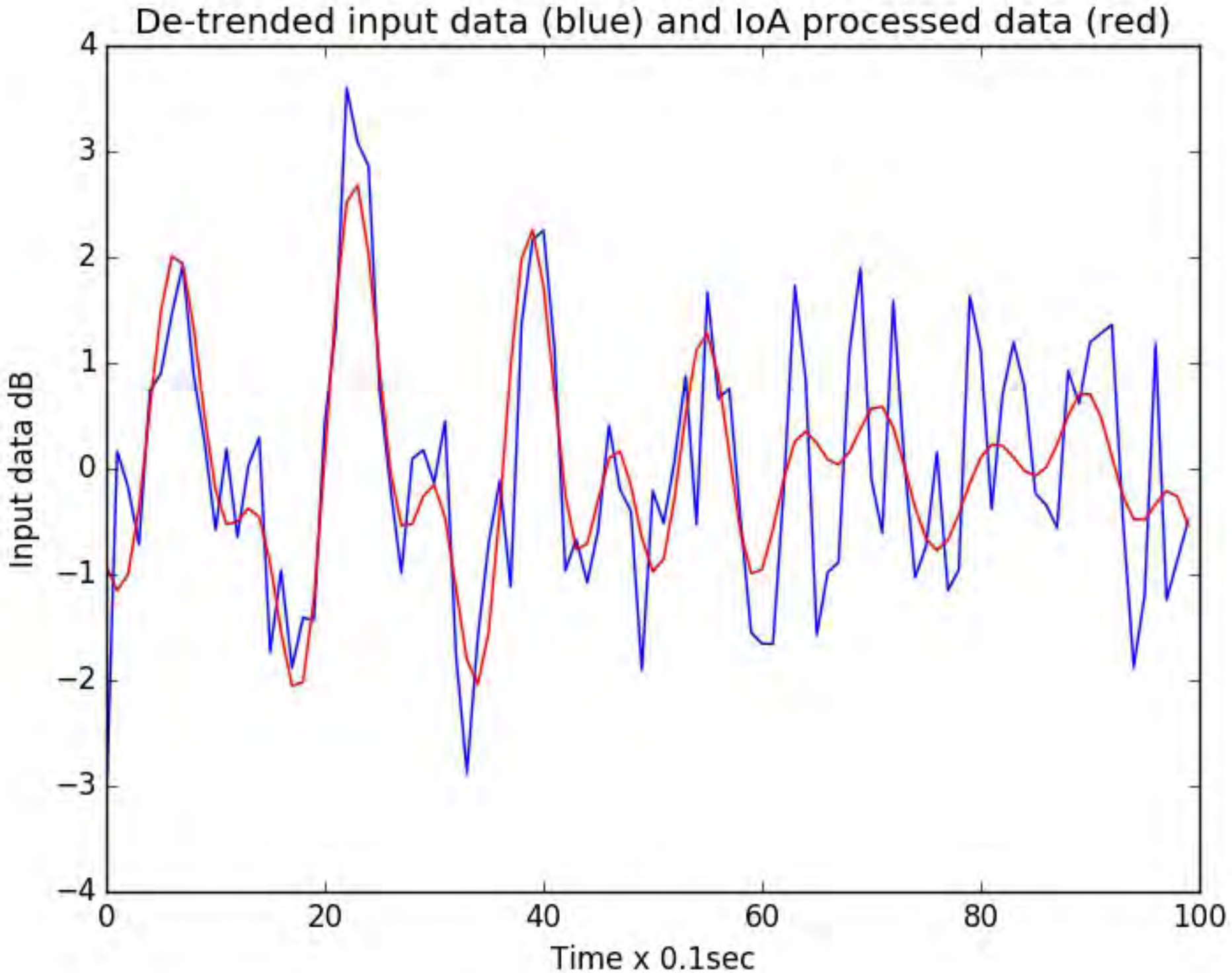
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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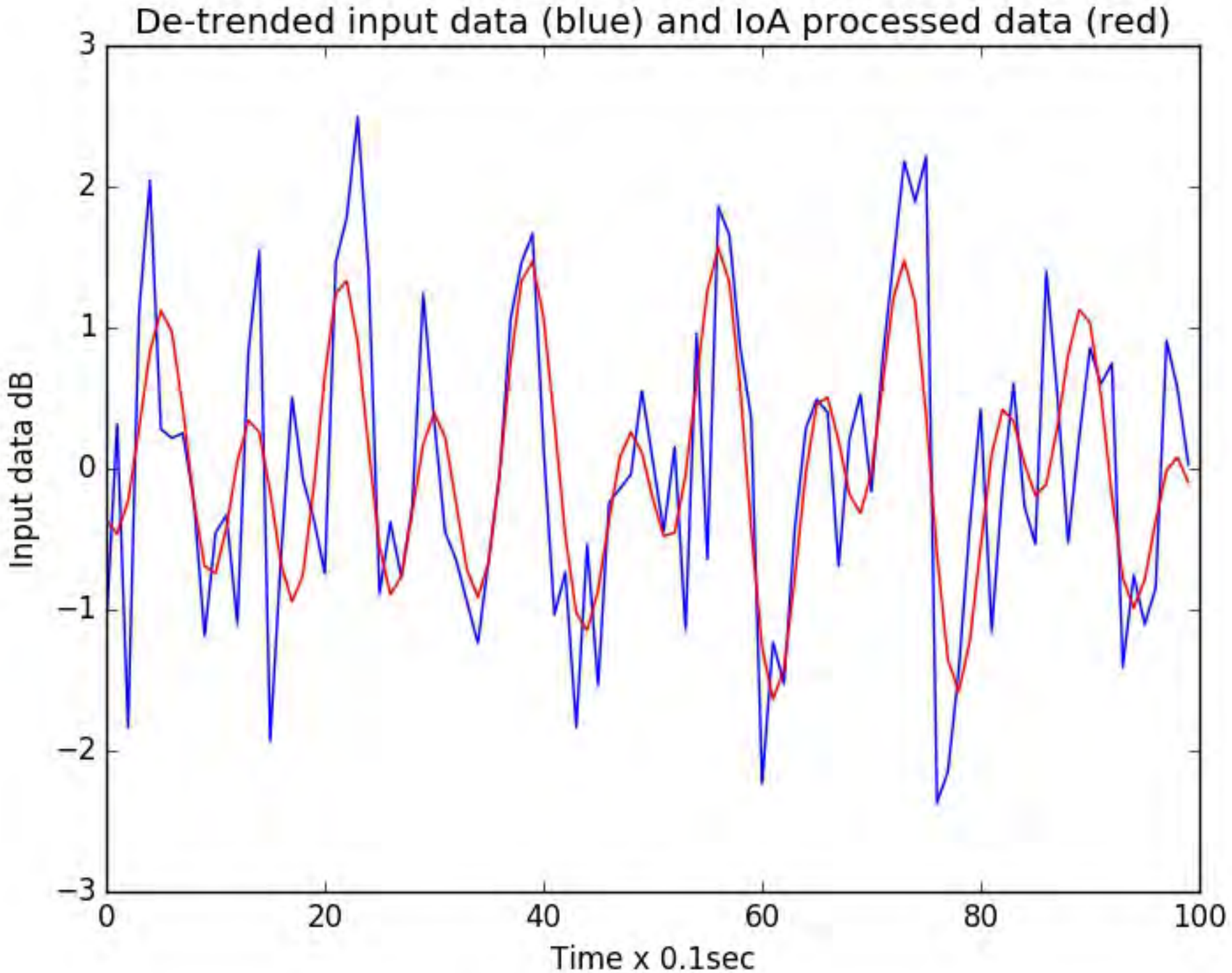
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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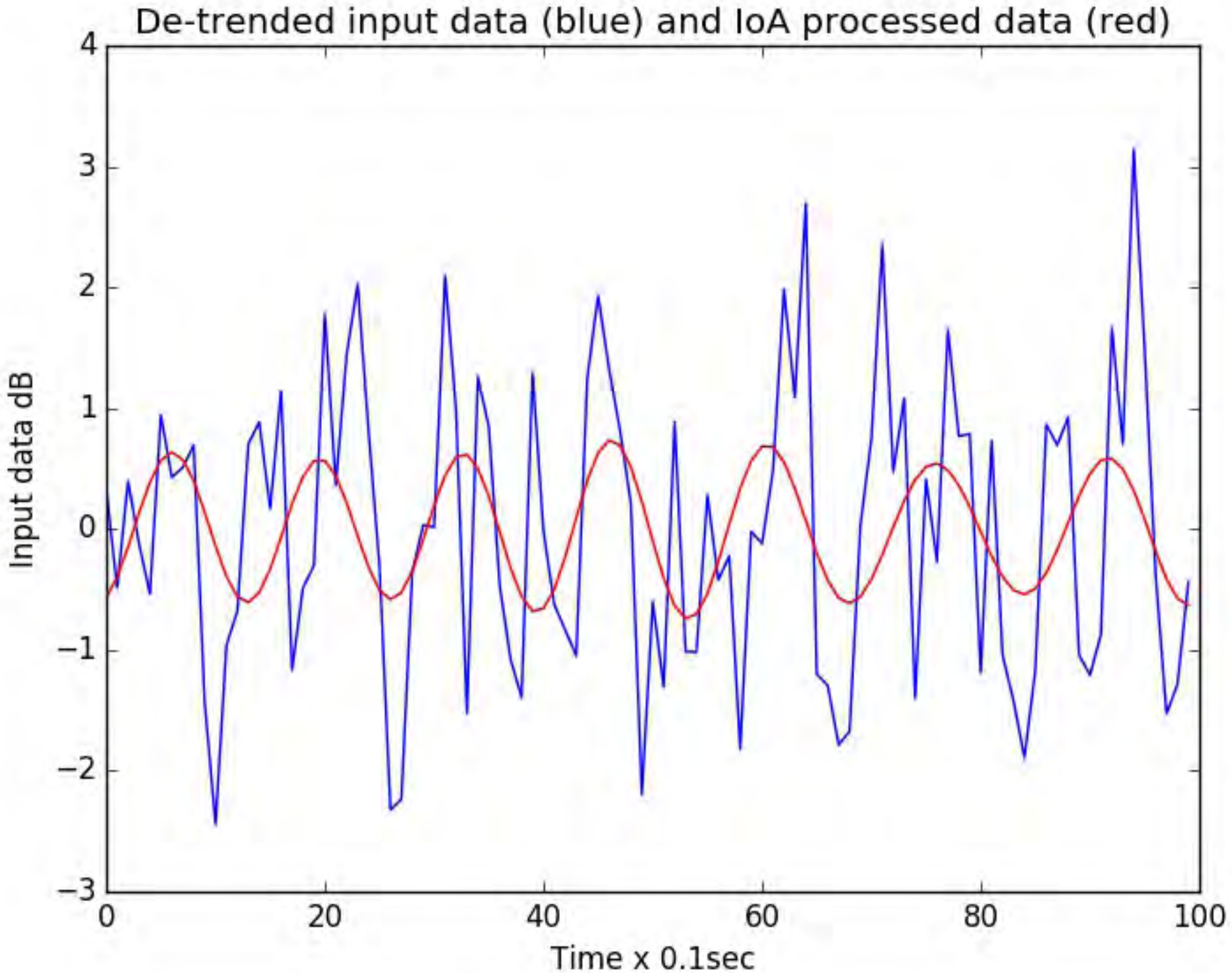
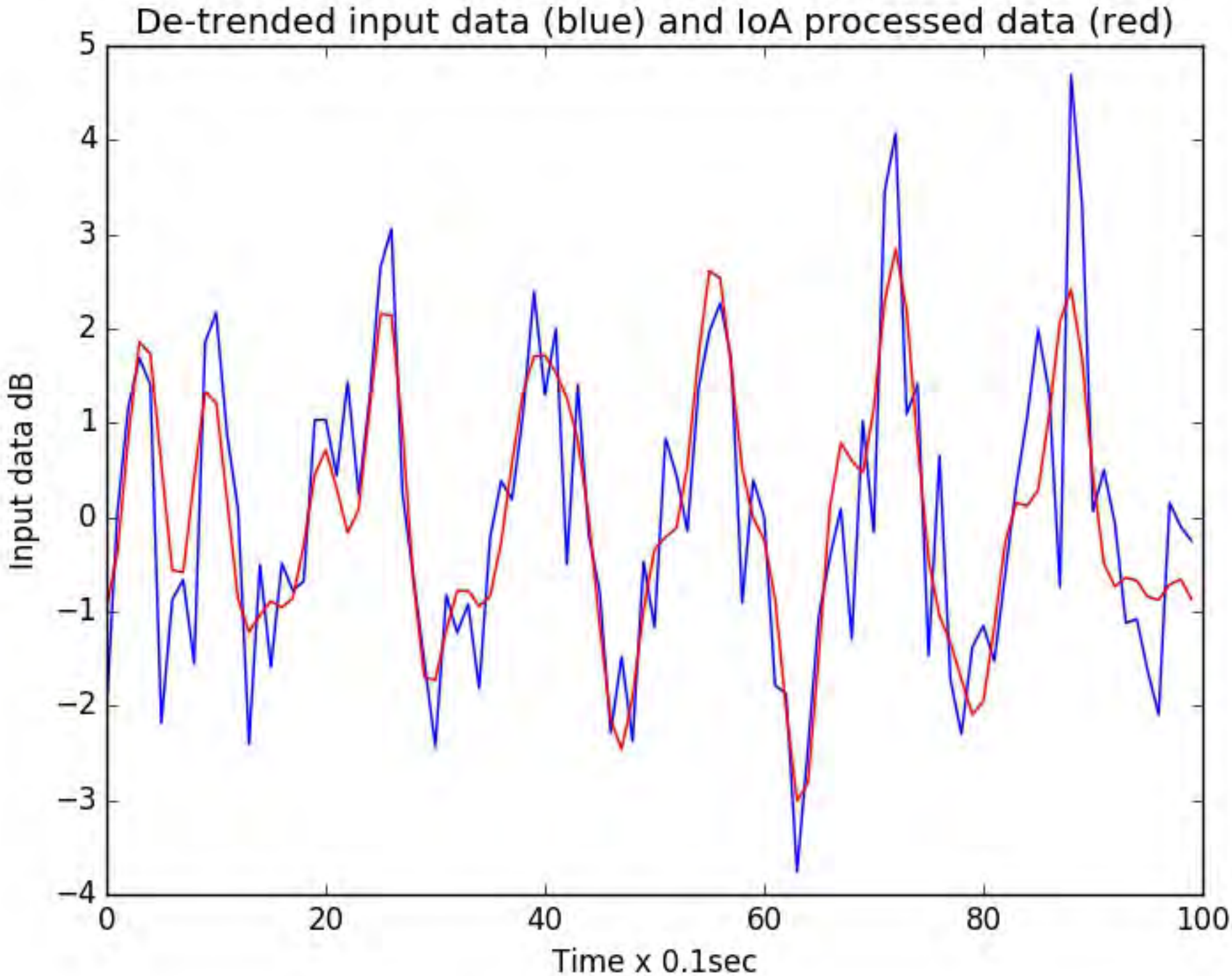
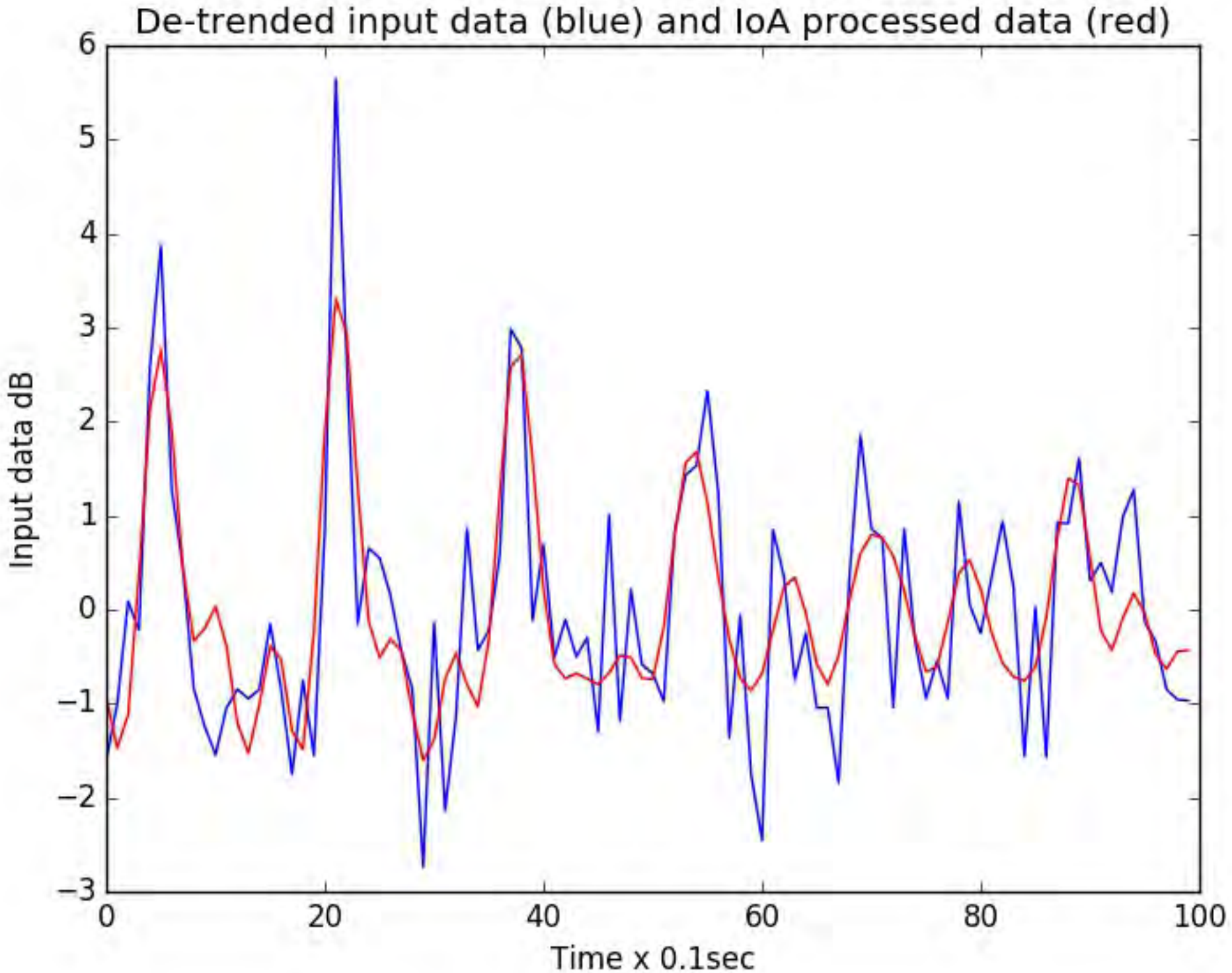
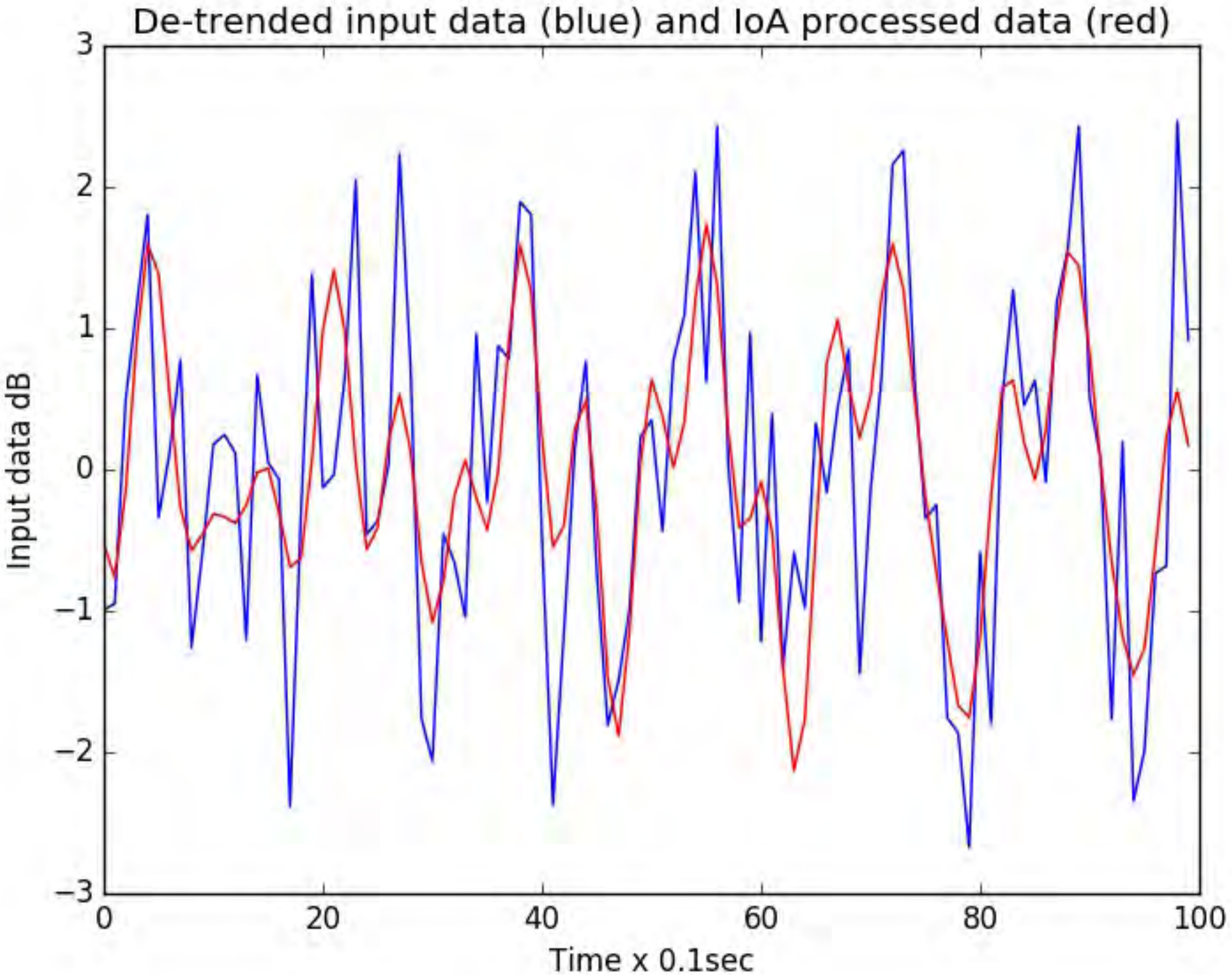
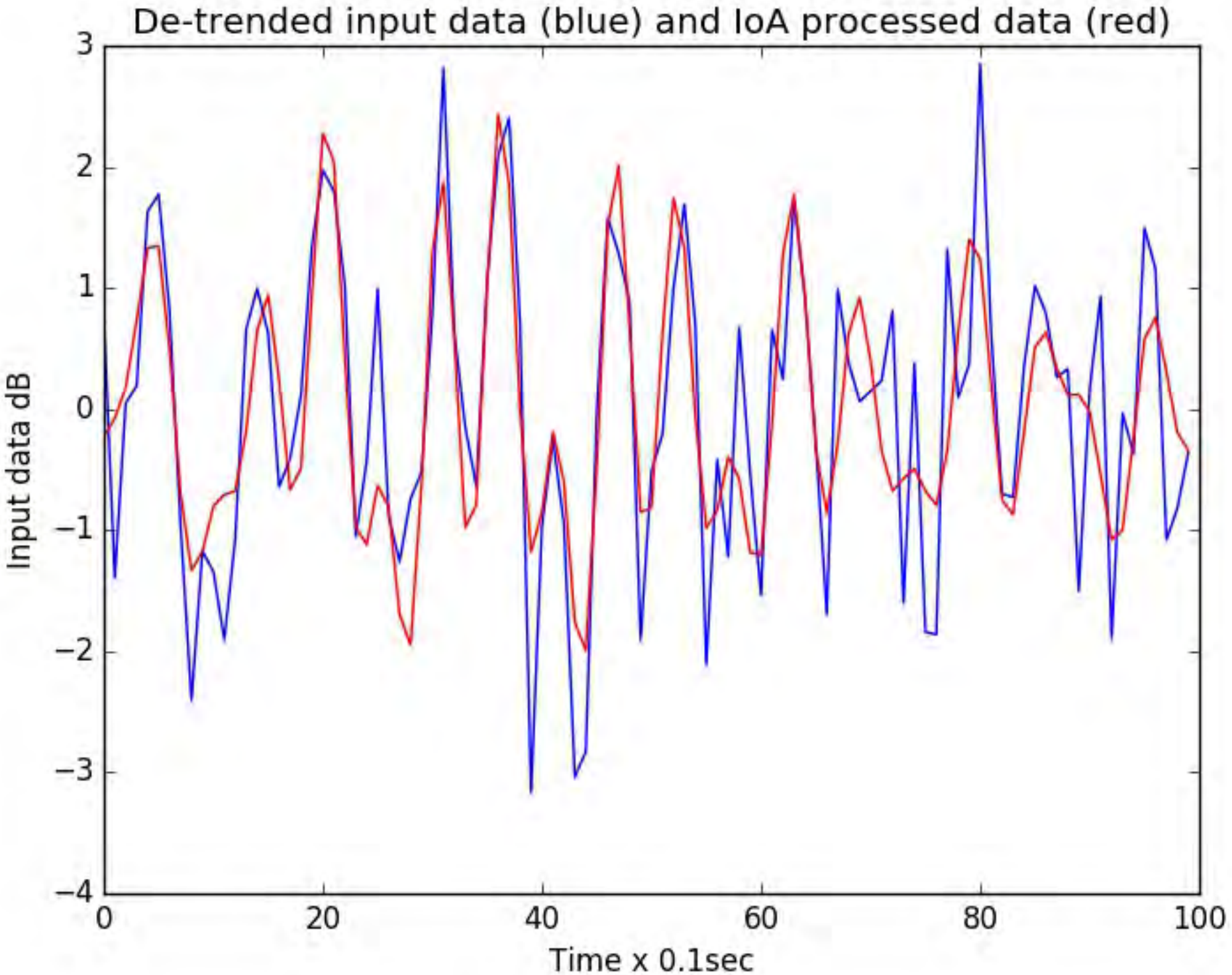
80
100

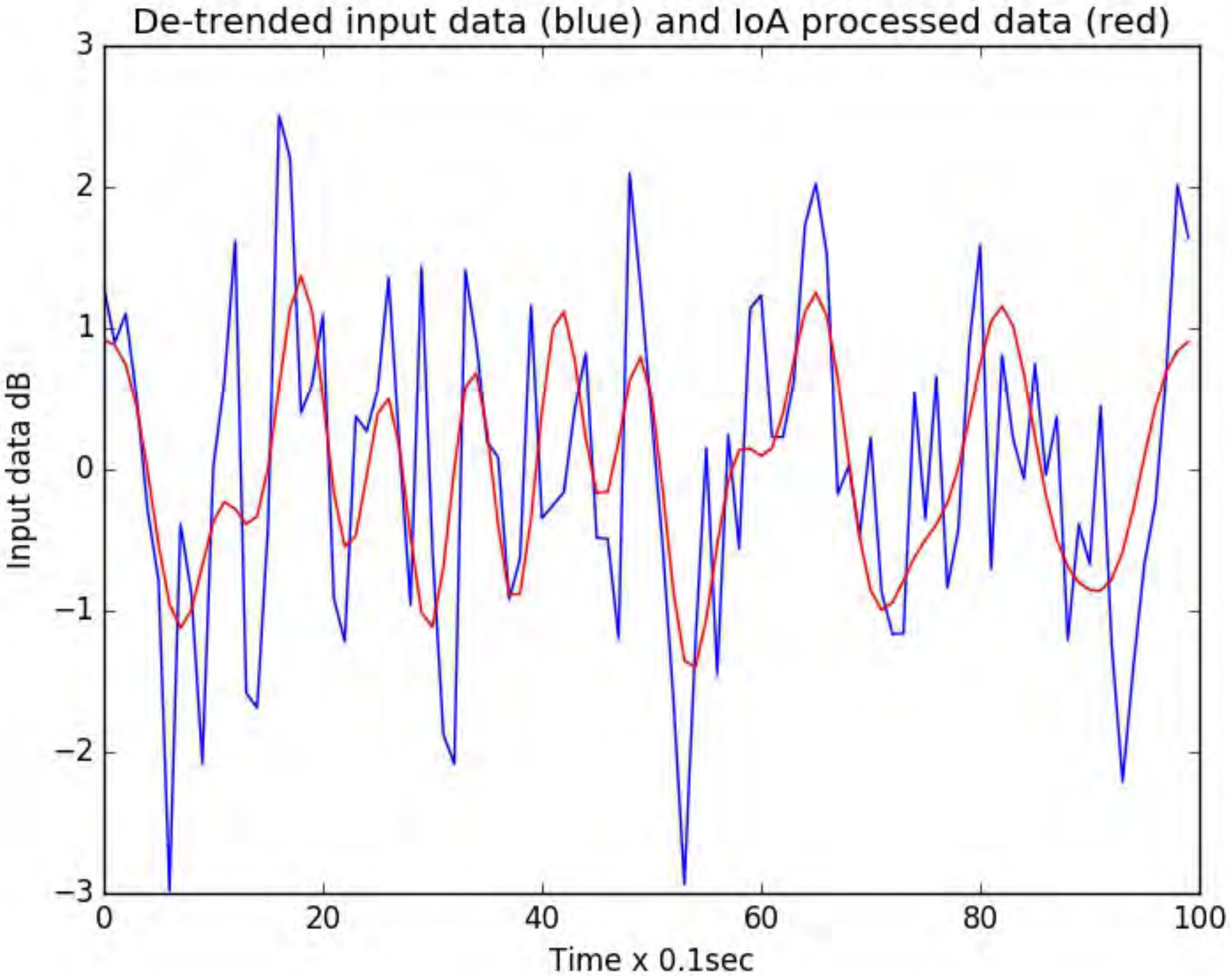

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

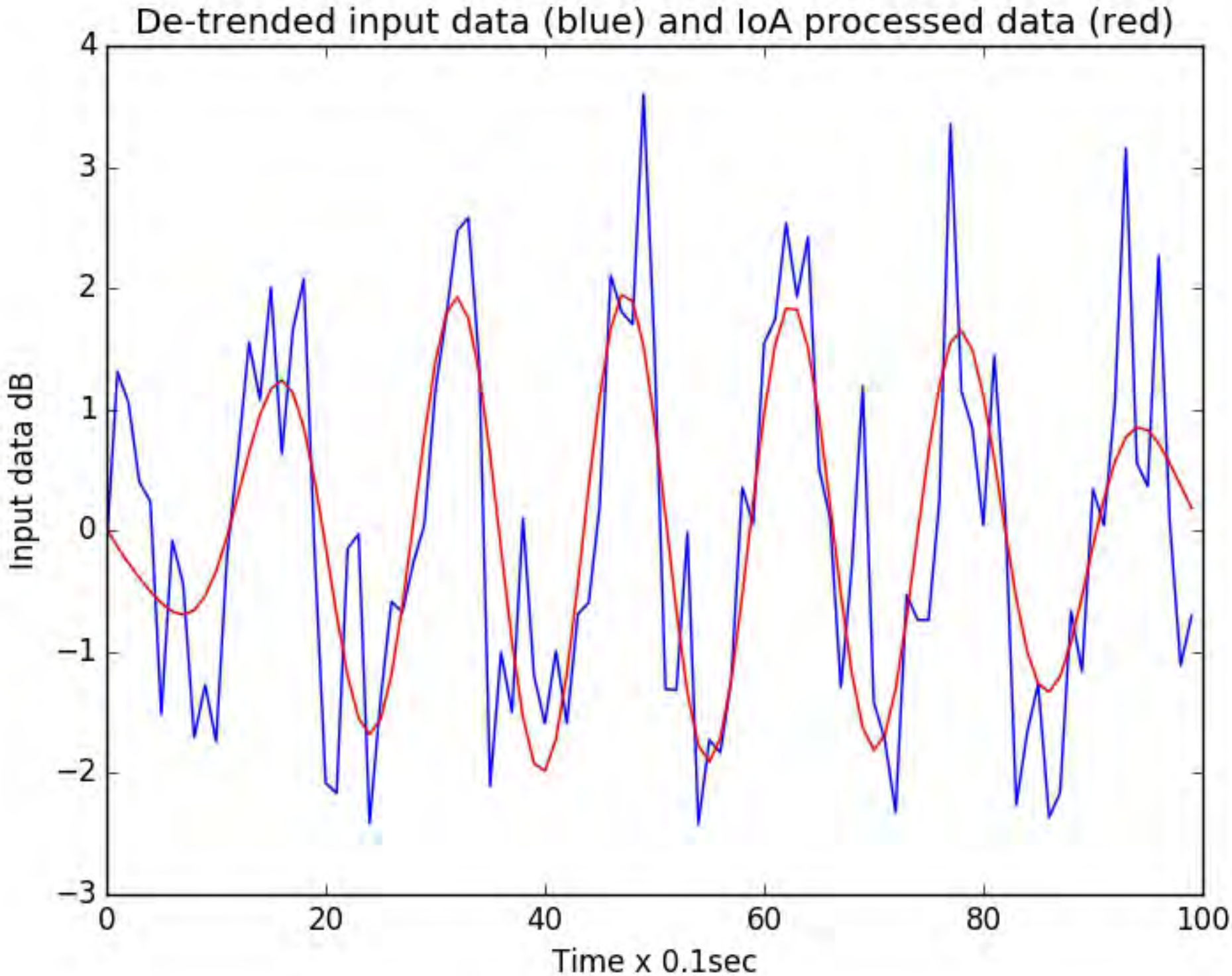

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

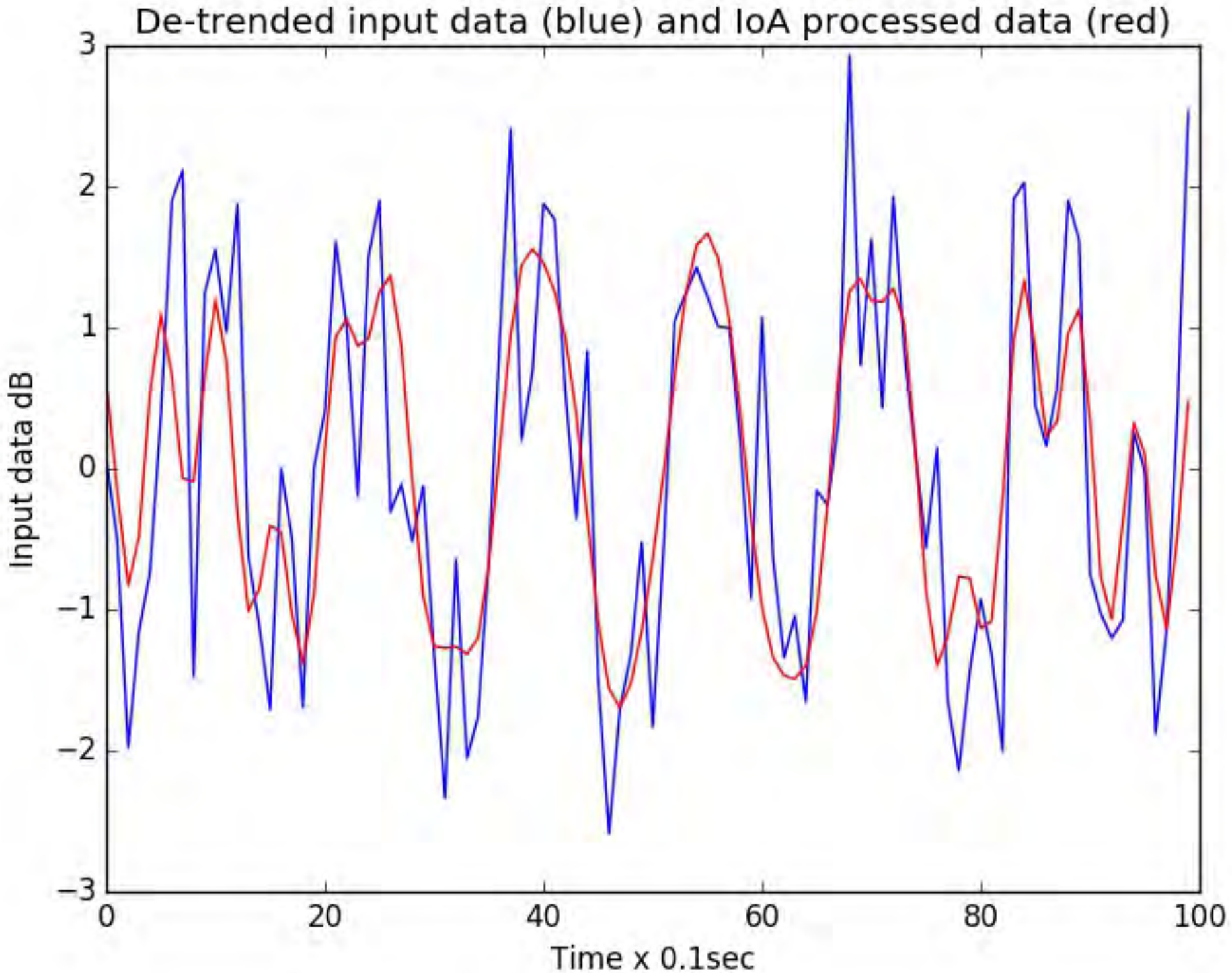

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

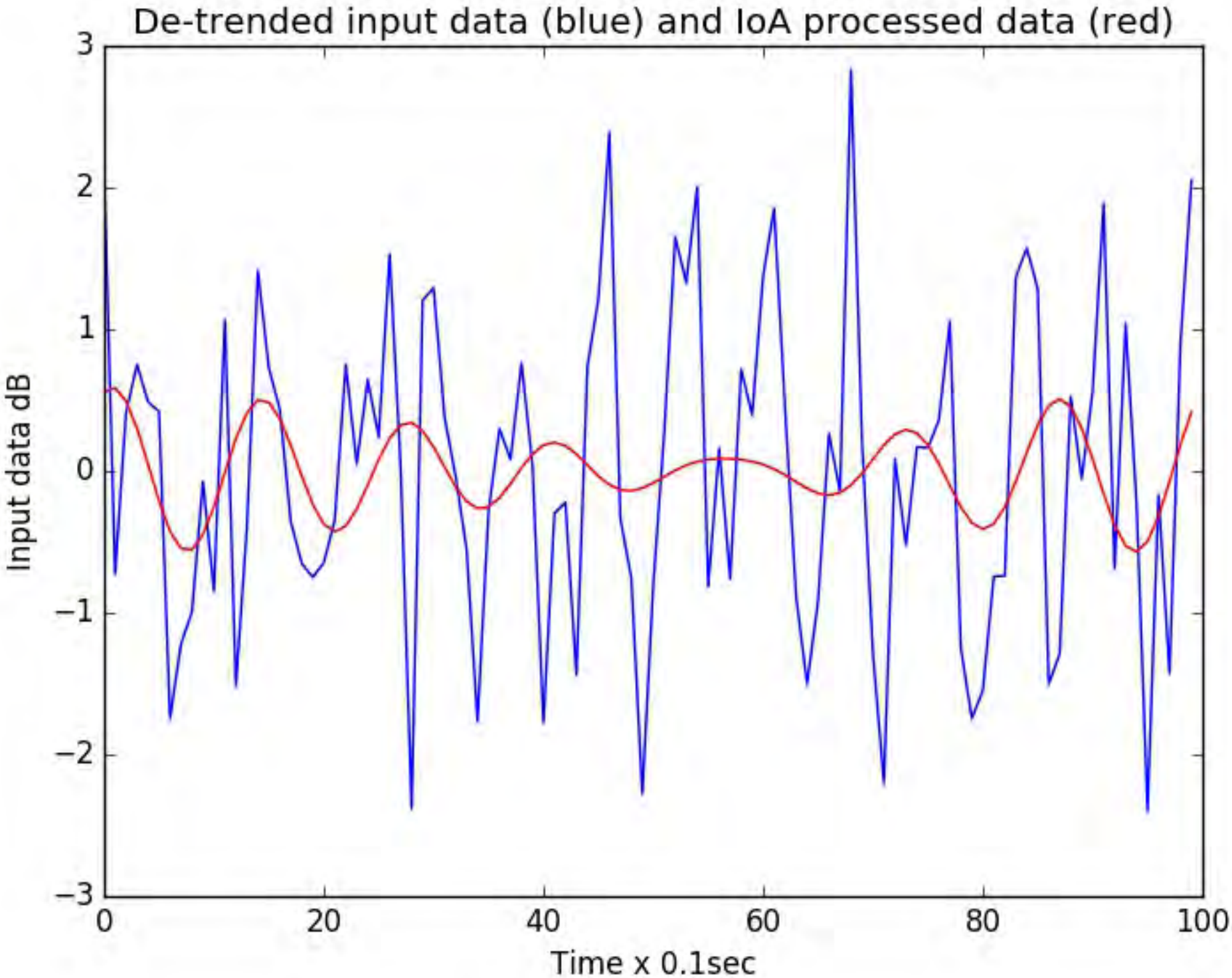

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

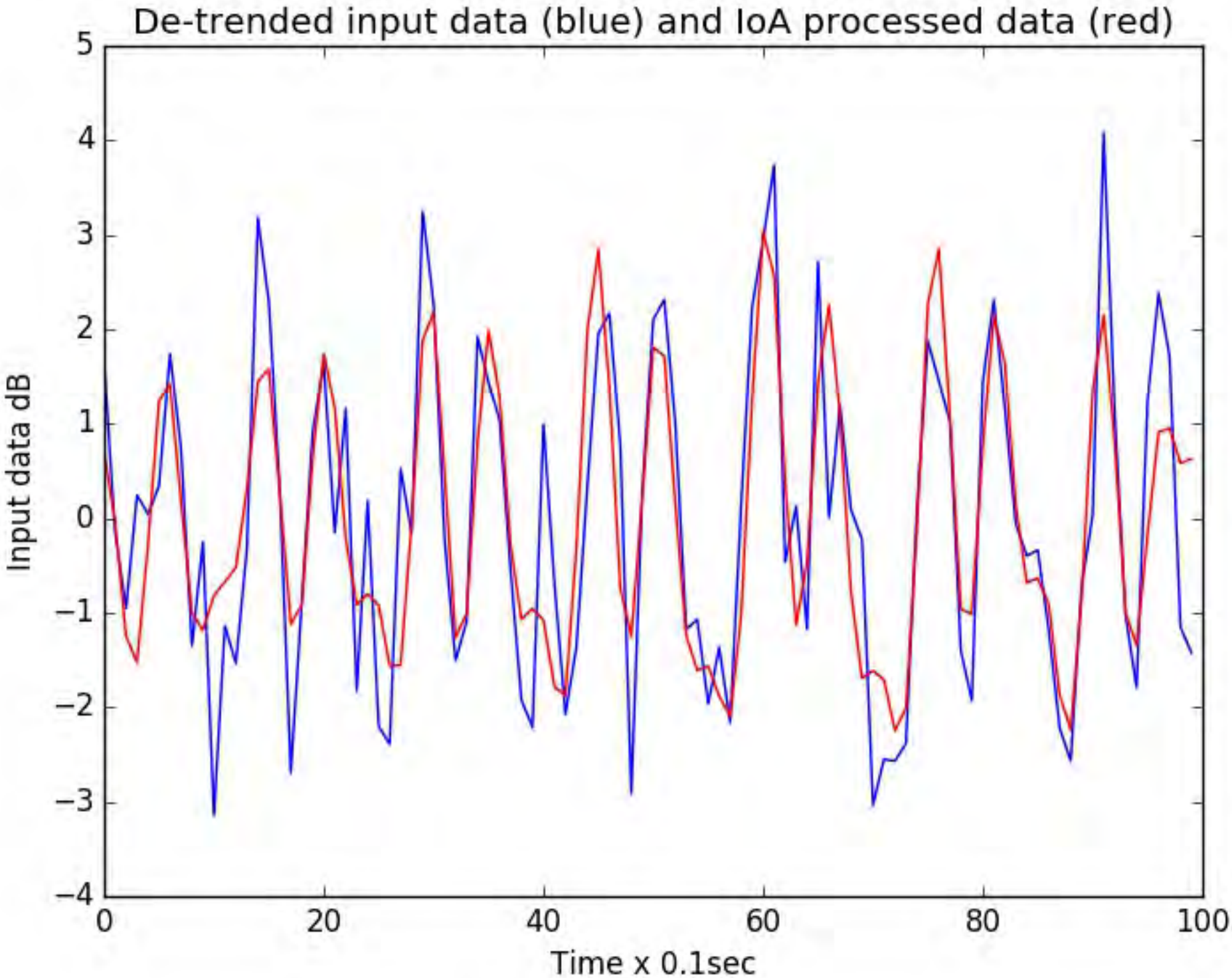

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

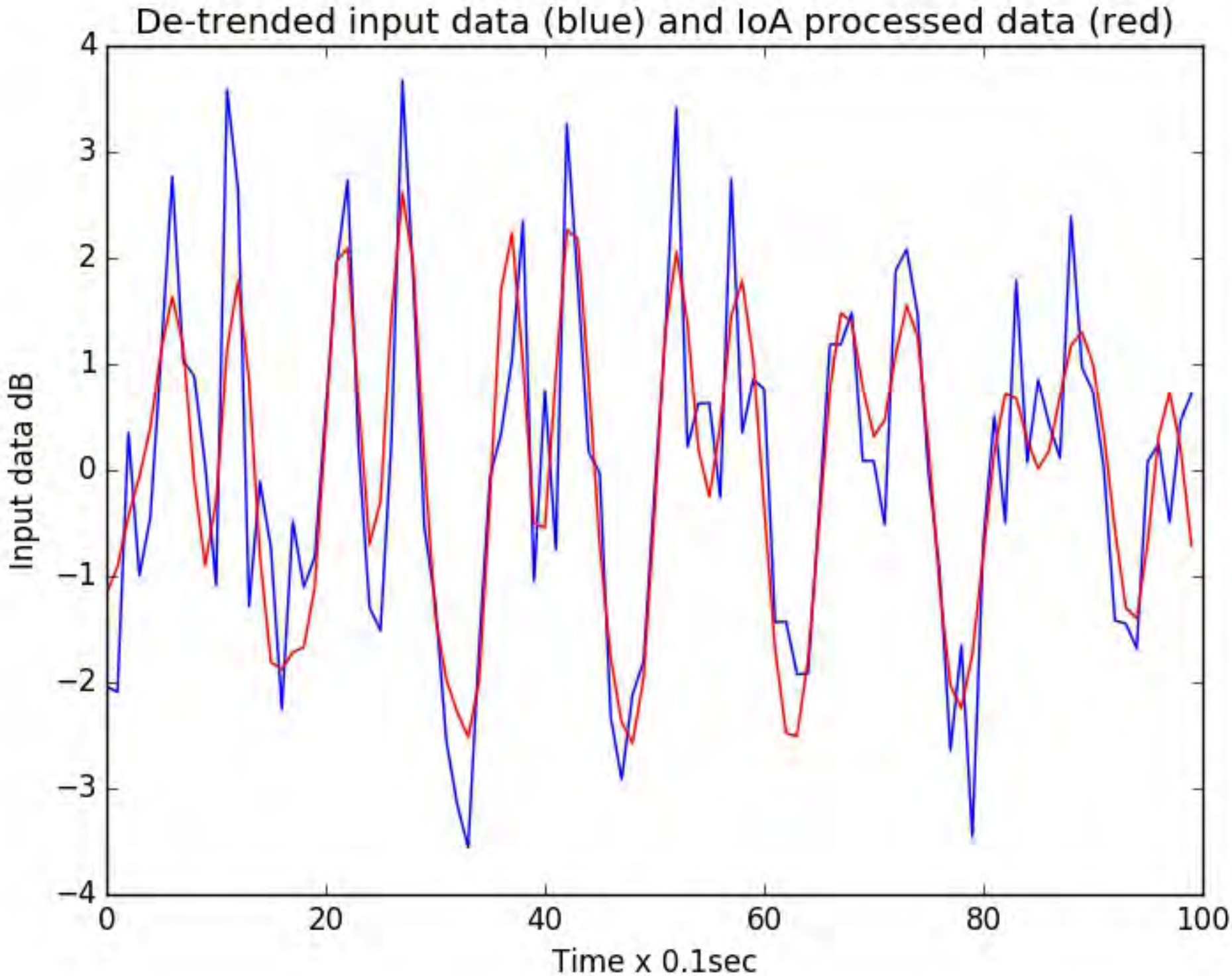

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

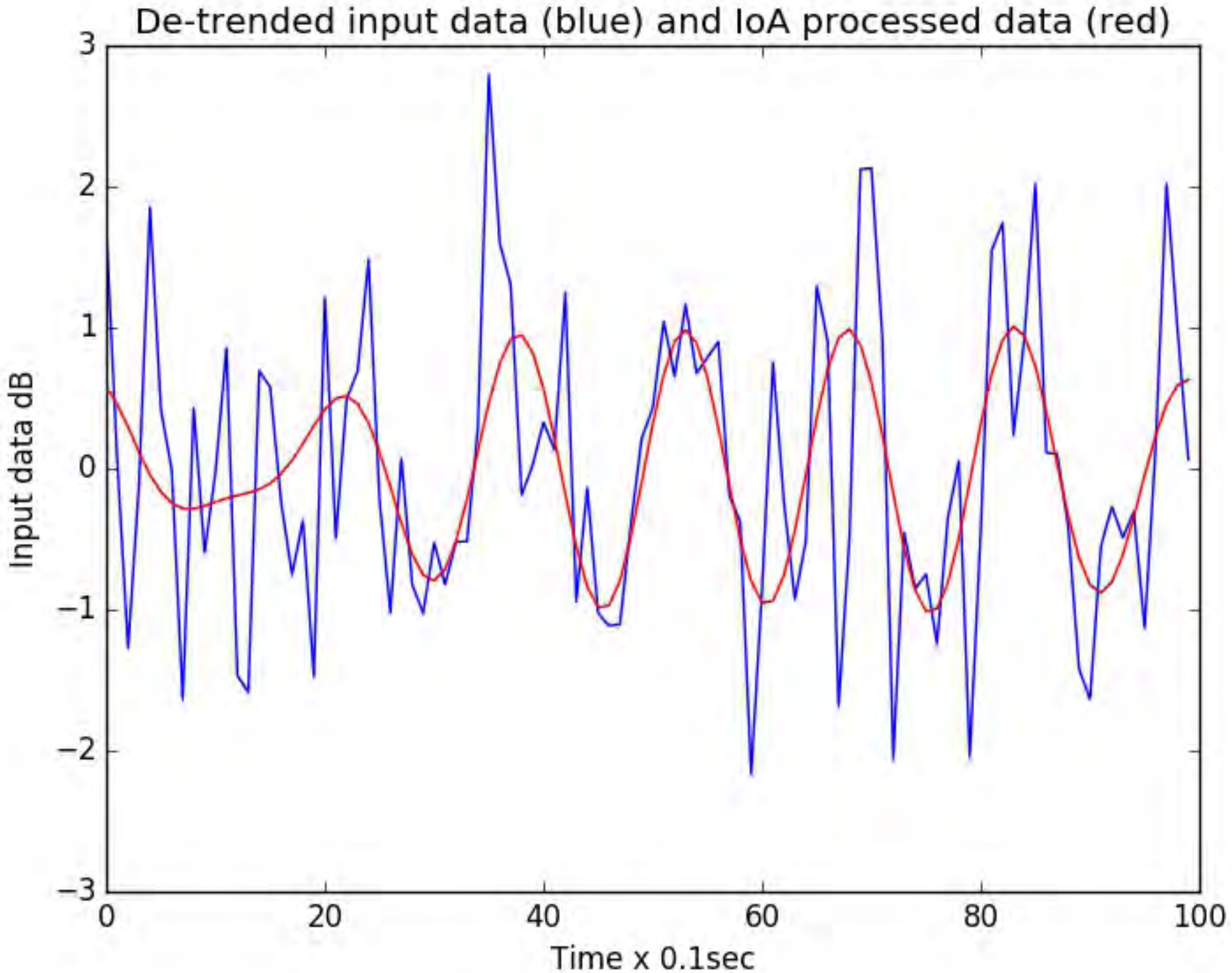

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

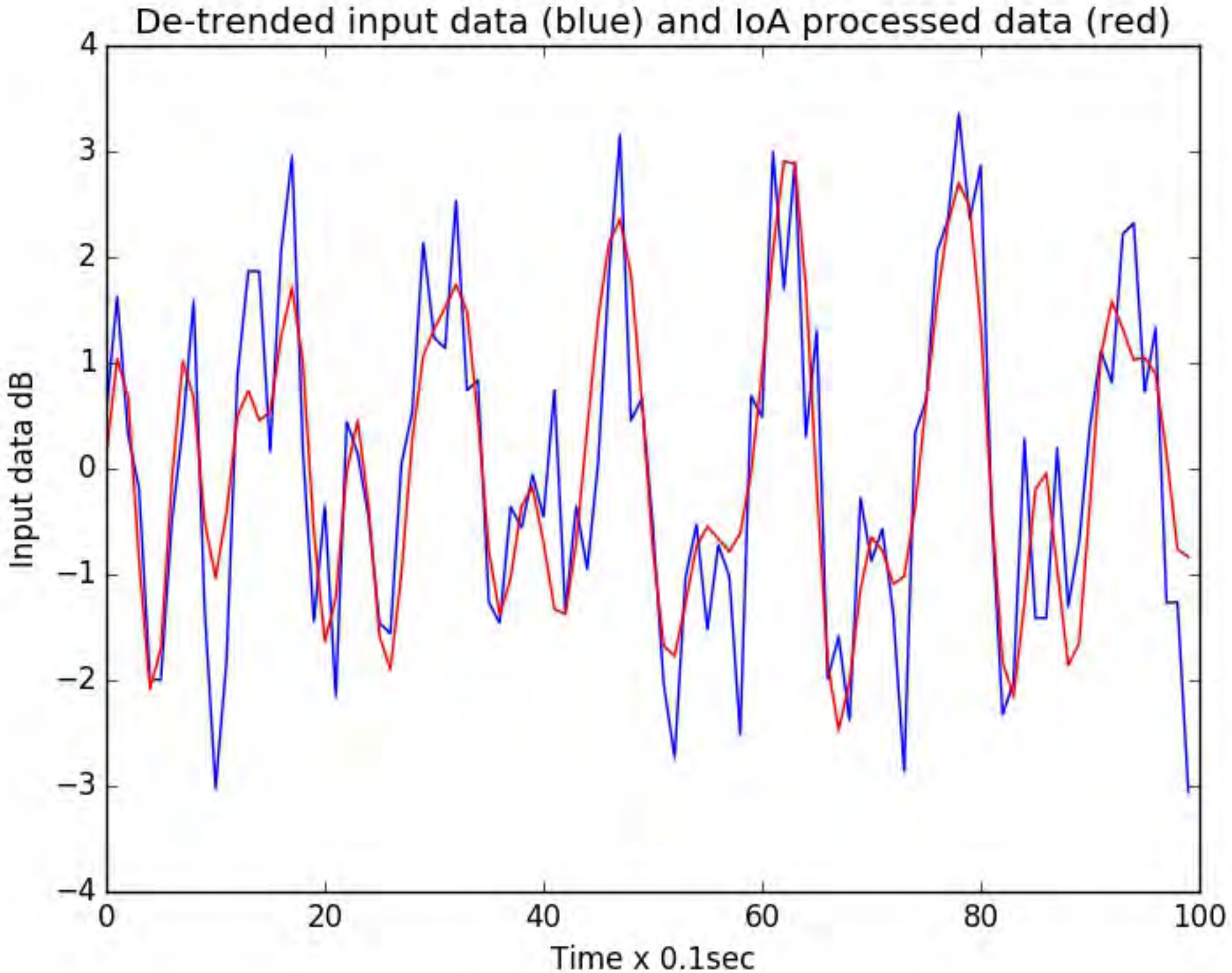

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

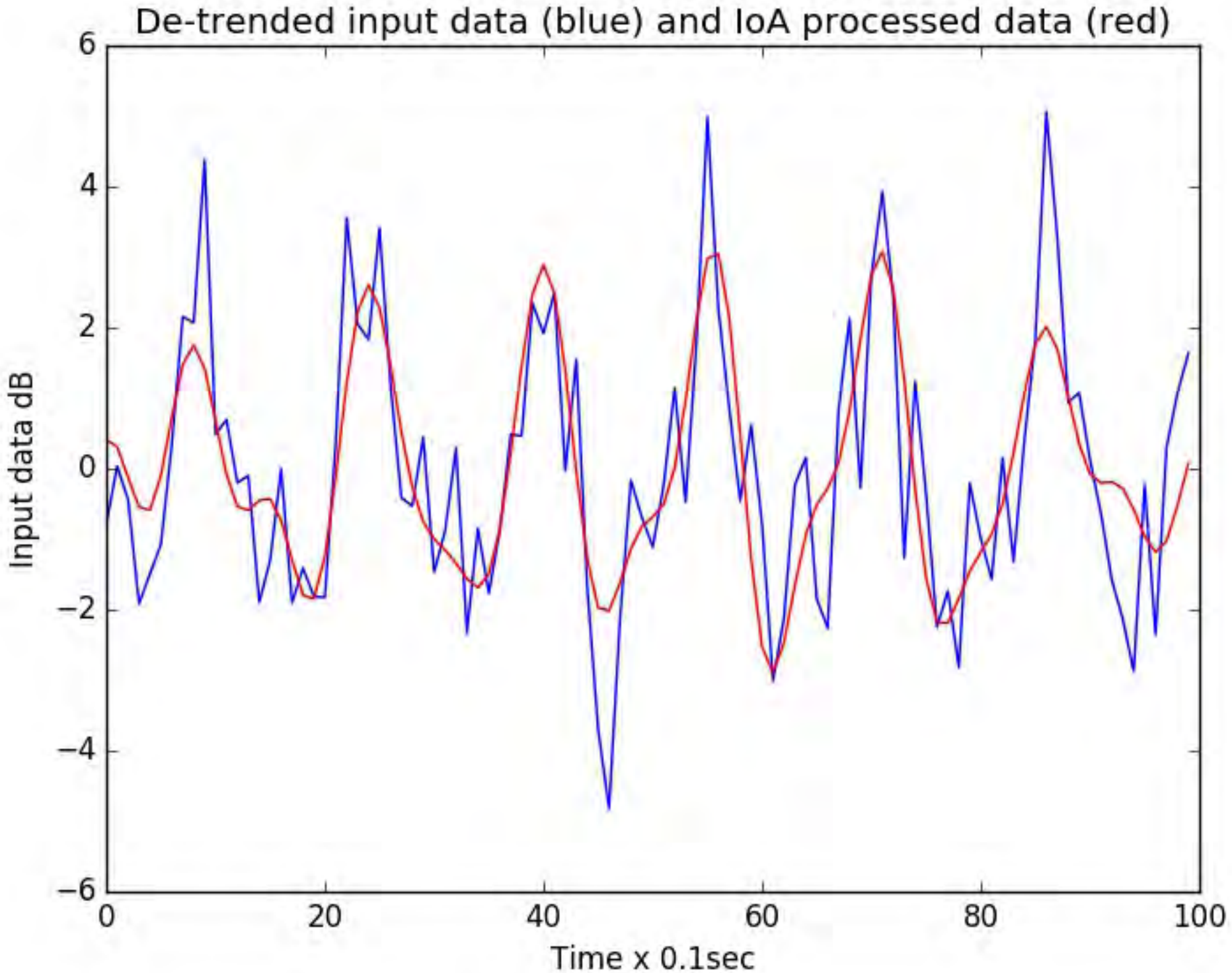

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

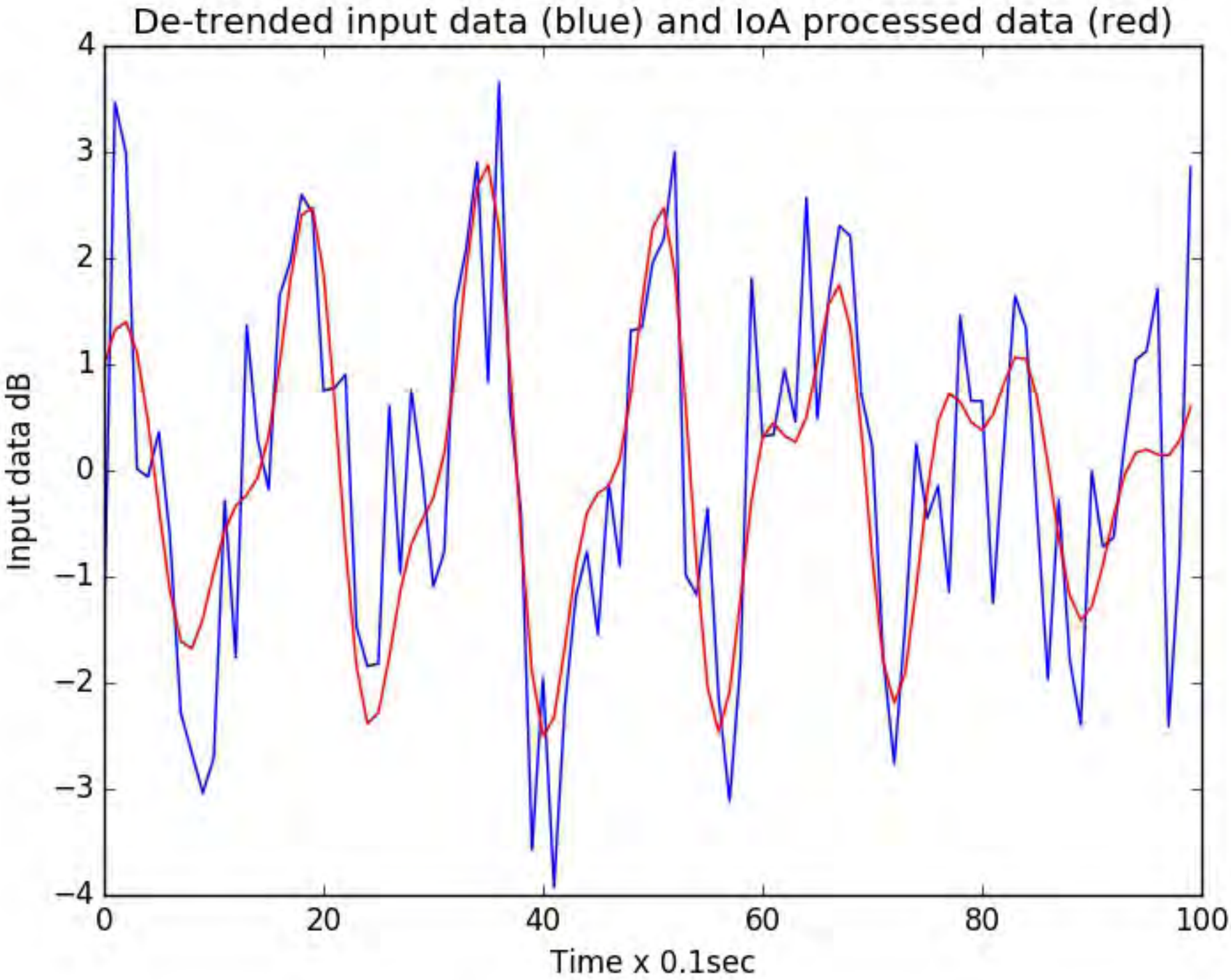

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

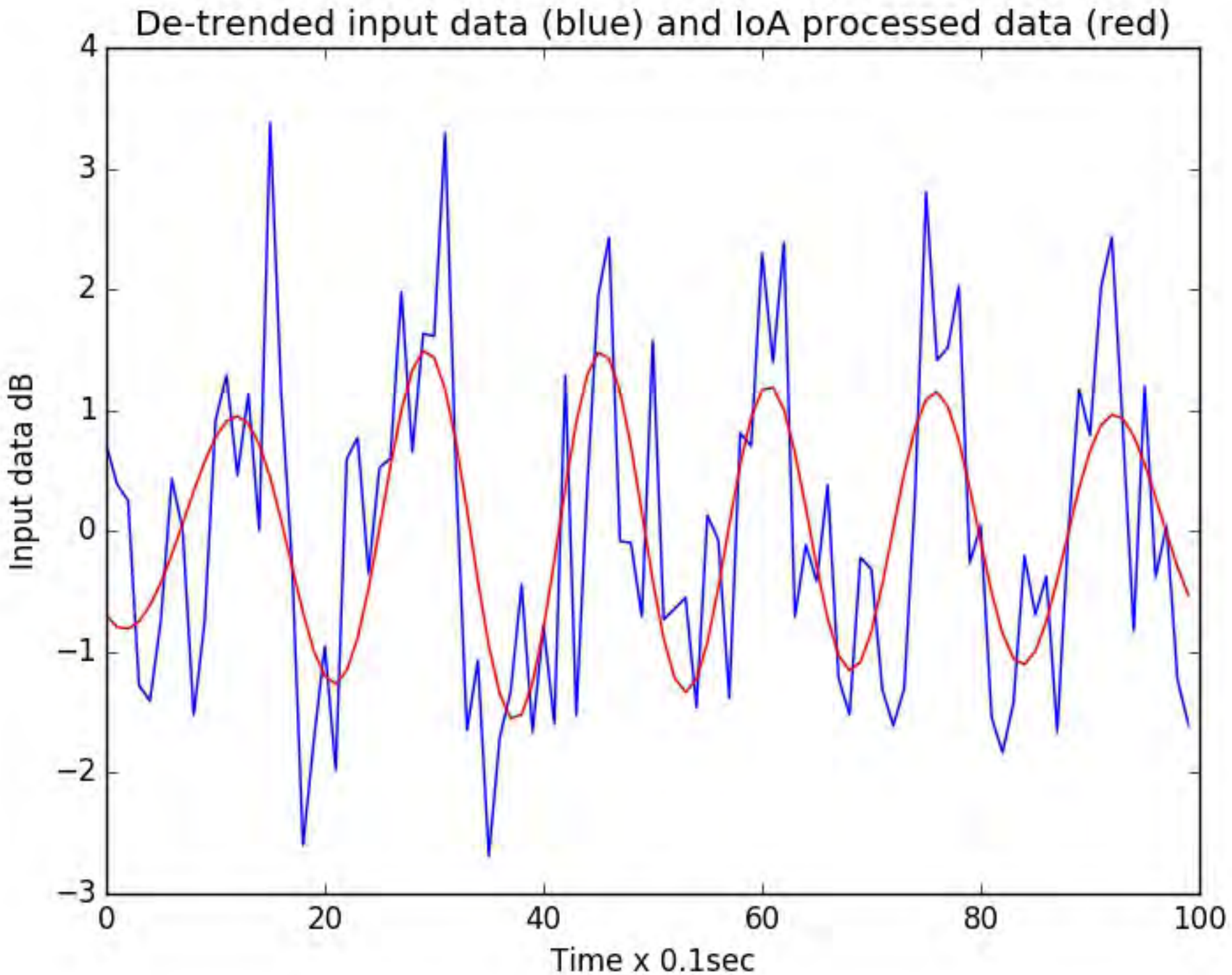

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

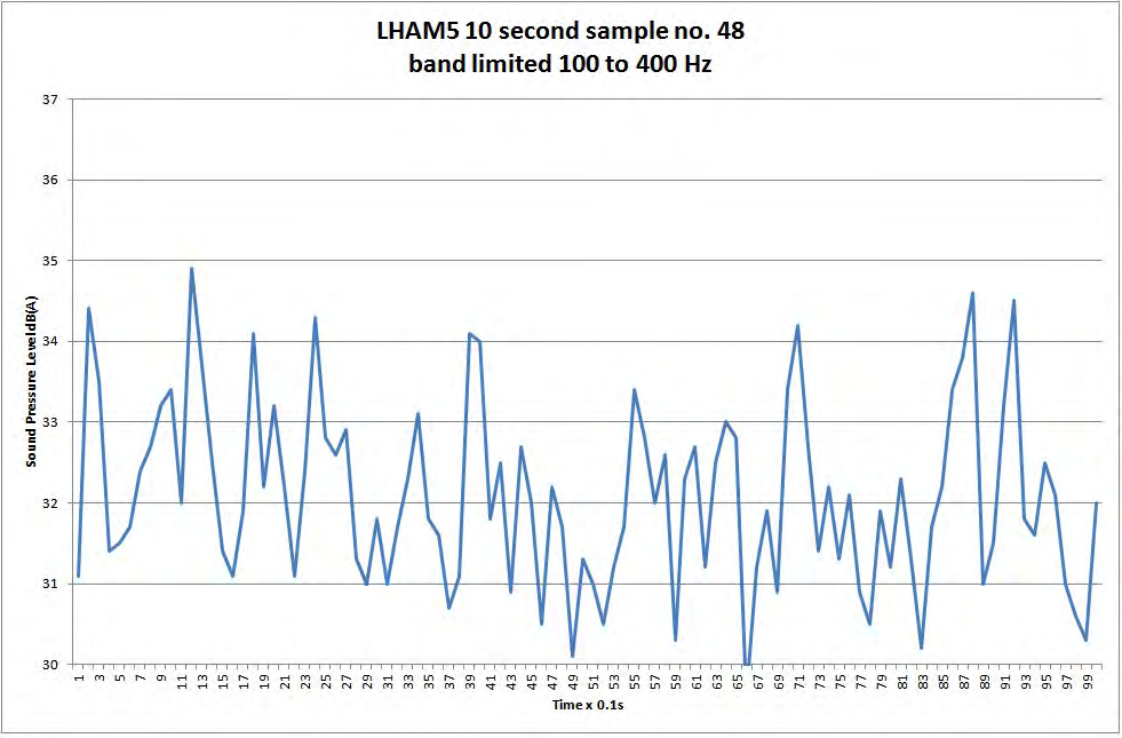

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

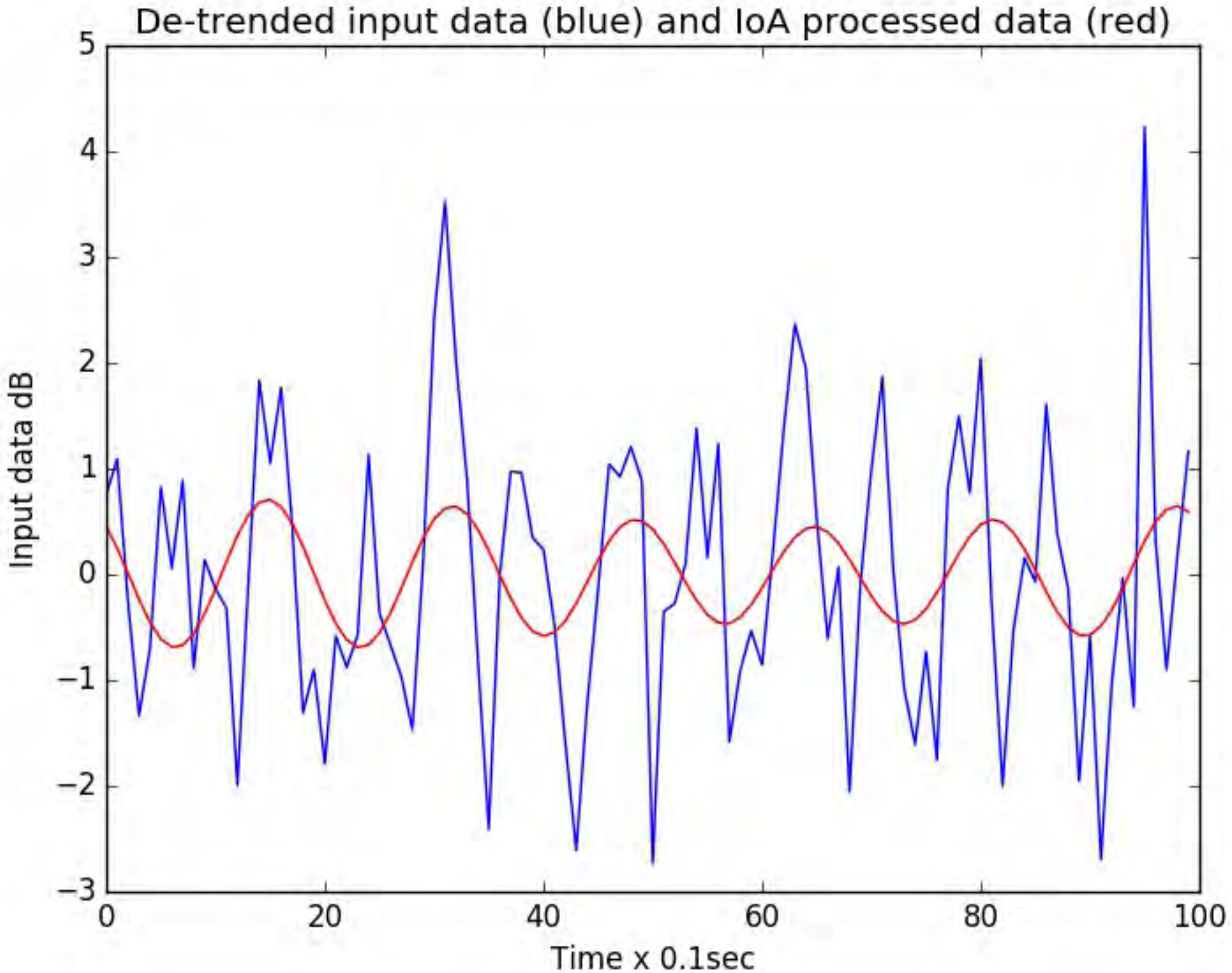

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

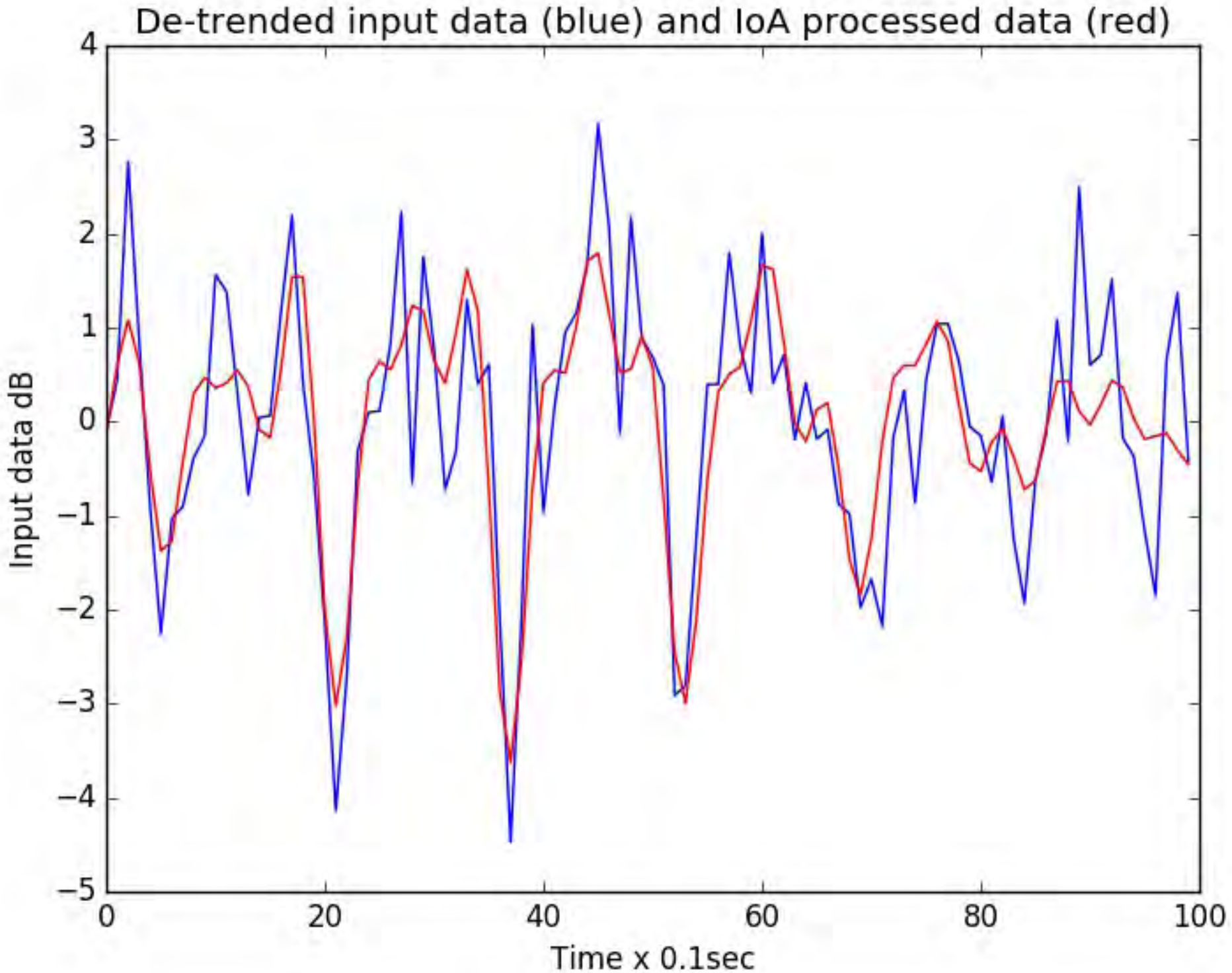

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100

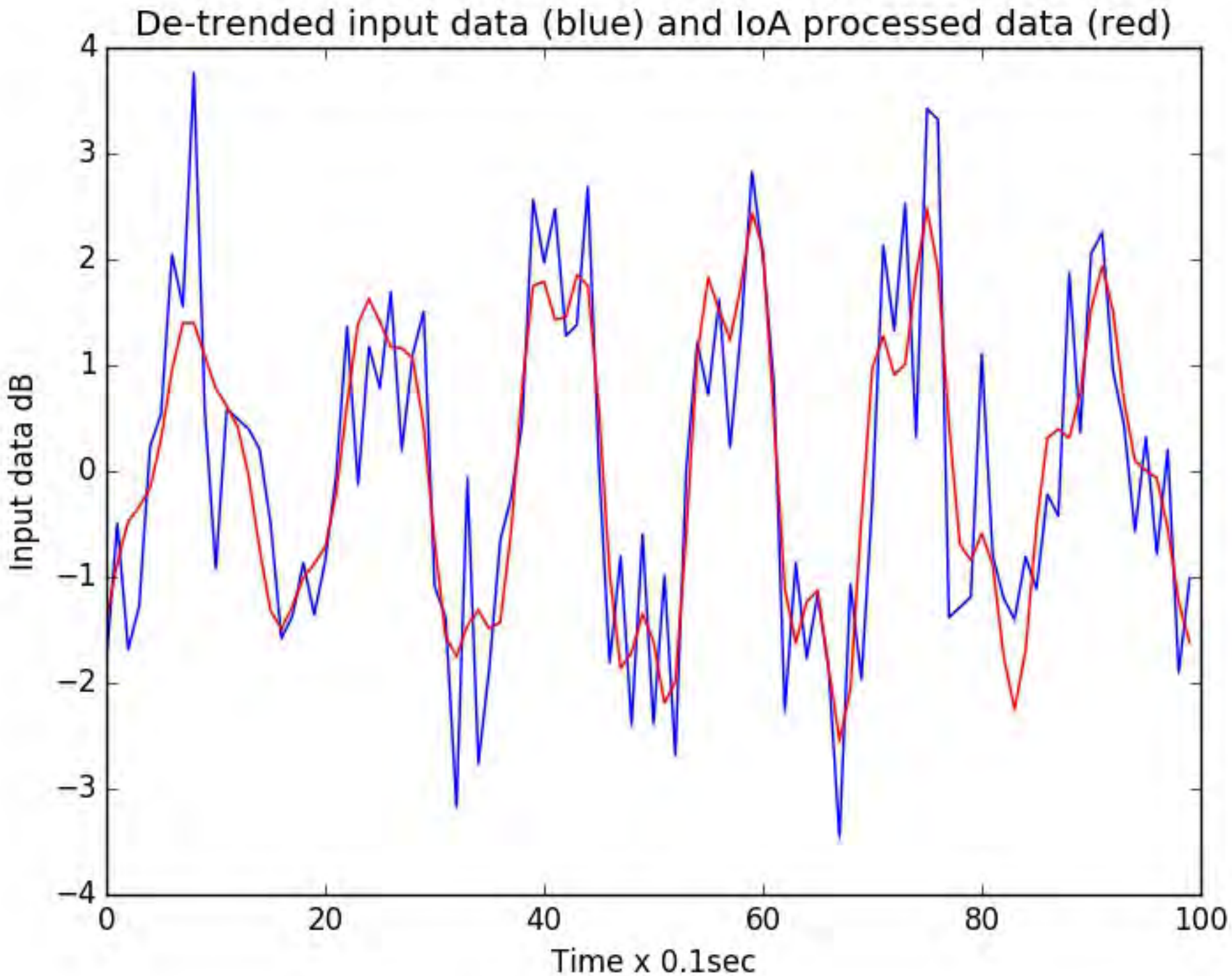

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

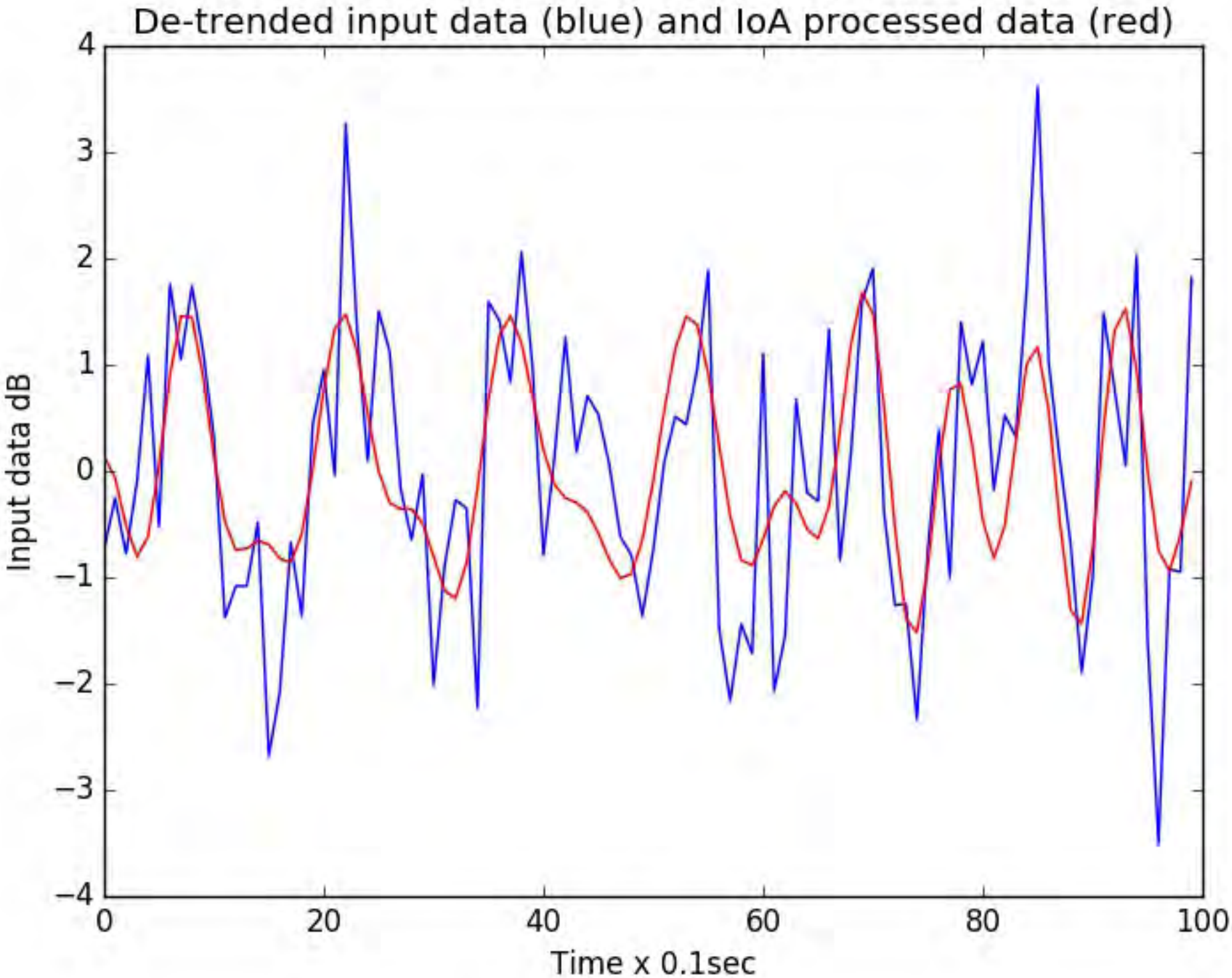

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

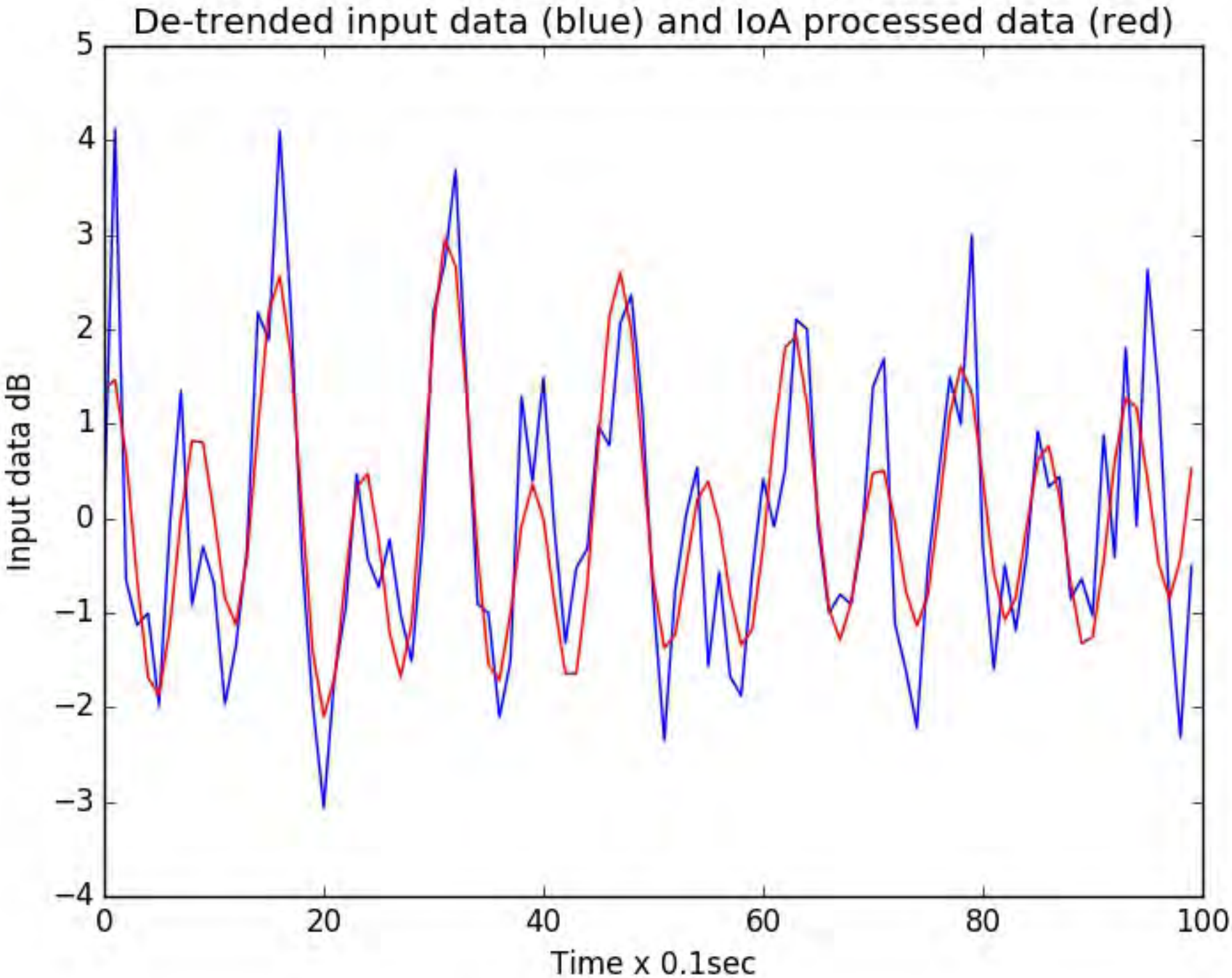

LHAM5 10 second sample no. 48
band limited 100 to 400 Hz
Sound Pressure LeveldB(A)
37
36
35
34
33
32
31
30
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Time x 0.1s

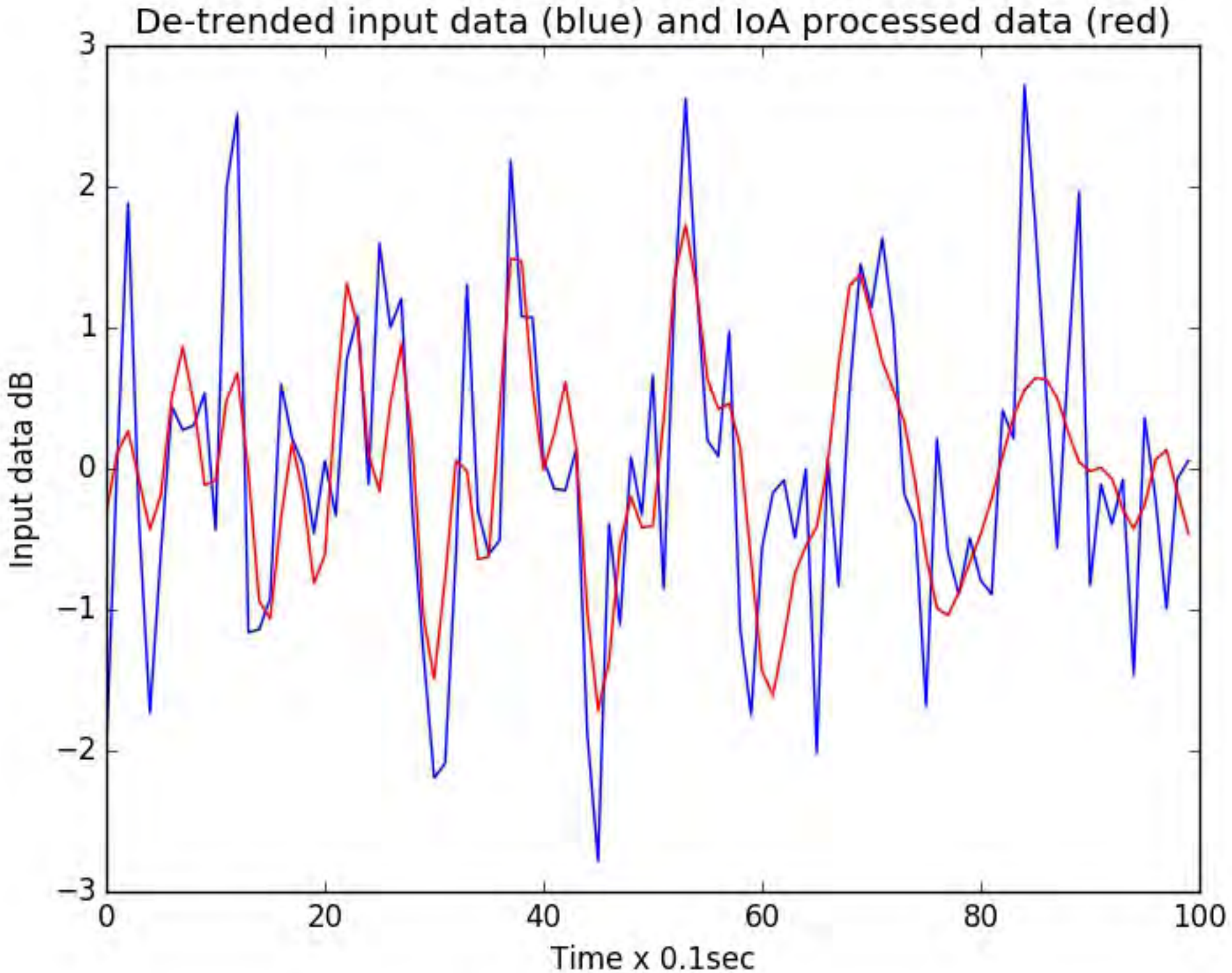

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

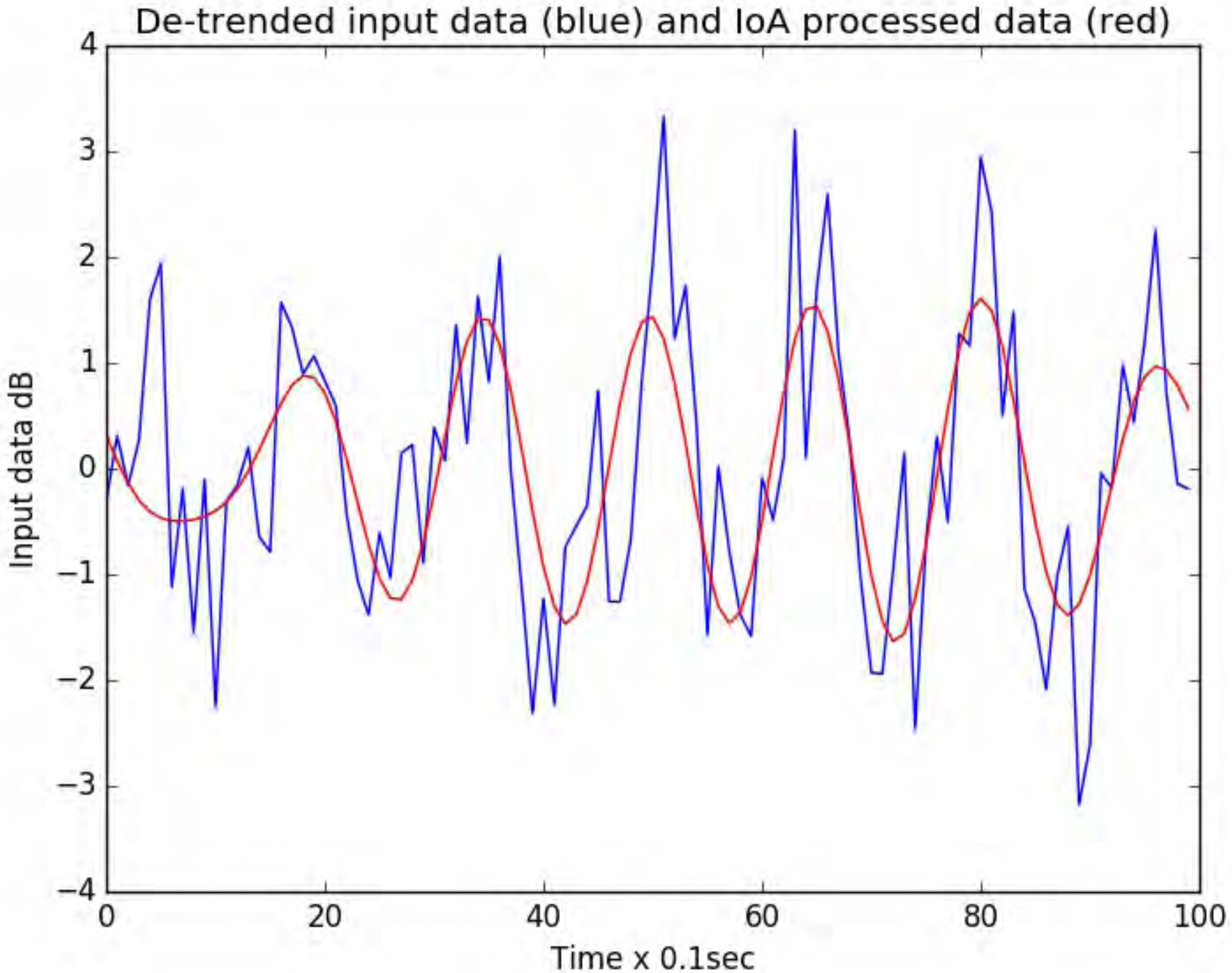

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
−5
0
20
40
60
80
100

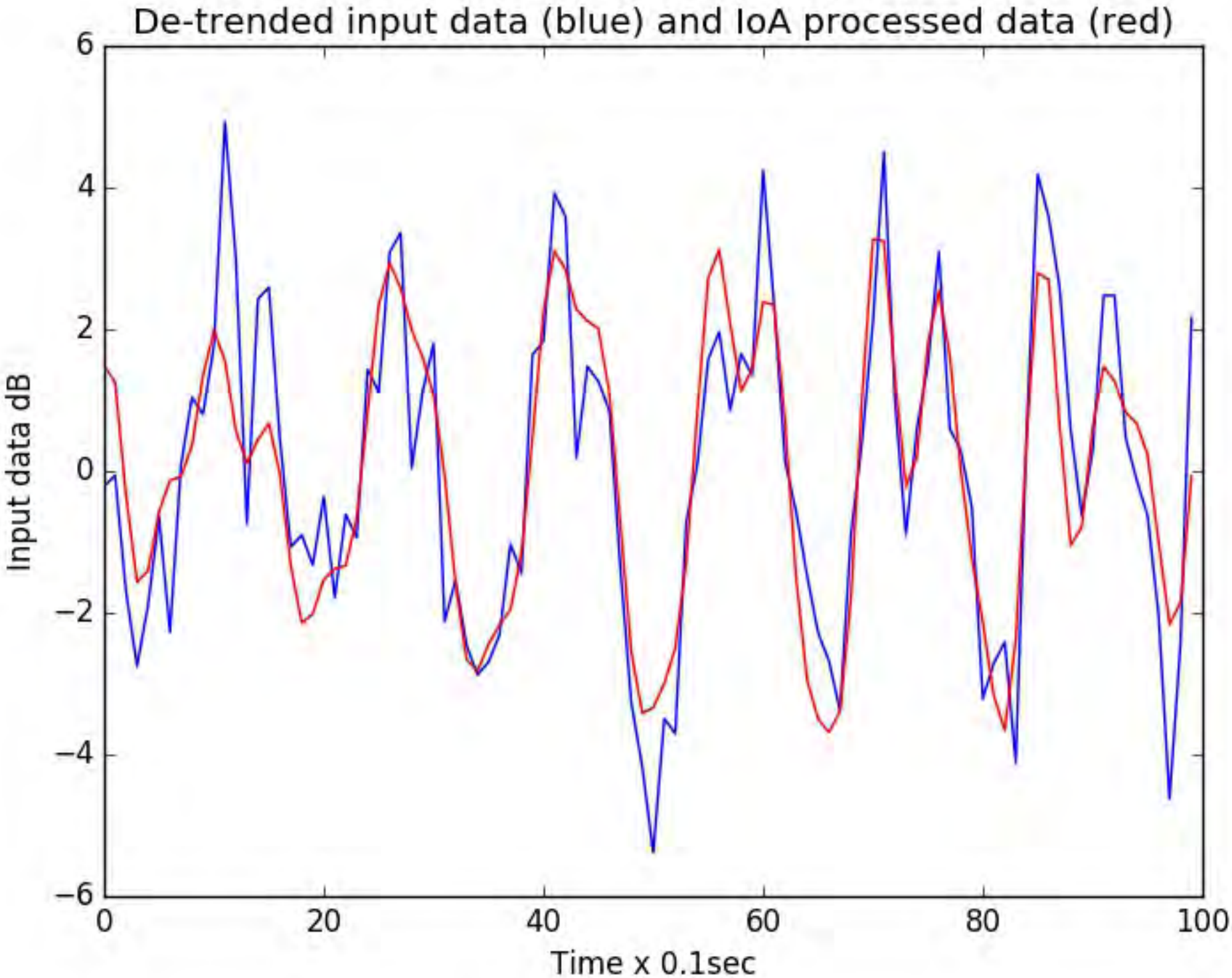

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

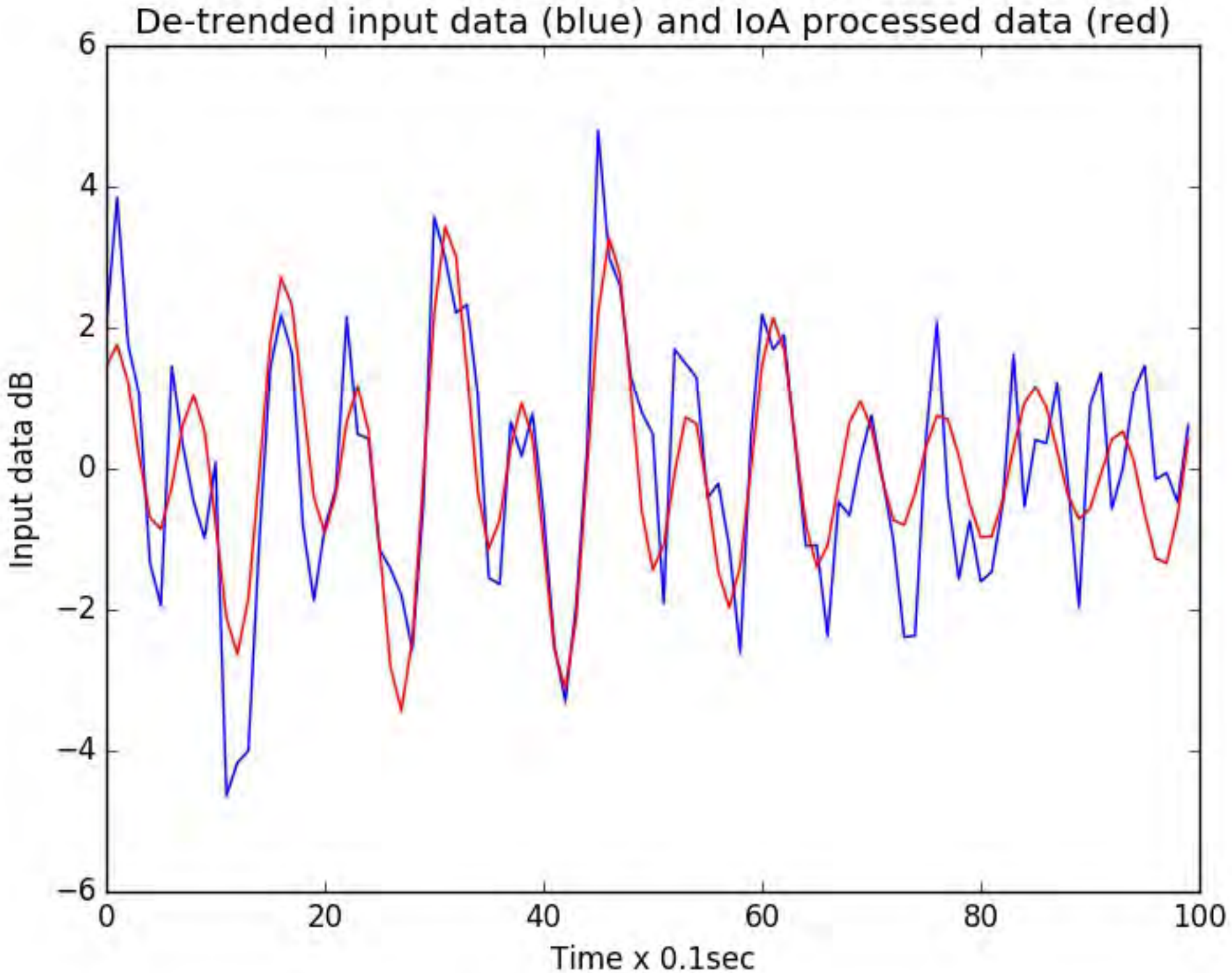

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

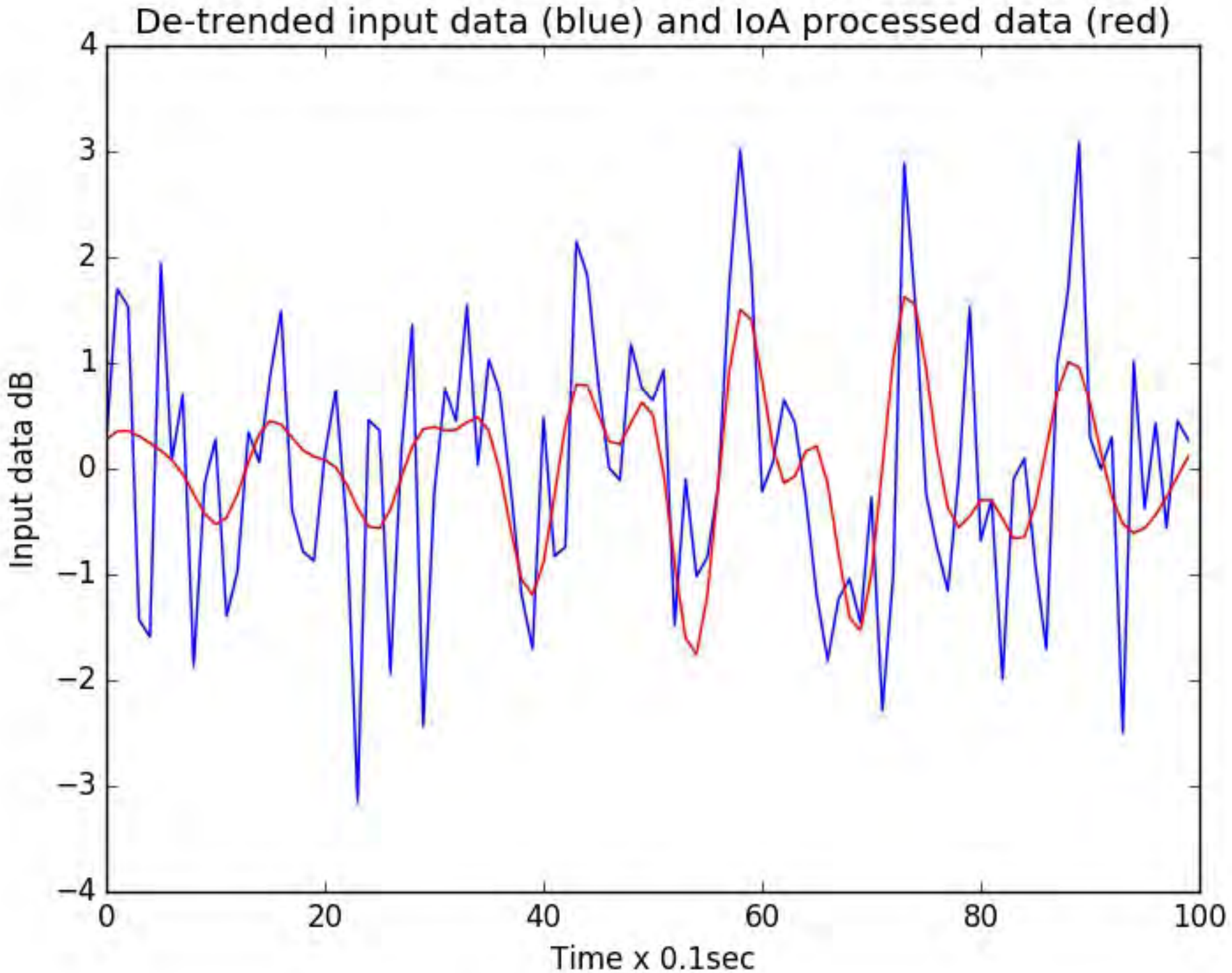

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

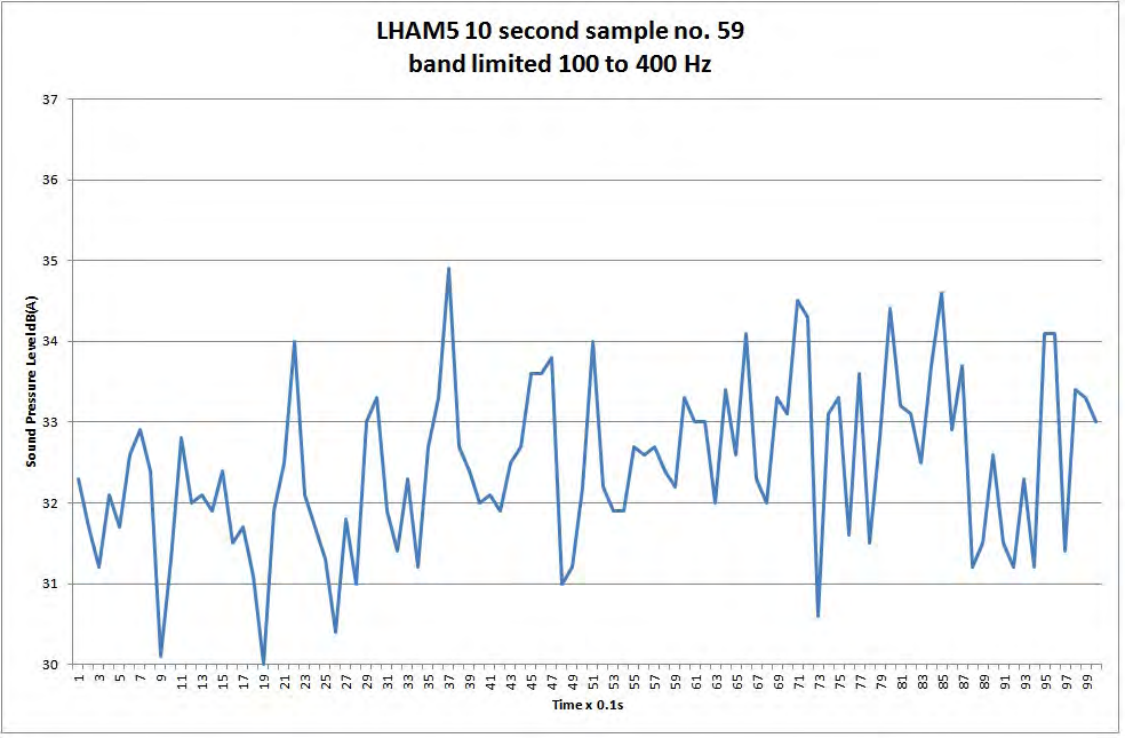

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

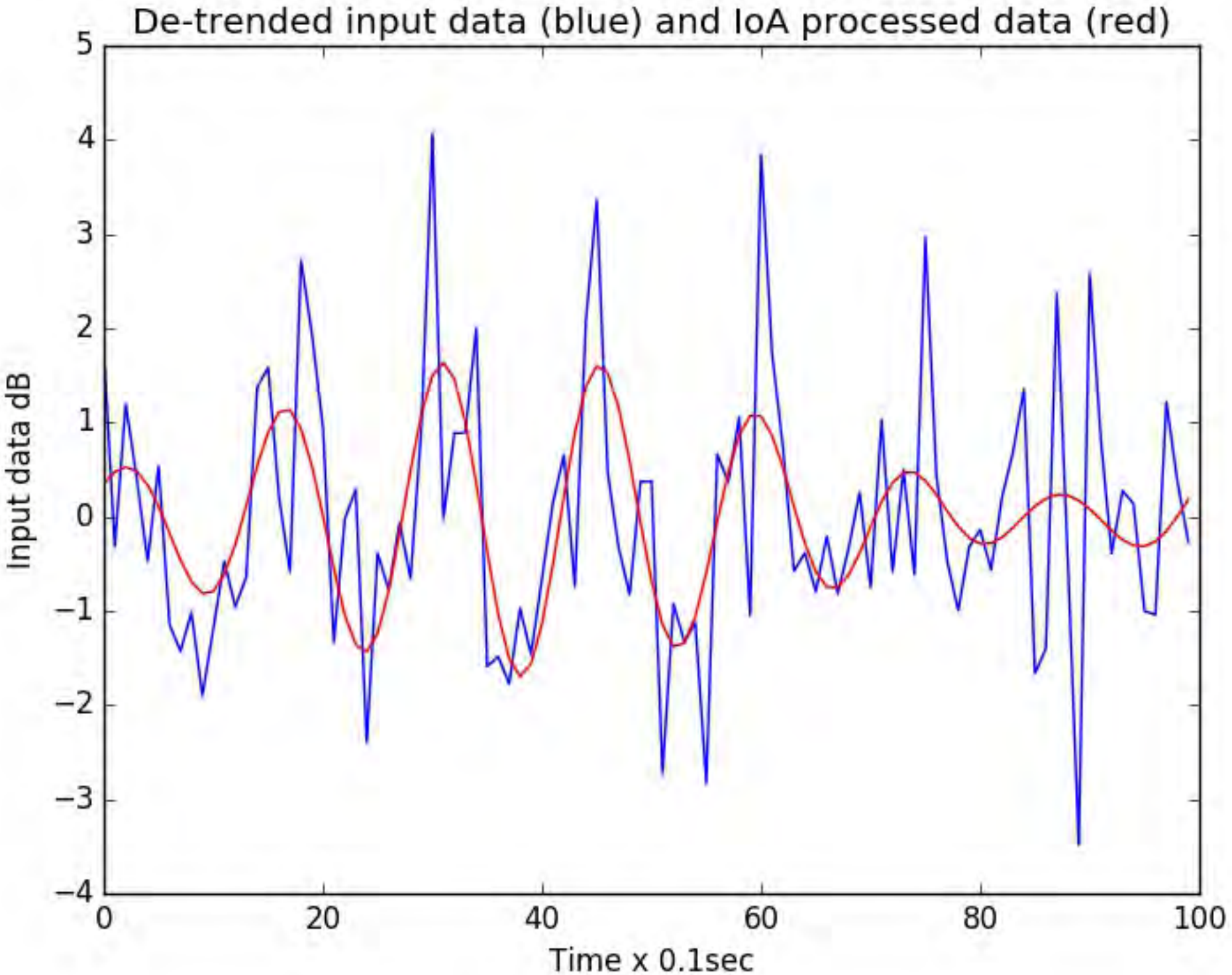

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

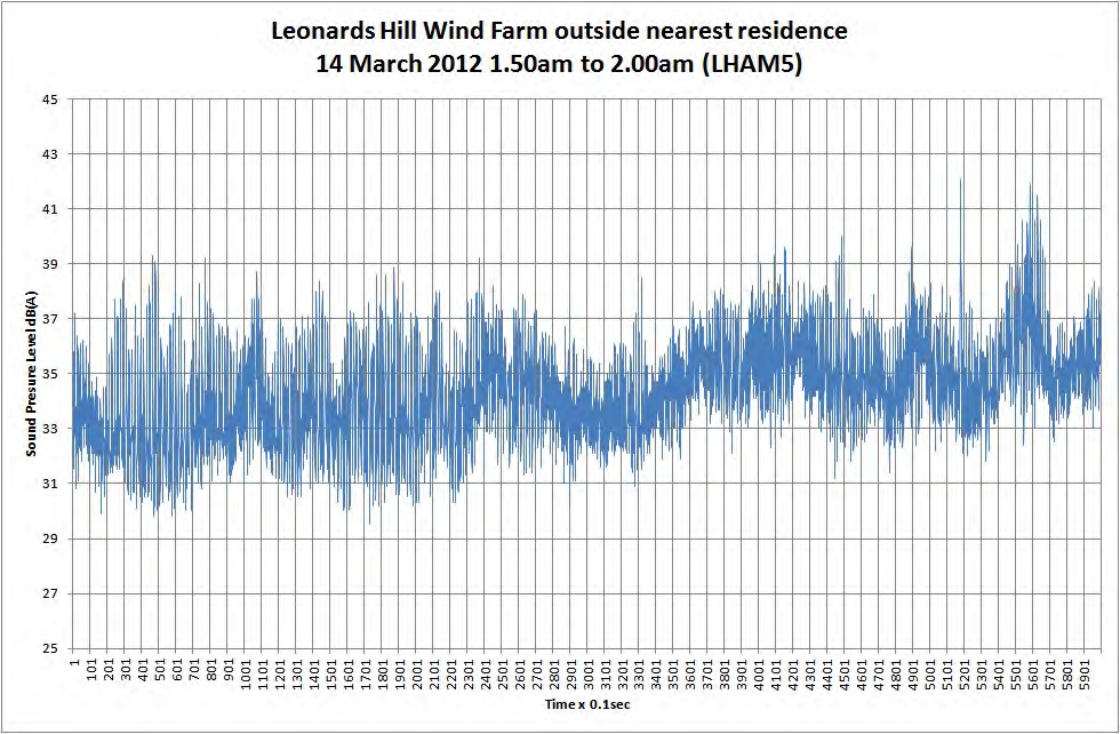

LHAM5 10 second sample no. 59
band limited 100 to 400 Hz
Sound Pressure LeveldB(A)
37
36
35
34
33
32
31
30
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Time x 0.1s

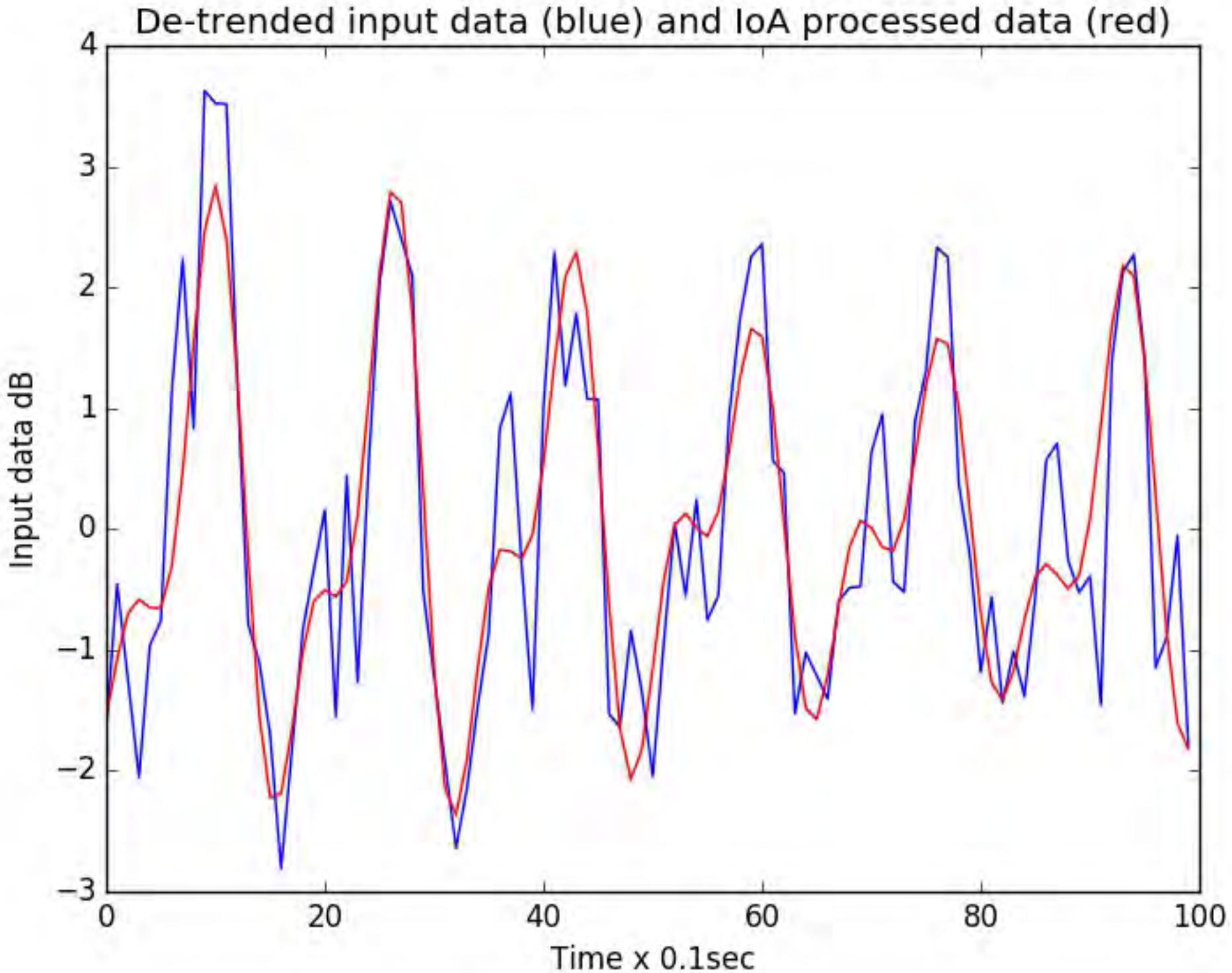

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

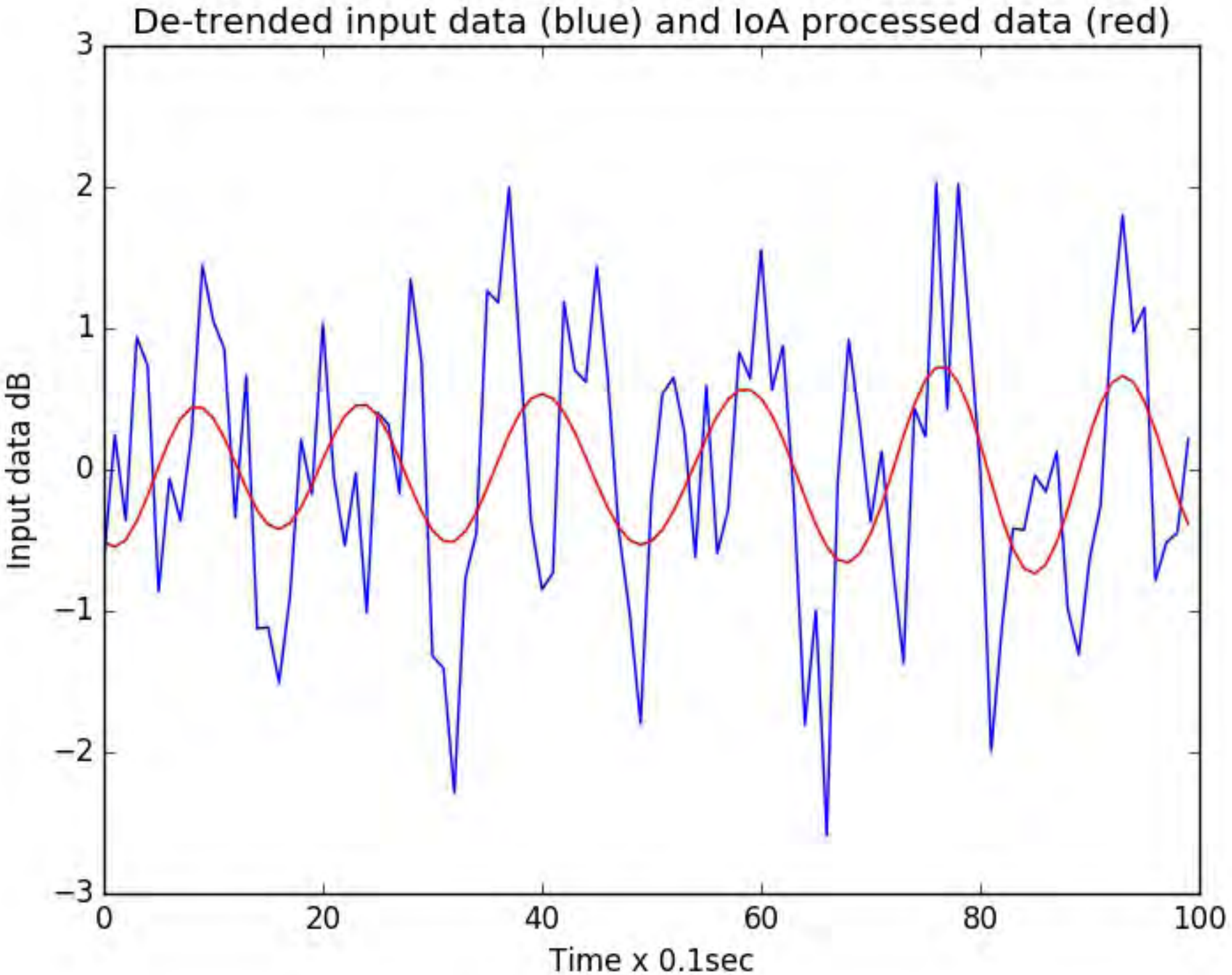
Input File name: LHAM5-100to400.txt
Frequency range for modulation frequency: 0.4 to 0.9 Hz
10 minute results
10 min Block No. 10 min AM Rating (dB)
10s results

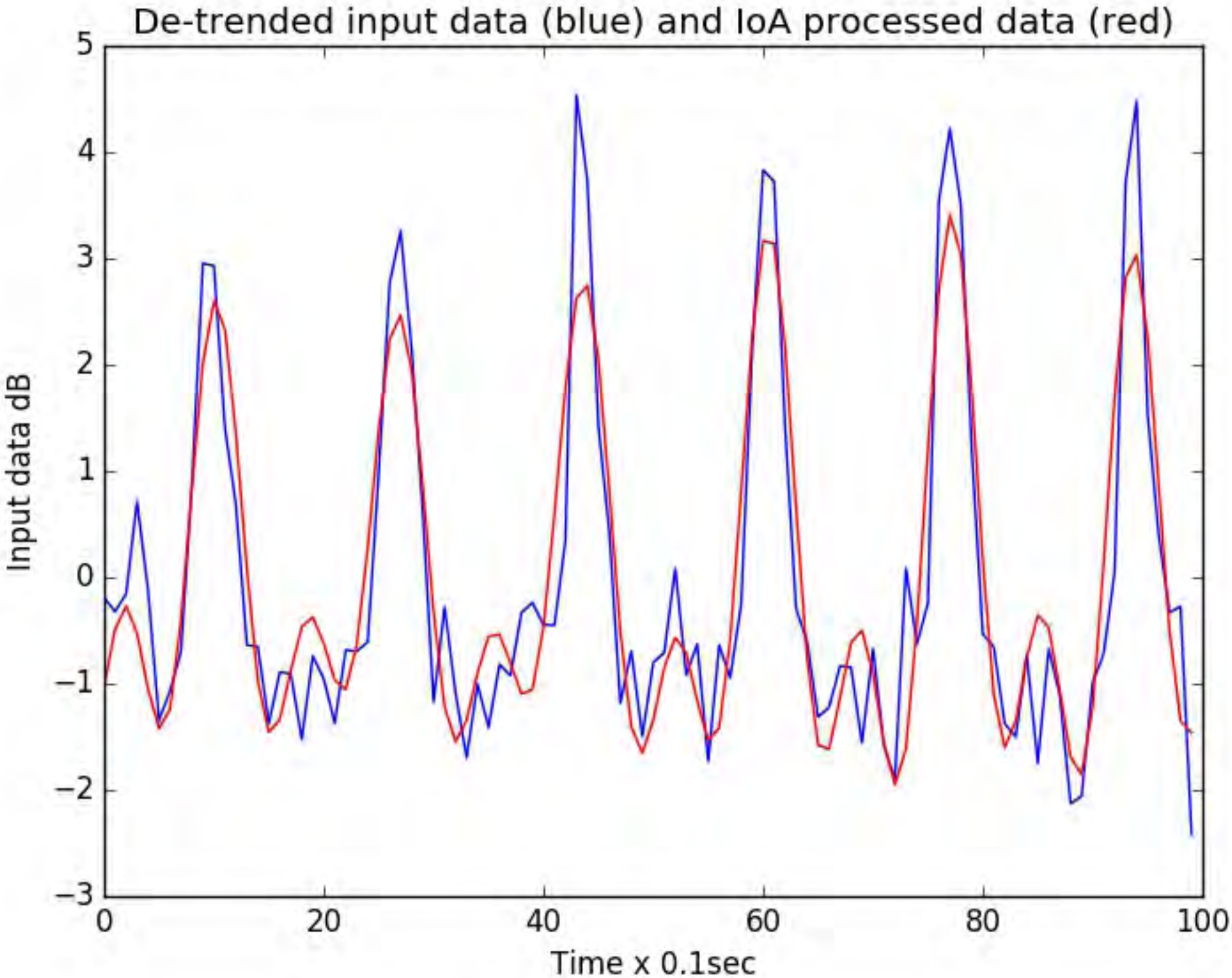
10 sec Block No.	Prominence	Fundamental Mod Freq (Hz)	10 sec AM rating (dB)	10 sec unprocessed AM (dB)
0	51.77	0.6	5.14	5.82
1	8.12	0.6	2.94	4.21
2	143.1	0.6	5.32	6.61
3	62.02	0.6	5.76	6.7
4	112.07	0.6	7.95	9.41
5	183.02	0.6	6.12	6.9
6	49.98	0.6	5.37	7.32
7	79.19	0.6	6.05	7.01
8	51.95	0.6	5.41	6.42
9	24.34	0.6	3.67	5.11
10	218.1	0.6	4.99	5.82
11	10.04	0.6	2.67	4.32
12	137.64	0.6	5.46	6.5
13	60.25	0.6	6.01	7.11
14	157.1	0.6	6.19	7.11
15	32.83	0.6	4.31	5
16	118.3	0.6	5.69	6.81
17	260.87	0.6	7.19	8.04
18	120.81	0.6	6.81	7.84
19	67.1	0.6	6.04	6.71
20	70.57	0.6	5.5	6.4
21	191.78	0.6	4.94	6.7
22	95.95	0.6	5.24	6.32
23	106.6	0.6	5.4	6.11
24	88.89	0.6	4.14	4.92
25	72.23	0.6	3.91	5.21
26	730.61	0.6	5.11	5.71

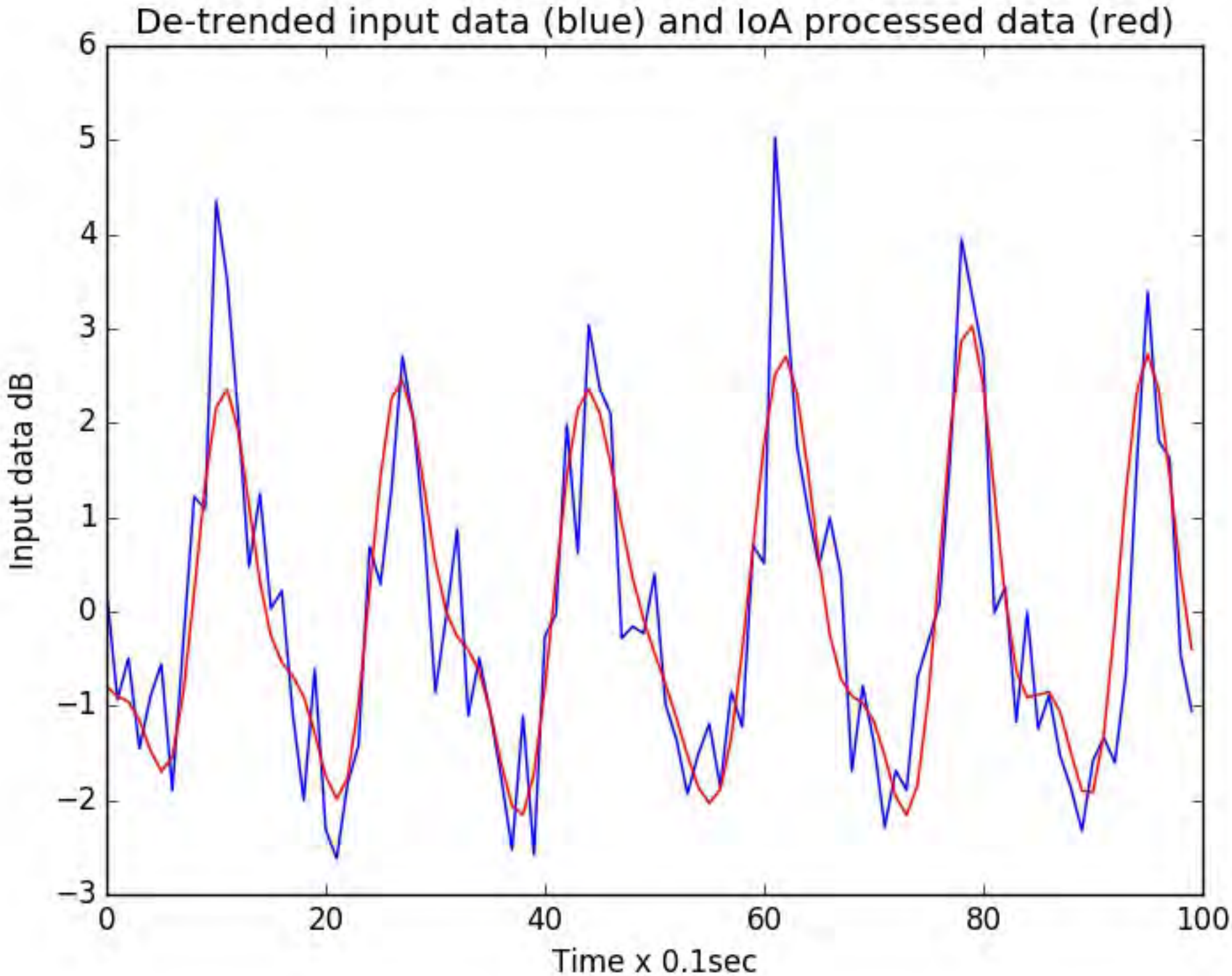
27	94.65	0.6	3.49	4.5
28	17.32	0.6	2.8	4.3
29	40.62	0.6	3.53	3.91
30	17.83	0.6	2.56	3.7
31	4.2	0.7	1.26	4.1
32	48.58	0.6	4.24	5.01
33	23.51	0.6	3.45	4.31
34	16.66	0.6	2.93	4.02
35	11.98	0.6	3.06	4.02
36	6.93	0.5	2.14	3.71
37	22.37	0.6	3.52	4.61
38	22.18	0.6	2.84	4.01
39	4.63	0.7	0.93	4.1
40	11.33	0.6	4.14	5.23
41	24.08	0.6	4.35	5.5
42	26.8	0.6	1.87	3.5
43	21.96	0.6	4.18	5.21
44	13.3	0.6	4.64	5.72
45	23.66	0.6	4.49	5.71
46	14.01	0.6	2.55	4.7
47	3.24			
48	8.68	0.6	1.24	4.12
49	12.16	0.6	4	4.43
50	101.73	0.6	3.73	5.01
51	4.87	0.7	2.59	4.13
52	12.59	0.6	3.82	4.52
53	9.71	0.6	2.53	3.71
54	11.16	0.6	2.83	4.91
55	17.86	0.6	6.19	7.42
56	15.78	0.7	4.76	5.72
57	25.7	0.7	2.2	3.91
58	3.07			
59	24.53	0.7	2.74	4.52

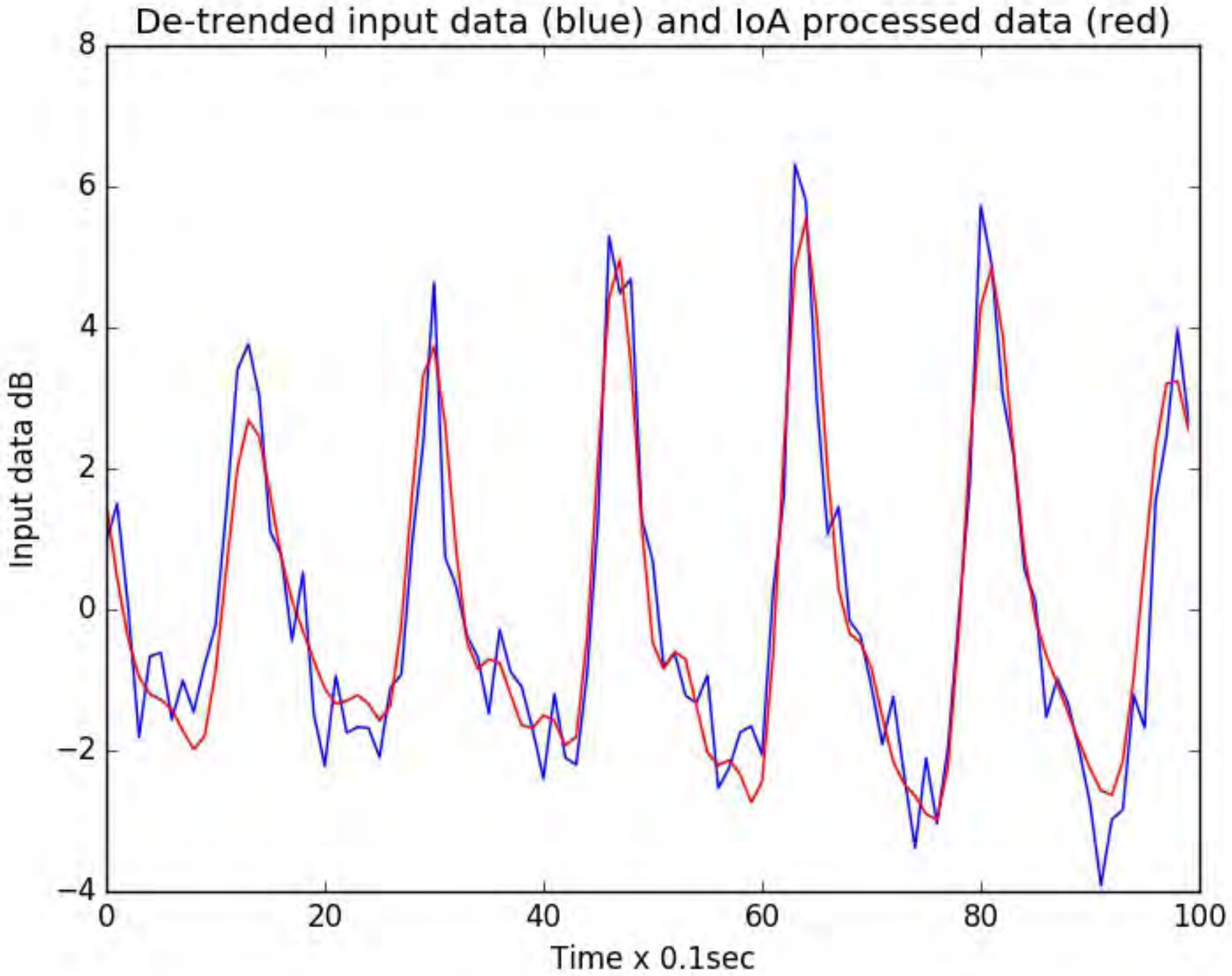

Leonards Hill Wind Farm outside nearest residence
14 March 2012 1.50am to 2.00am (LHAM5)
Sound Presure Level dB(A)
45
43
41
39
37
35
33
31
29
27
25
1
101
201
301
401
501
601
701
801
901
1001
1101
1201
1301
1401
1501
1601
1701
1801
1901
2001
2101
2201
2301
2401
2501
2601
2701
2801
2901
3001
3101
3201
3301
3401
3501
3601
3701
3801
3901
4001
4101
4201
4301
4401
4501
4601
4701
4801
4901
5001
5101
5201
5301
5401
5501
5601
5701
5801
5901
Time x 0.1sec

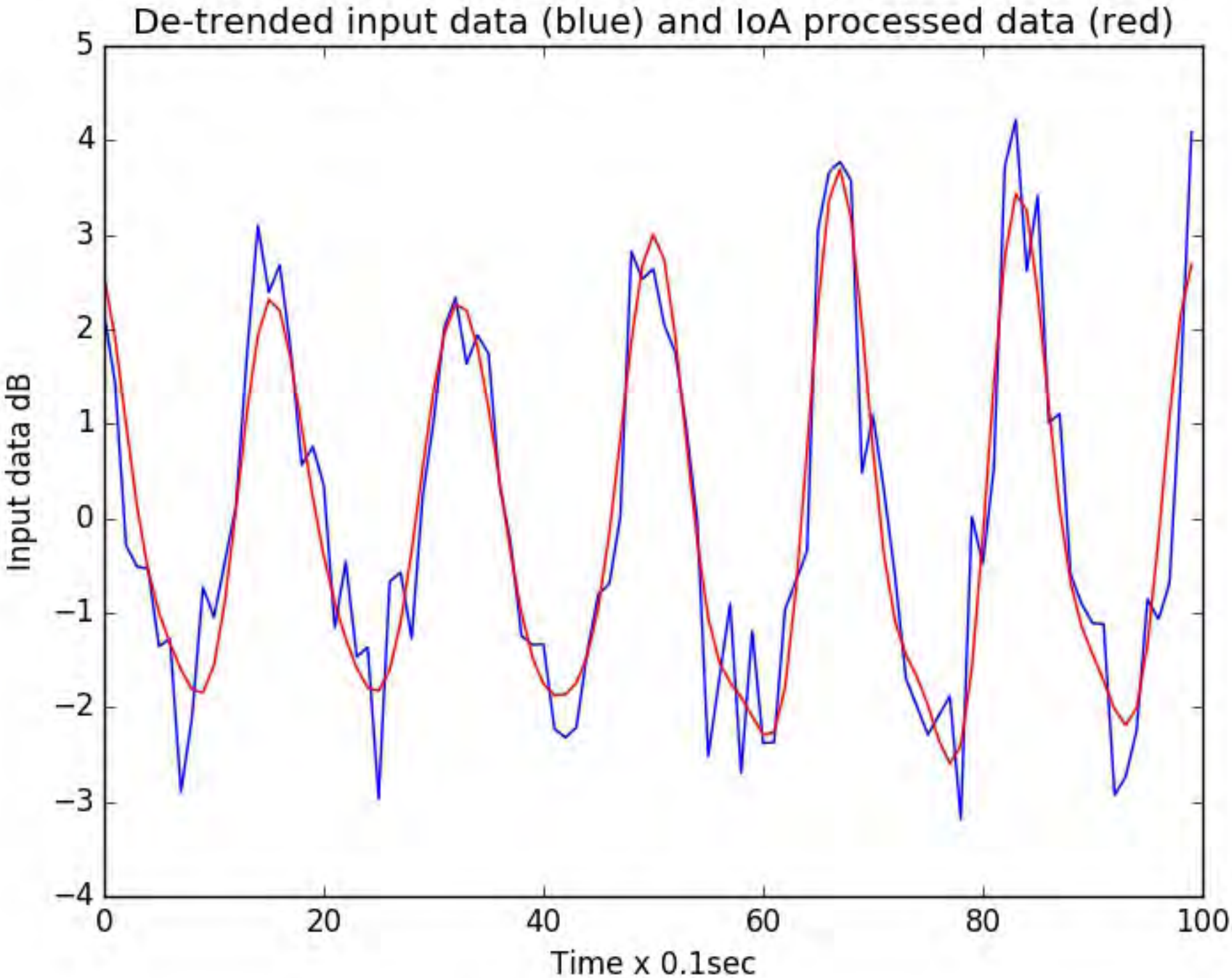

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

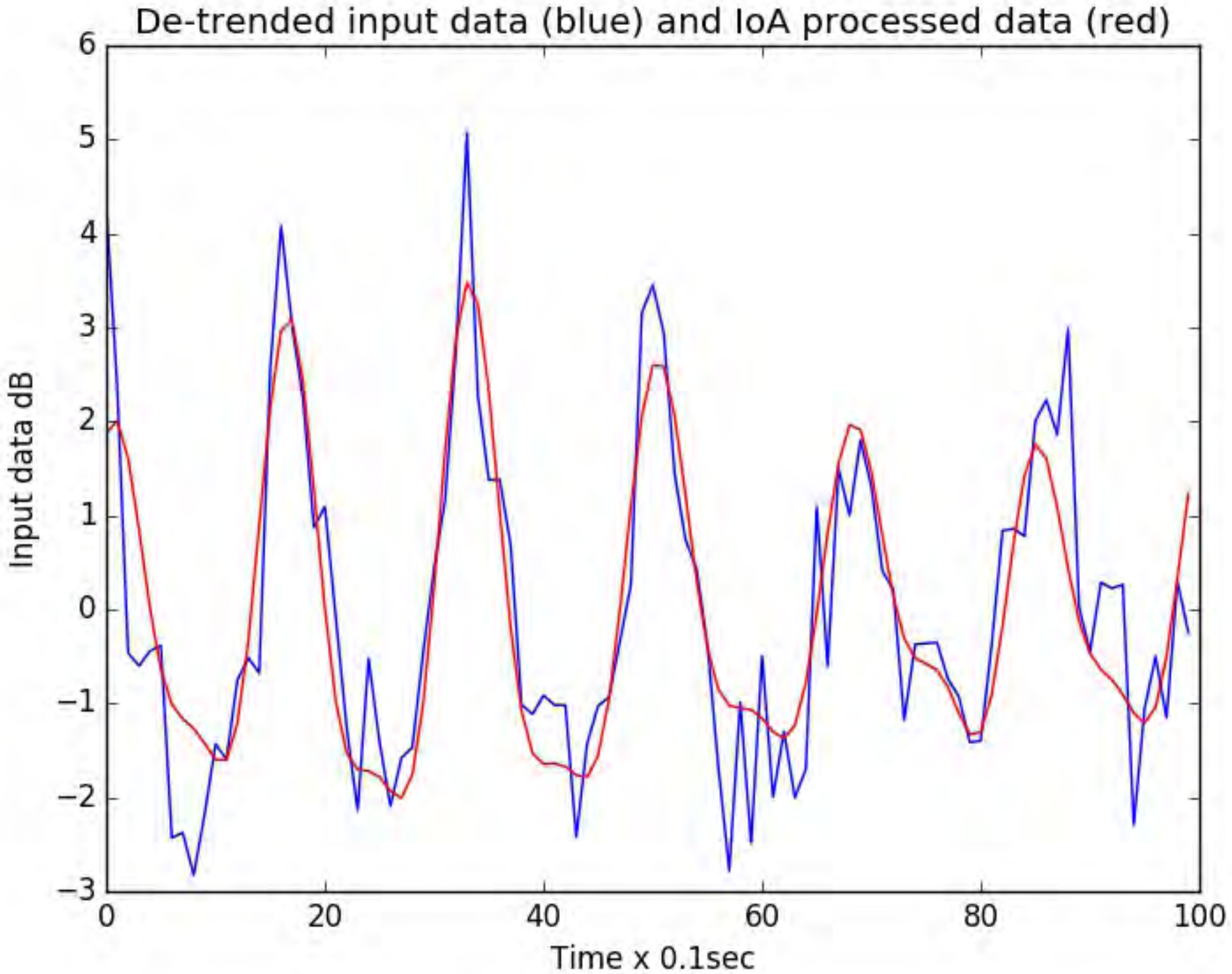

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

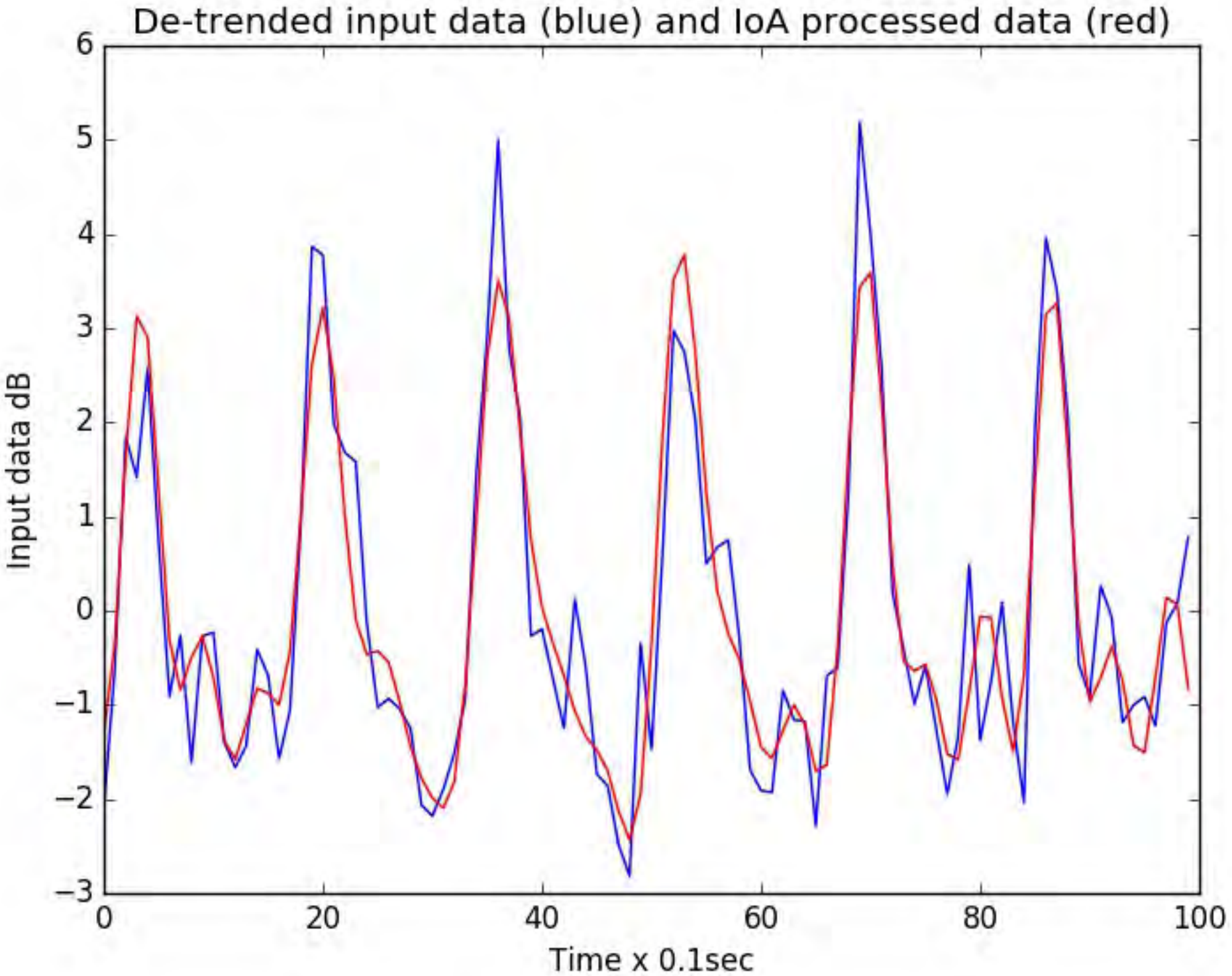

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

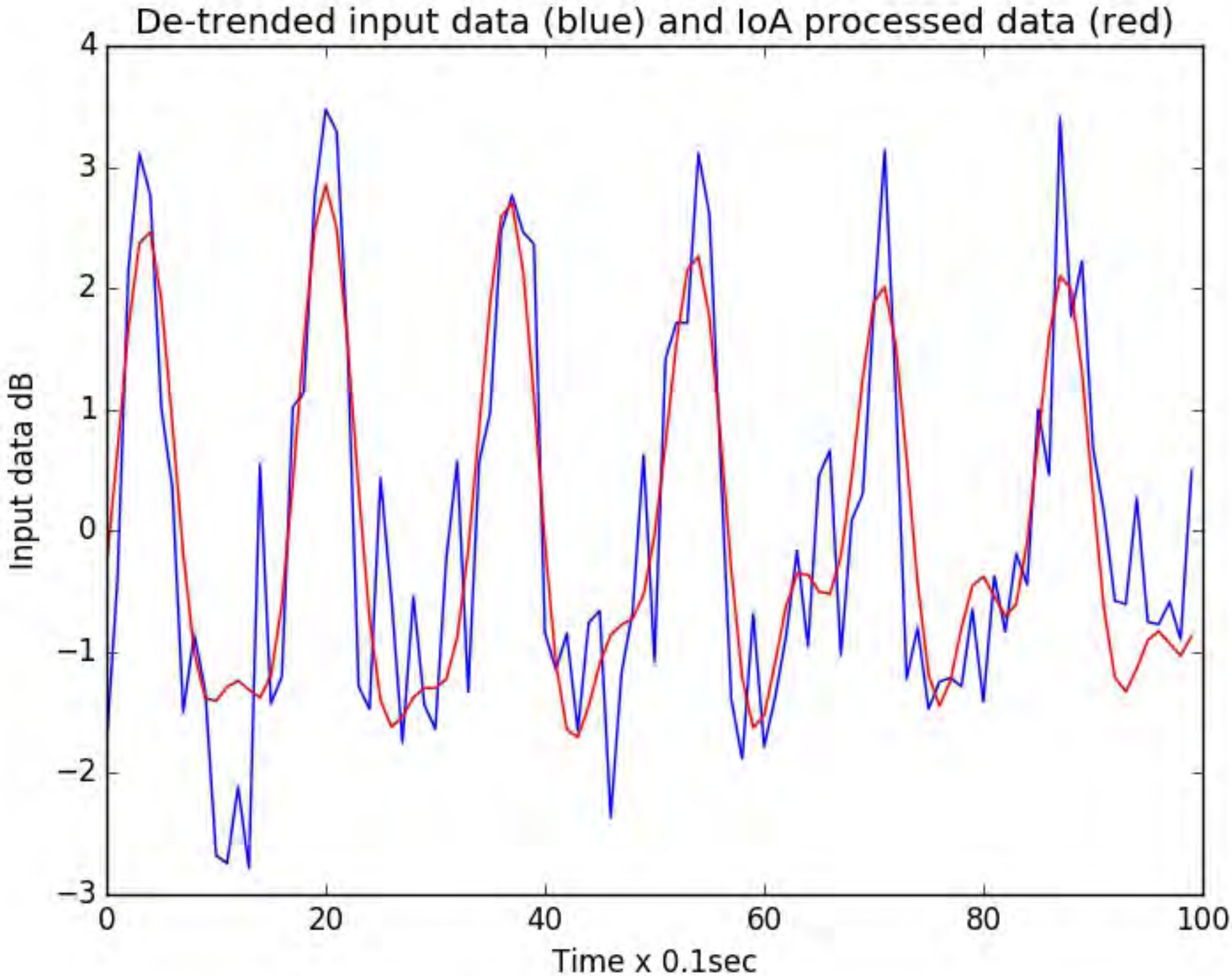

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

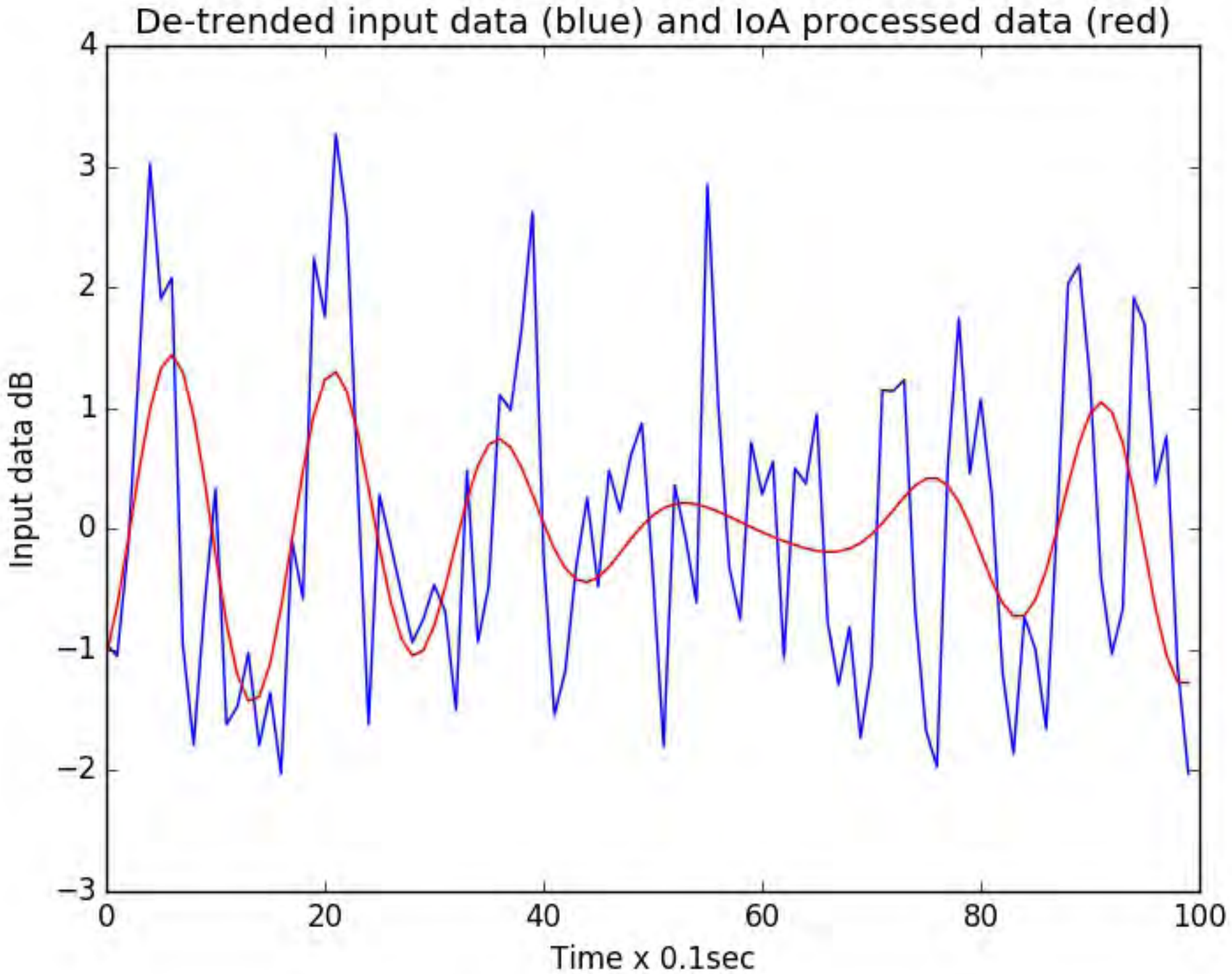

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
8
6
4
2
0
−2
−4
0
20
40
60
80
100

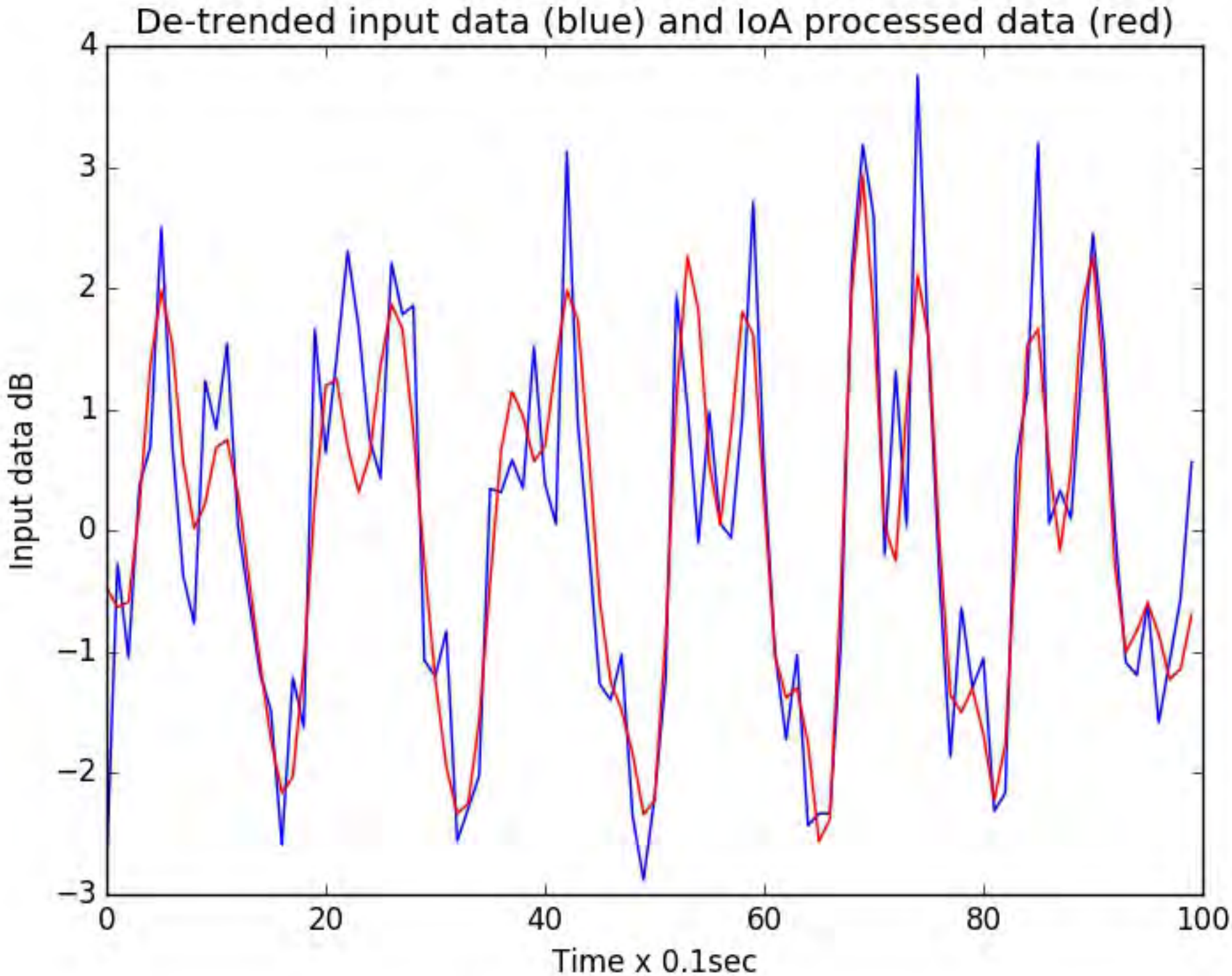

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

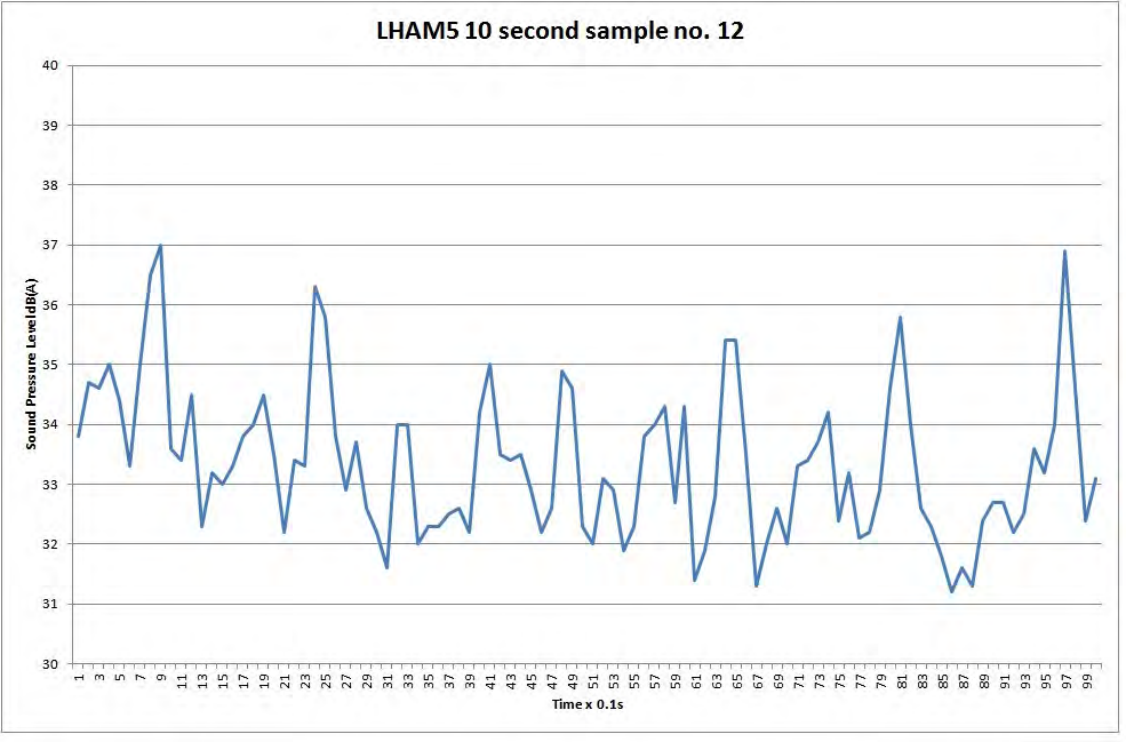

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

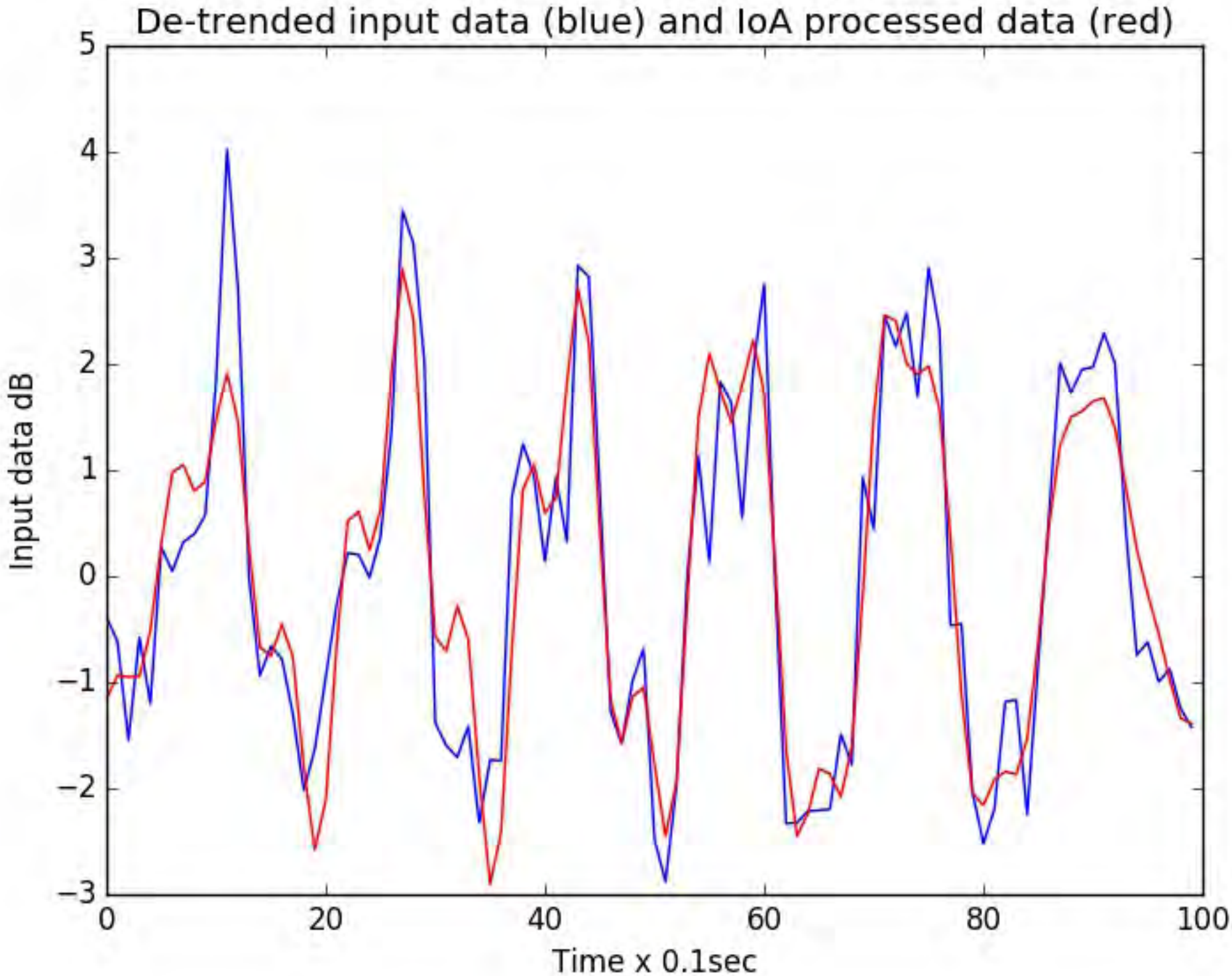

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

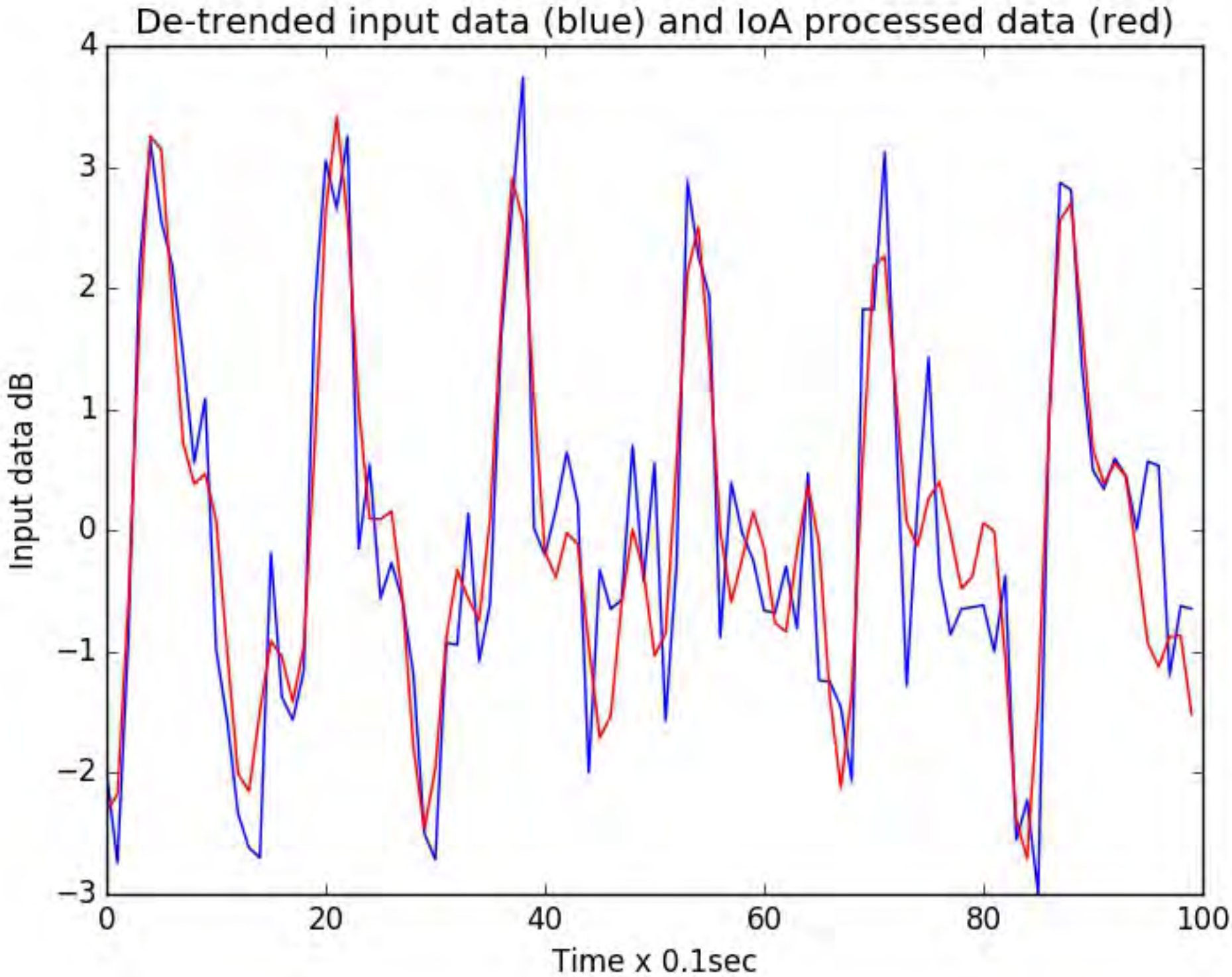

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

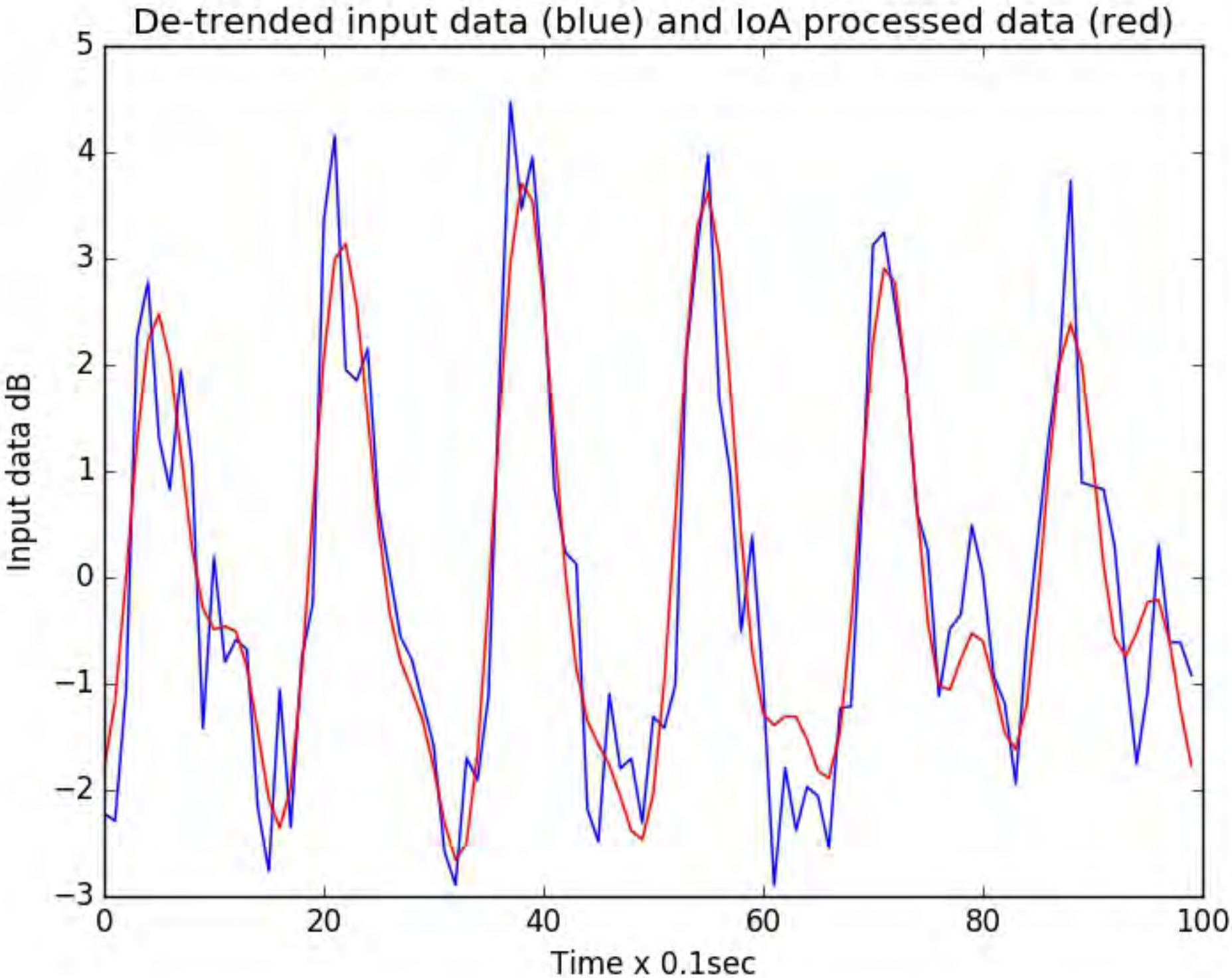

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

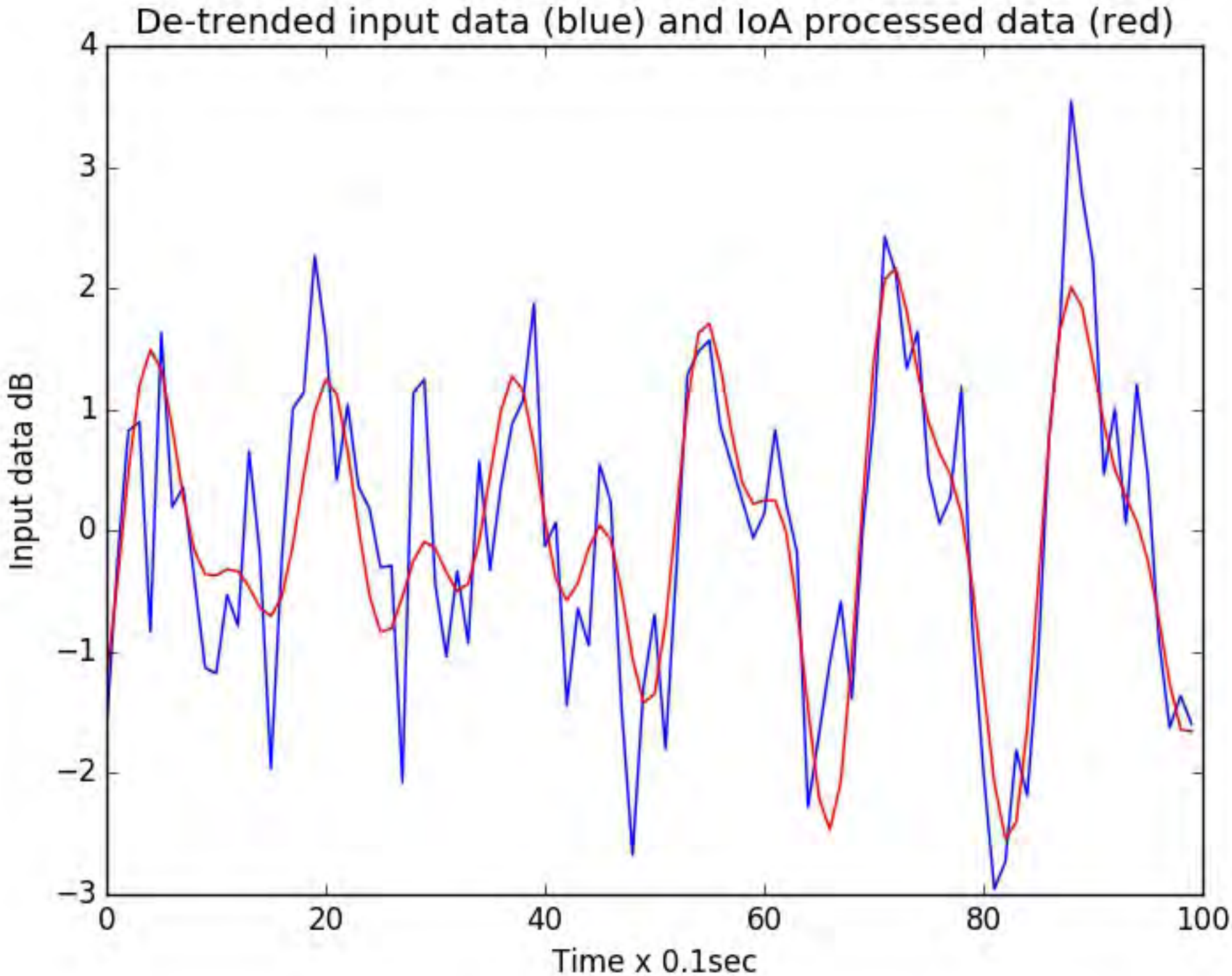

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

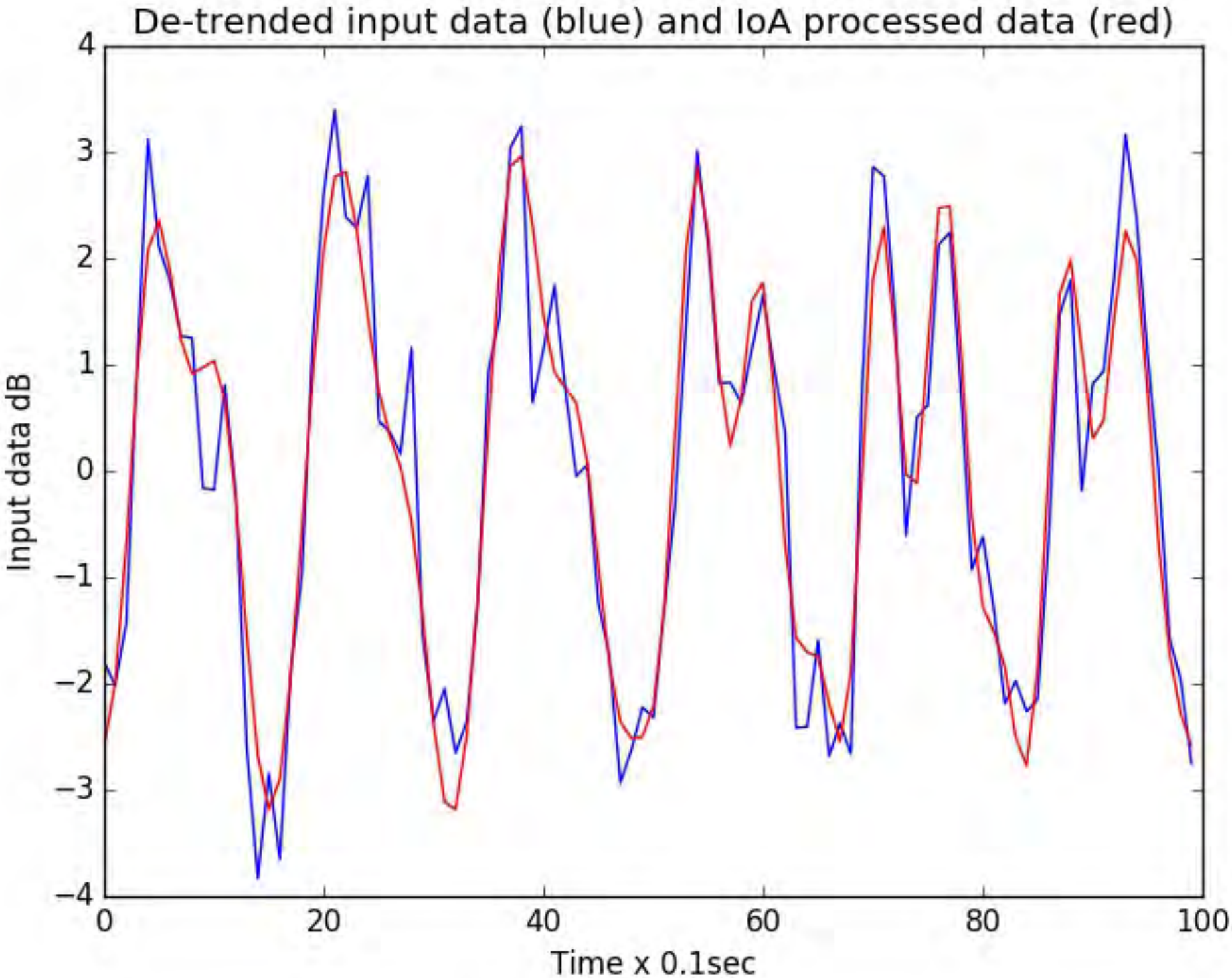

LHAM5 10 second sample no. 12
Sound Pressure LevelldB(A)
40
39
38
37
36
35
34
33
32
31
30
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Time x 0.1s

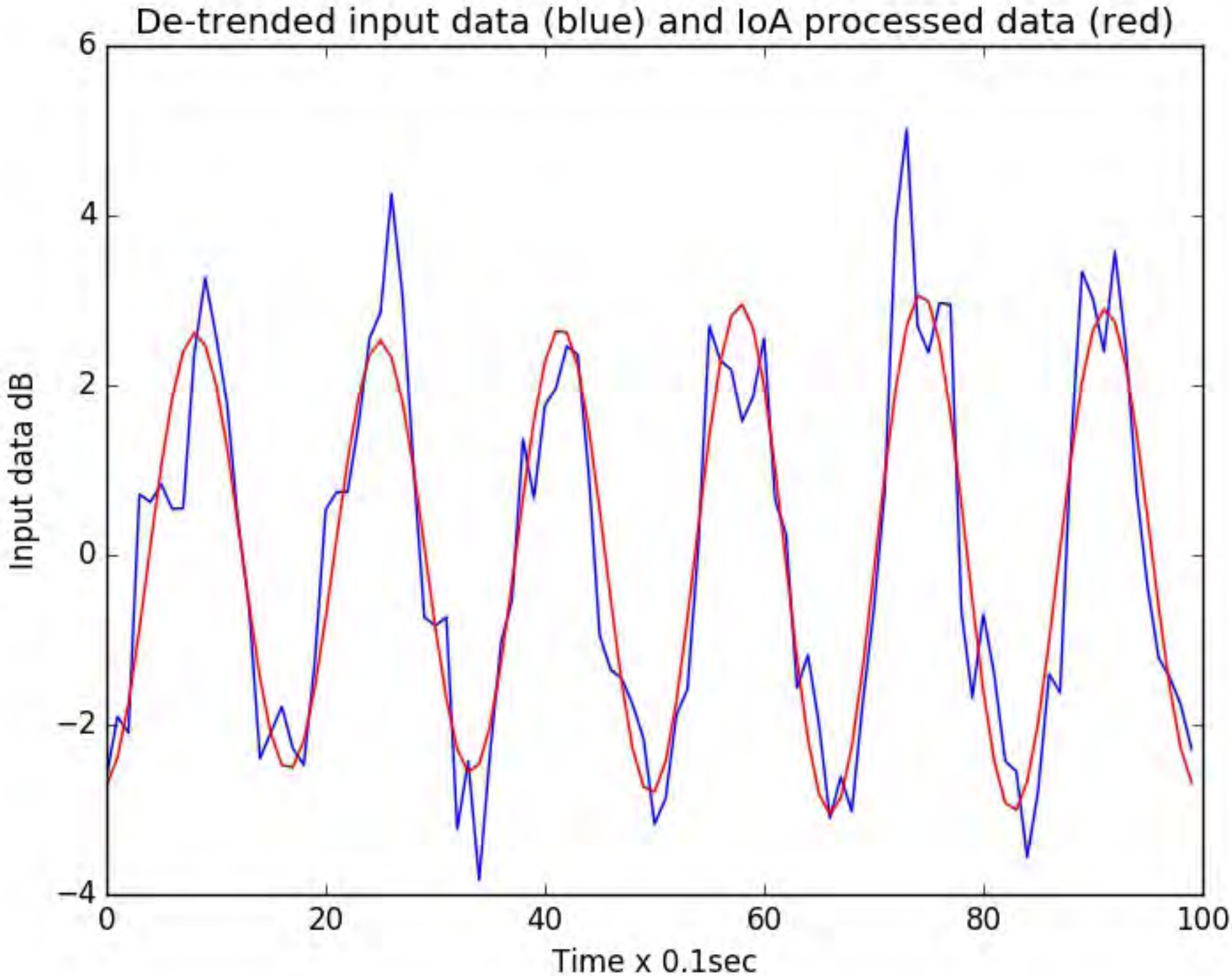

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

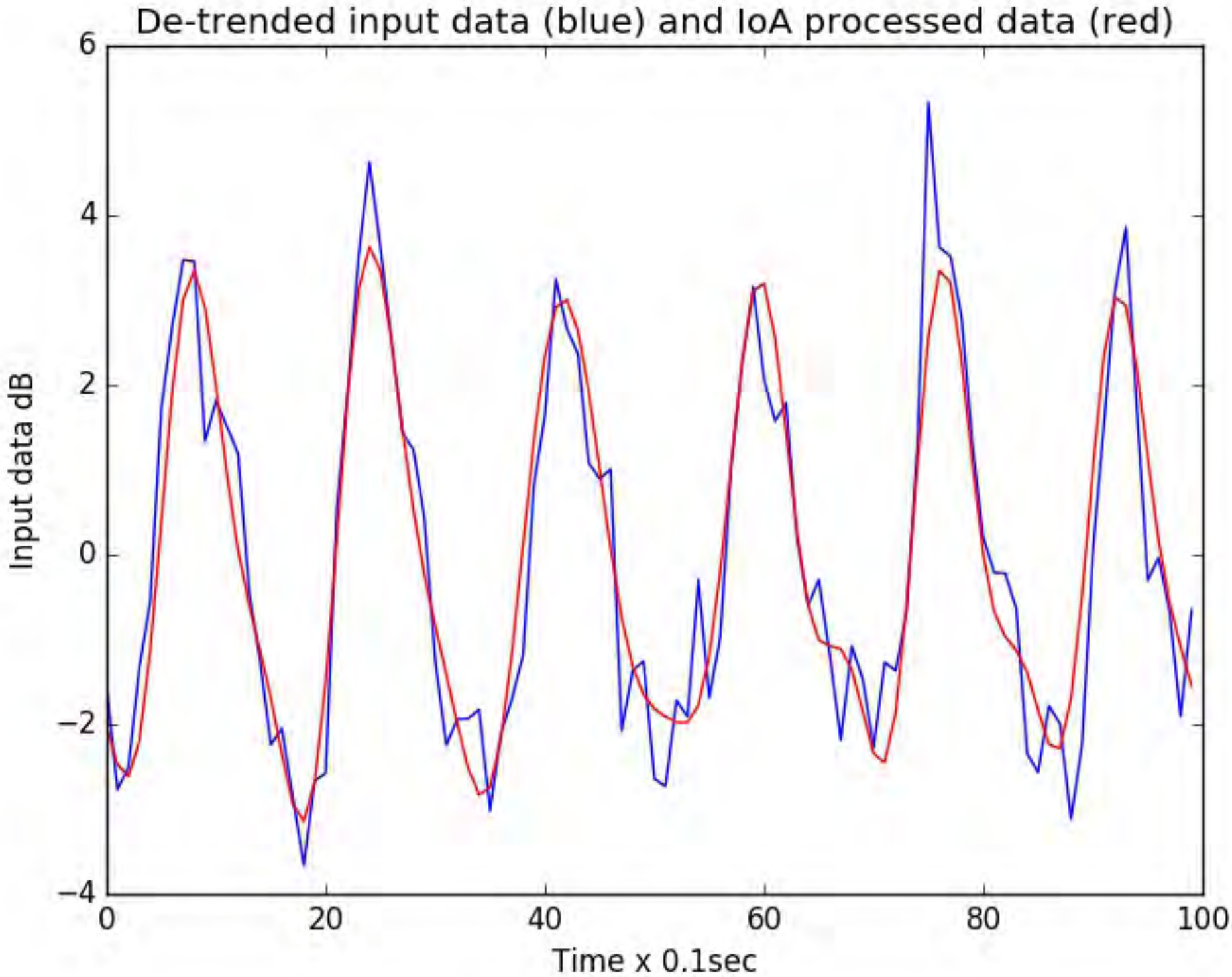

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

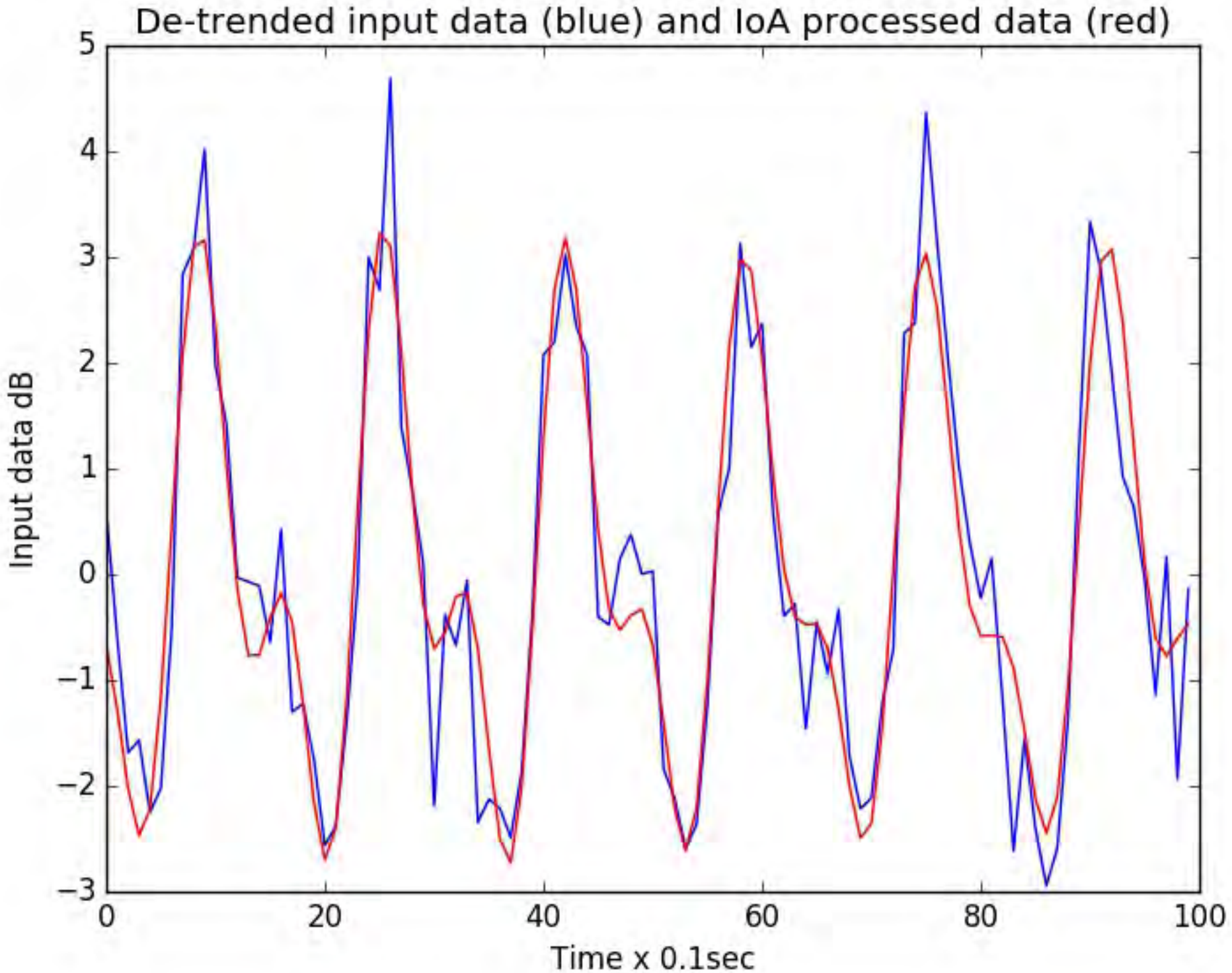

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

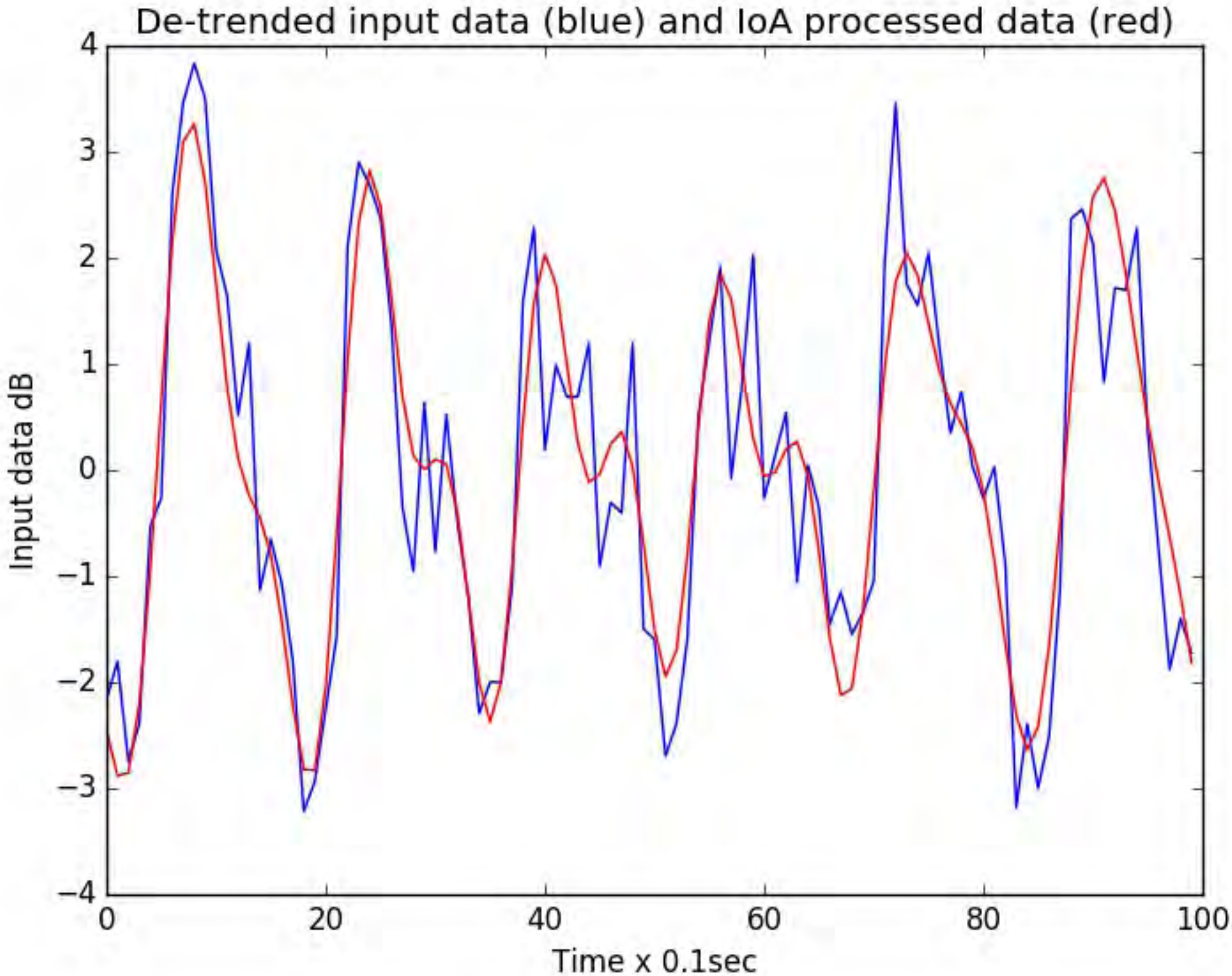

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

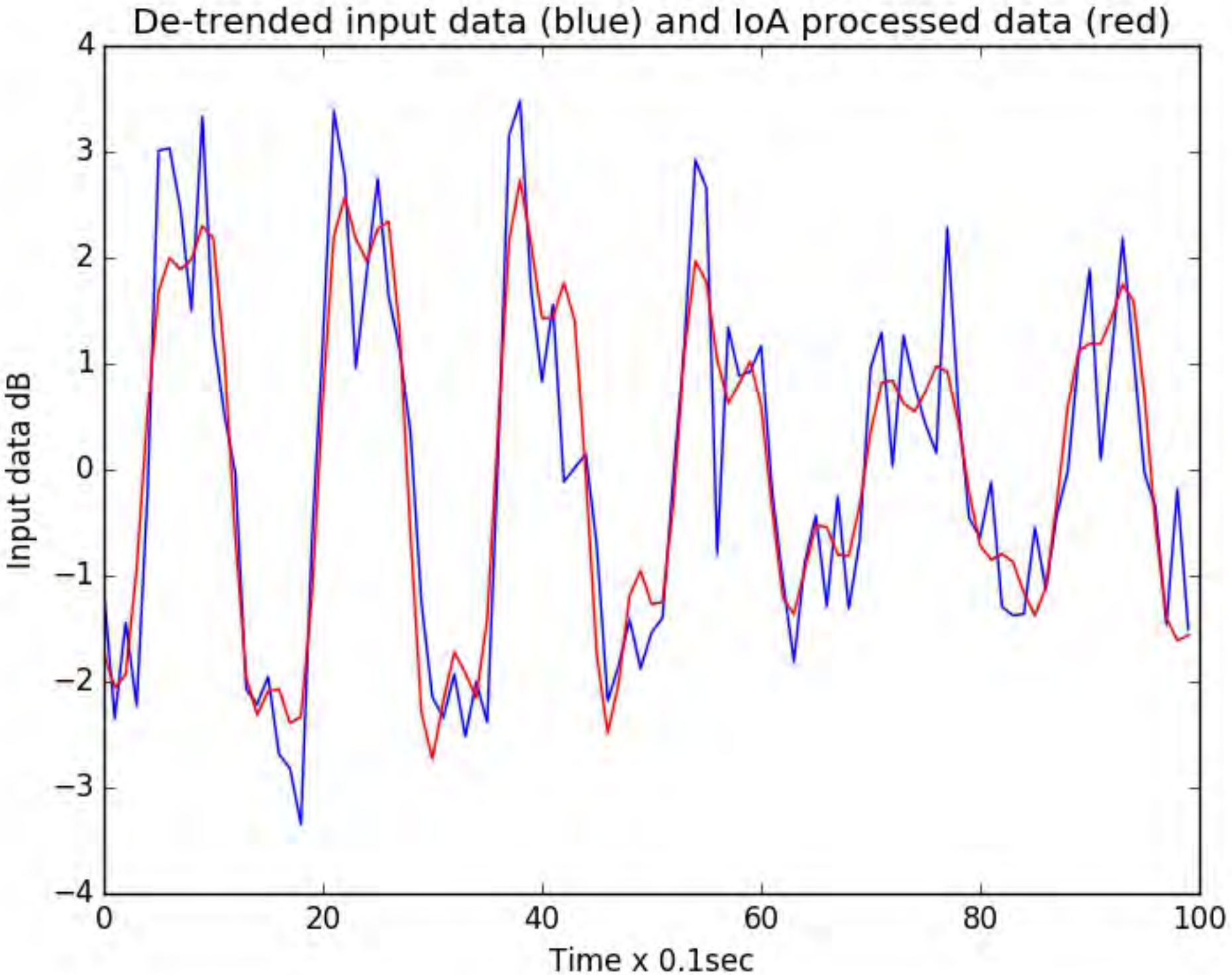

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

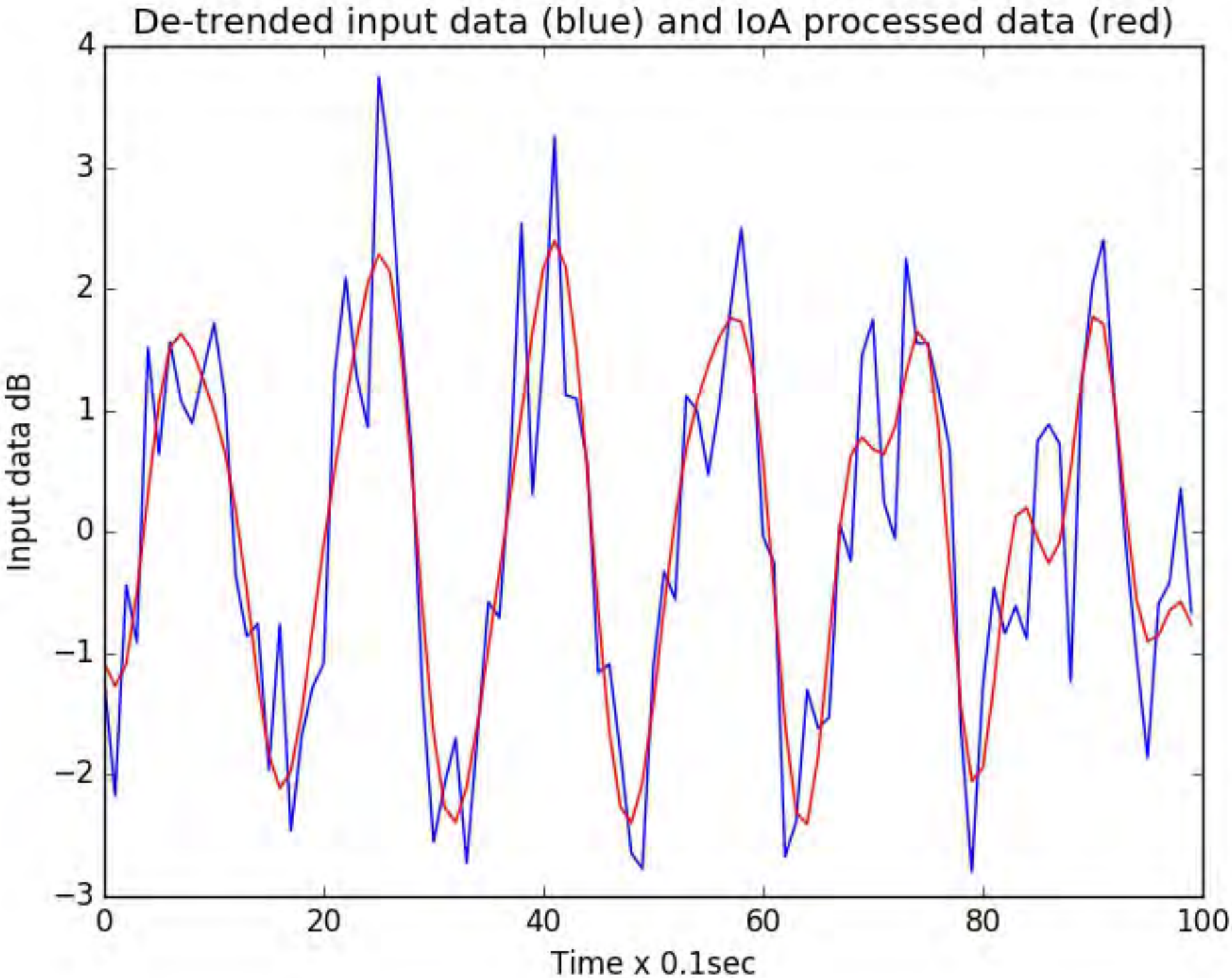

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100

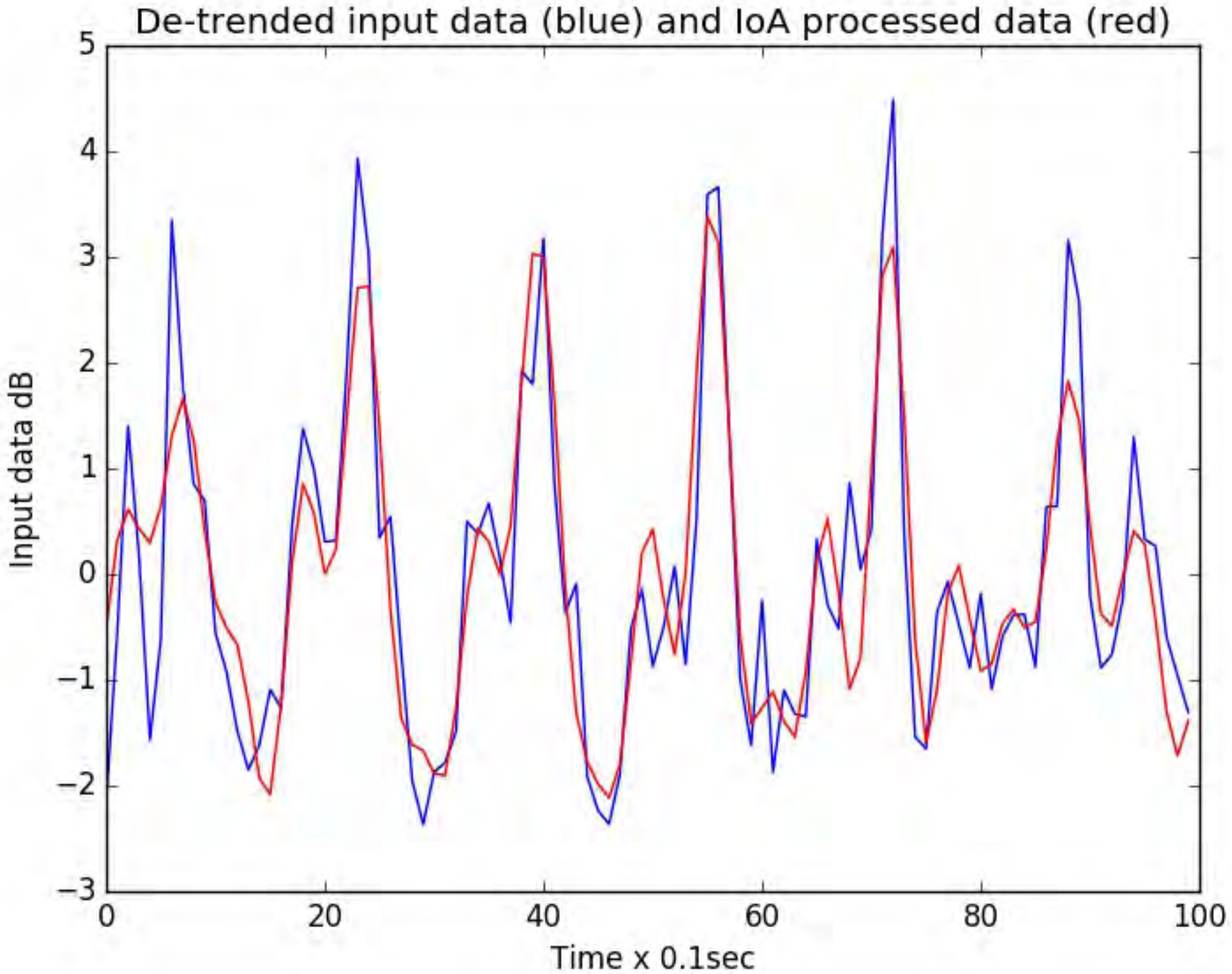

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100

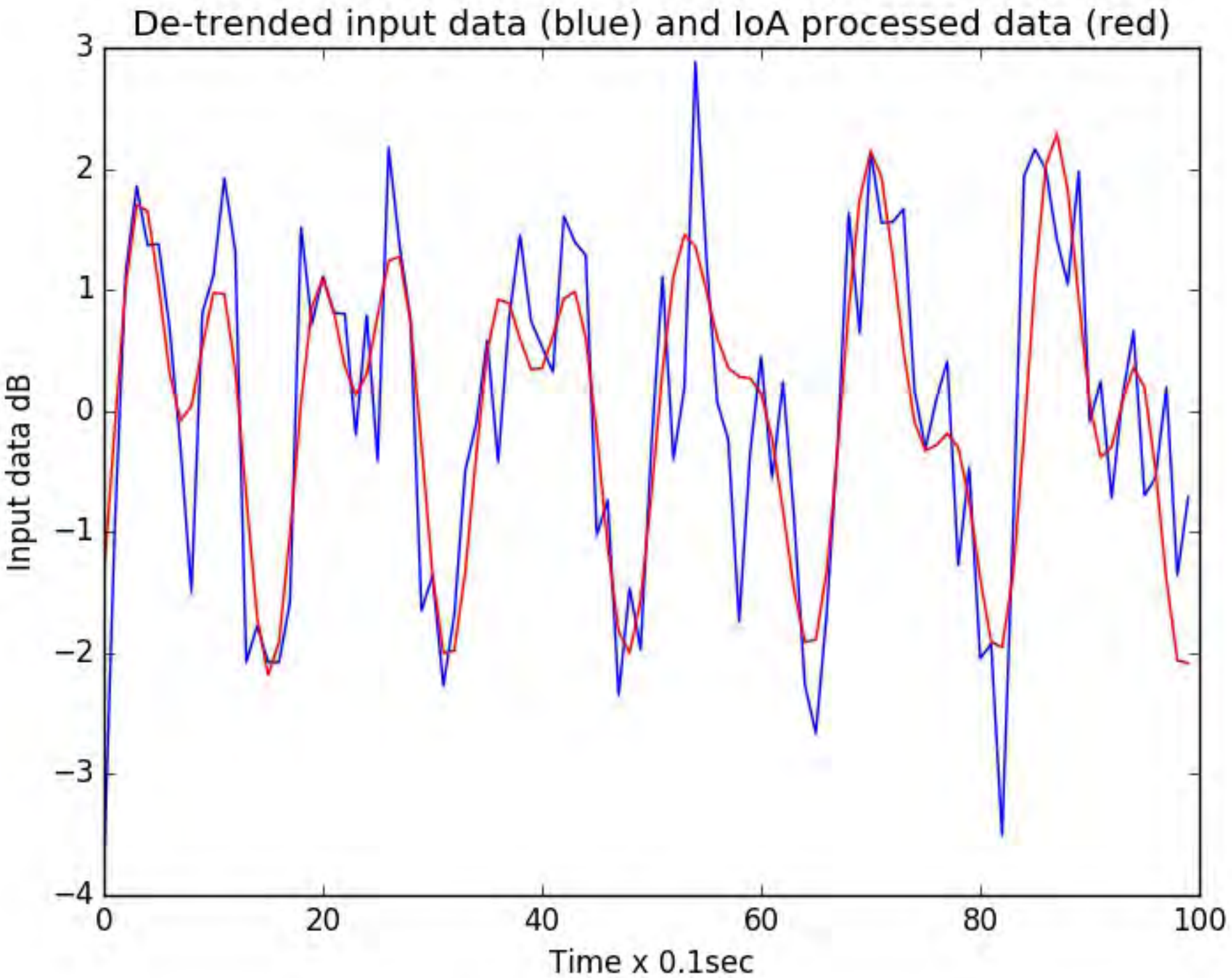

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

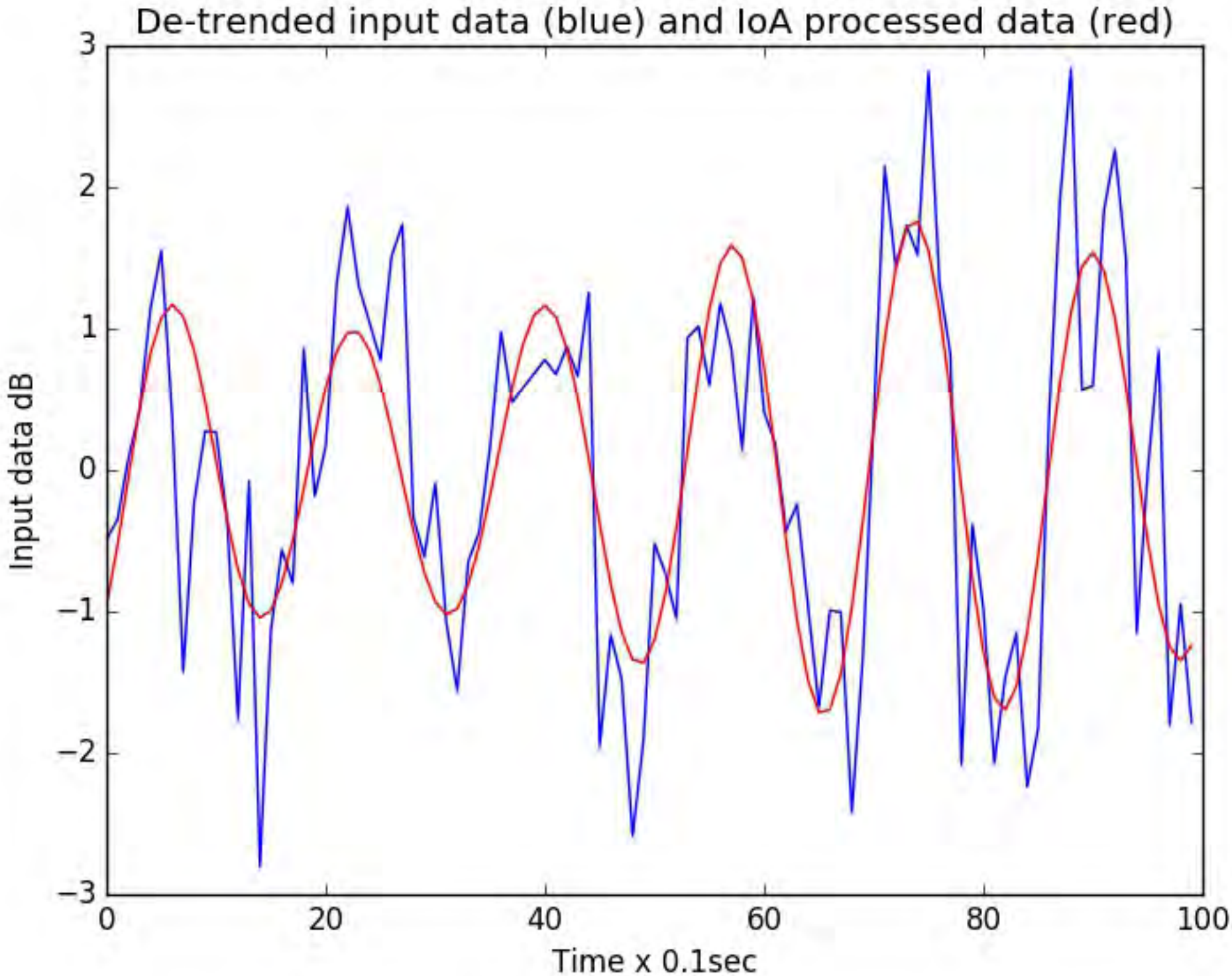

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

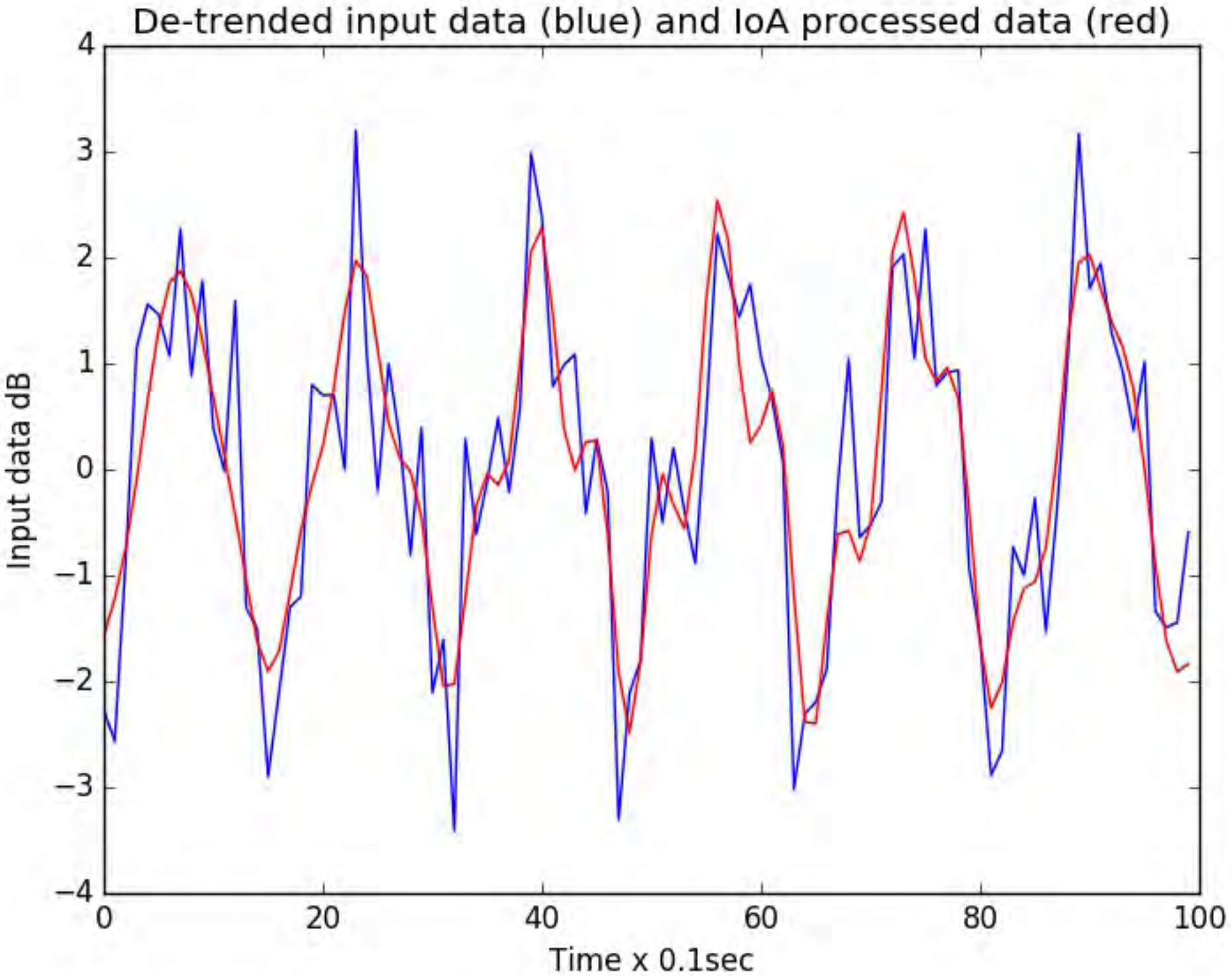

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

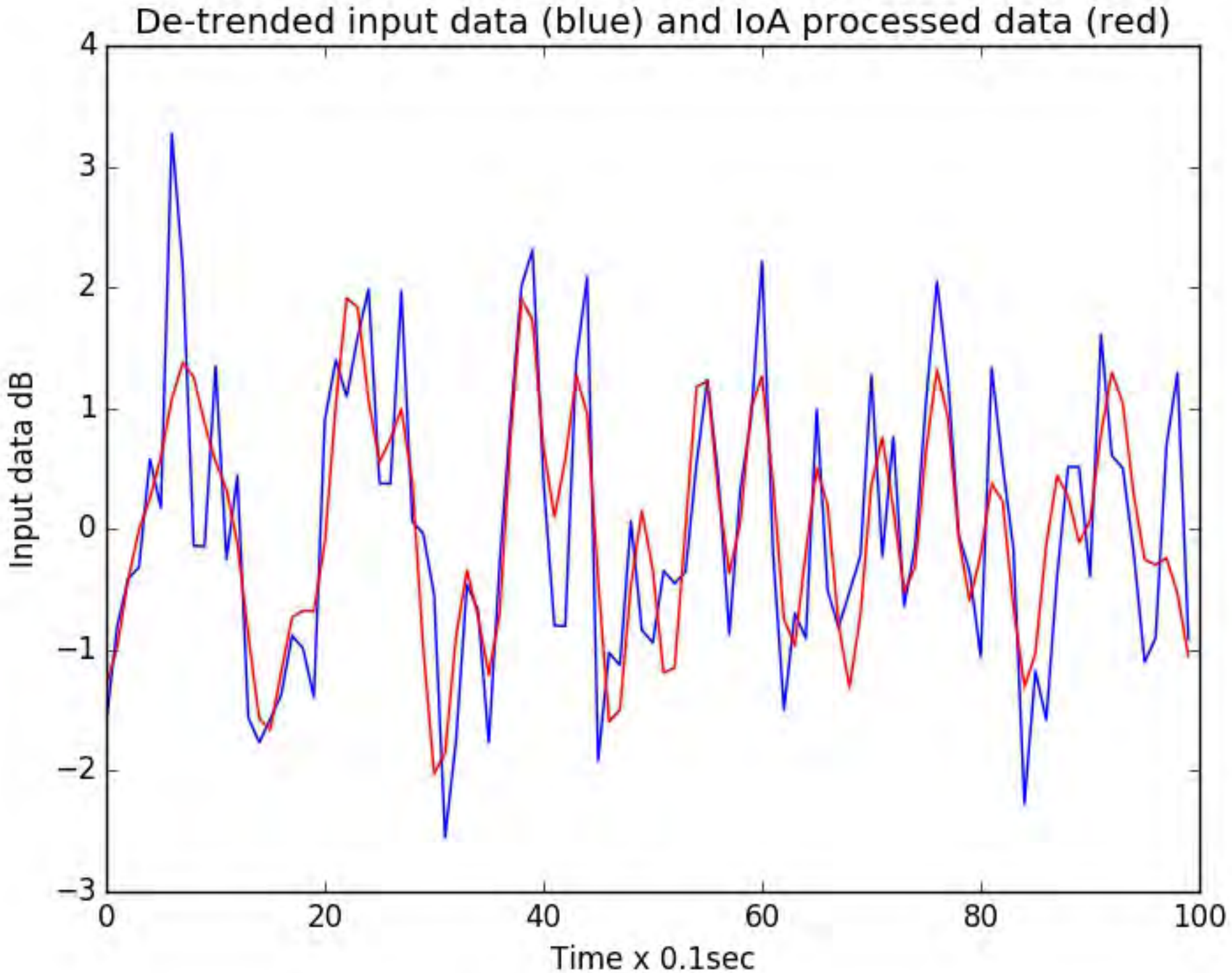

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

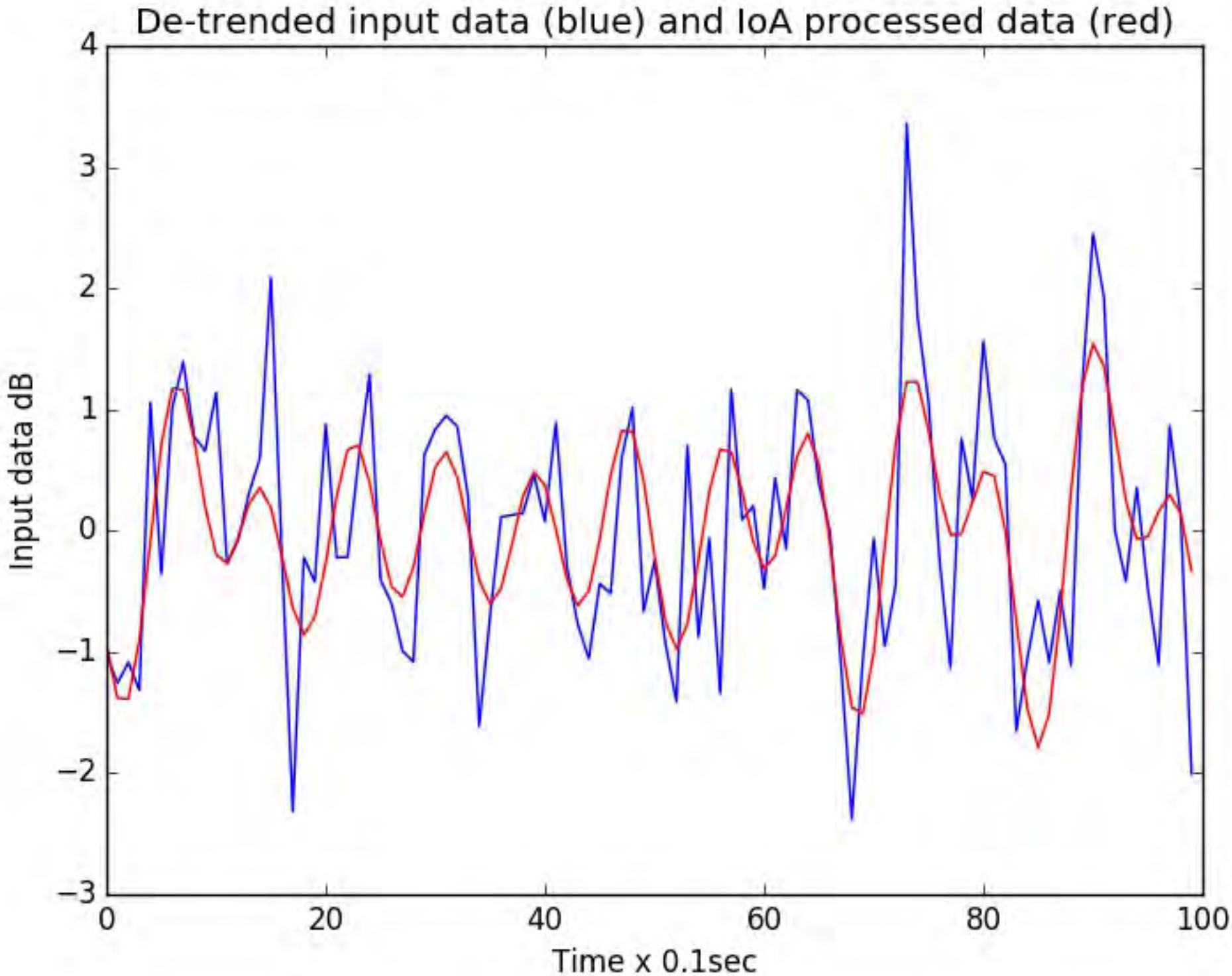

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

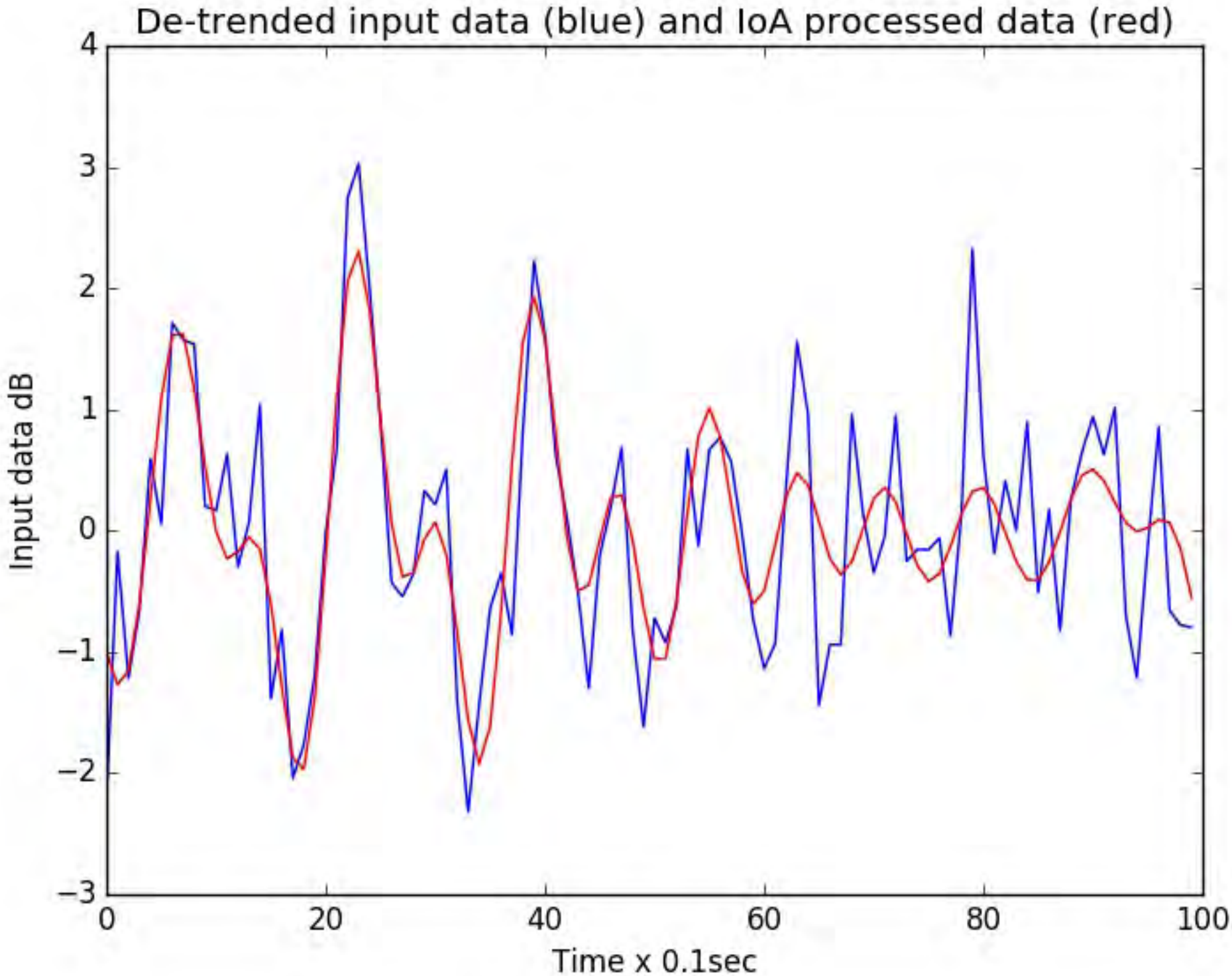

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

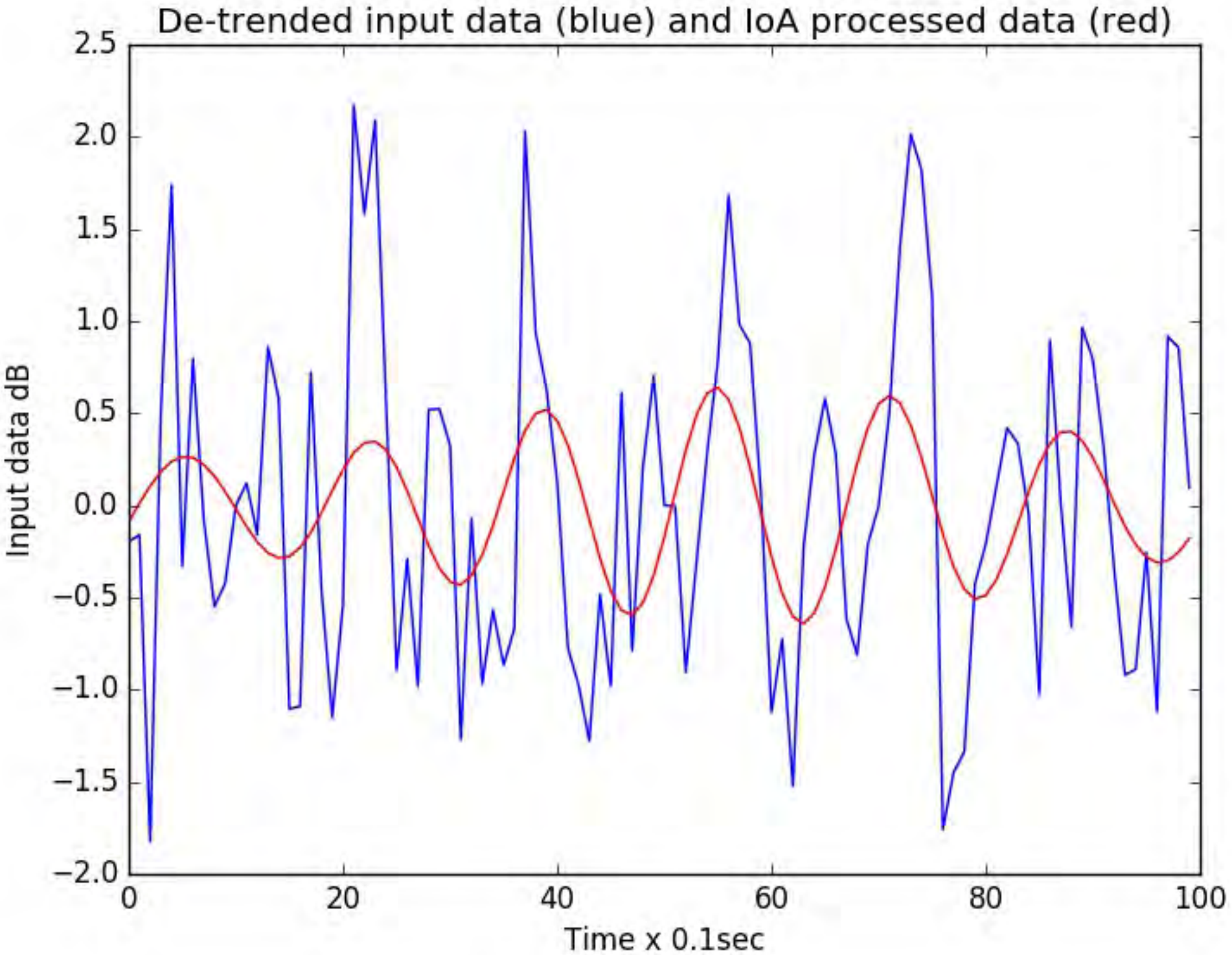

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

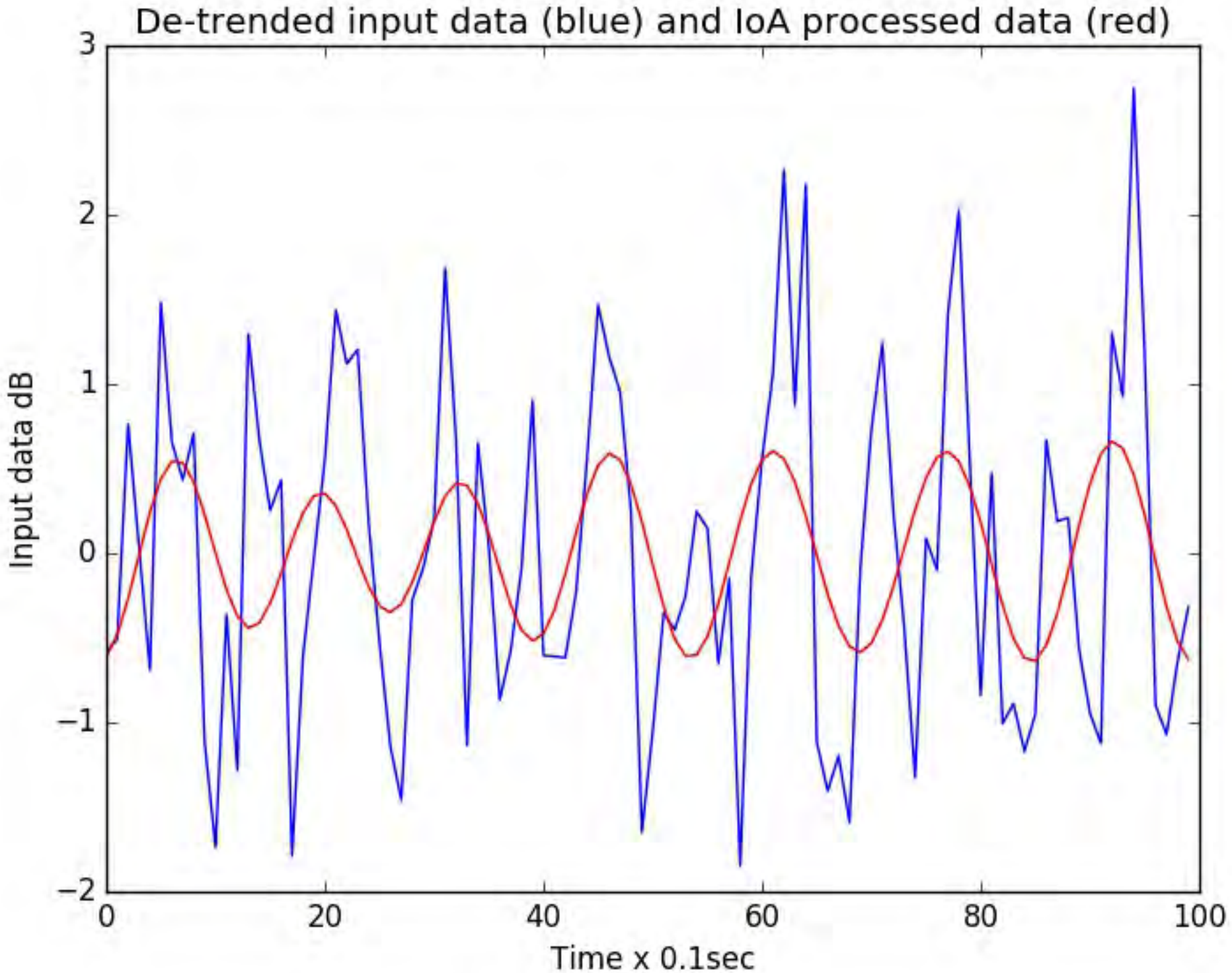

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

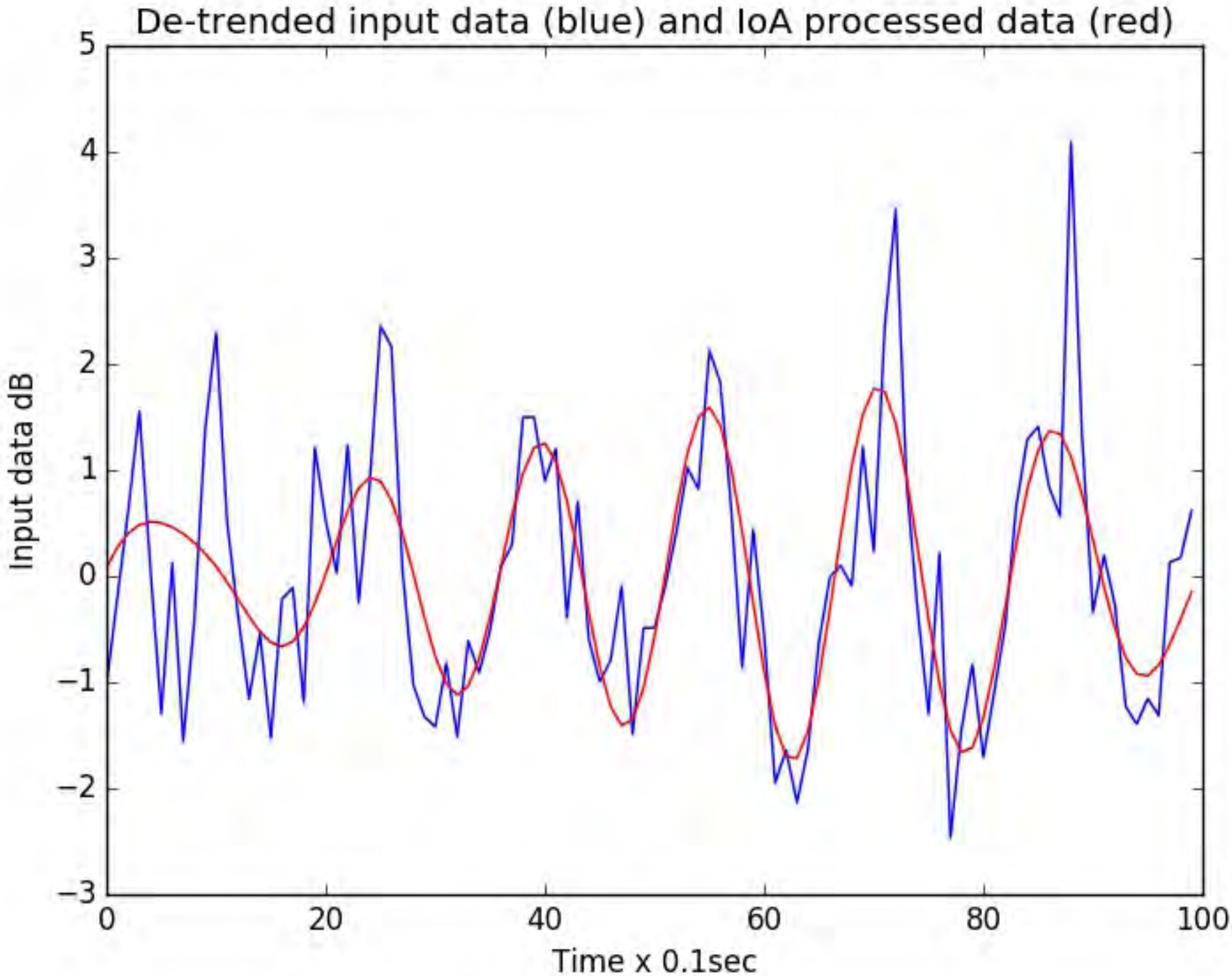

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

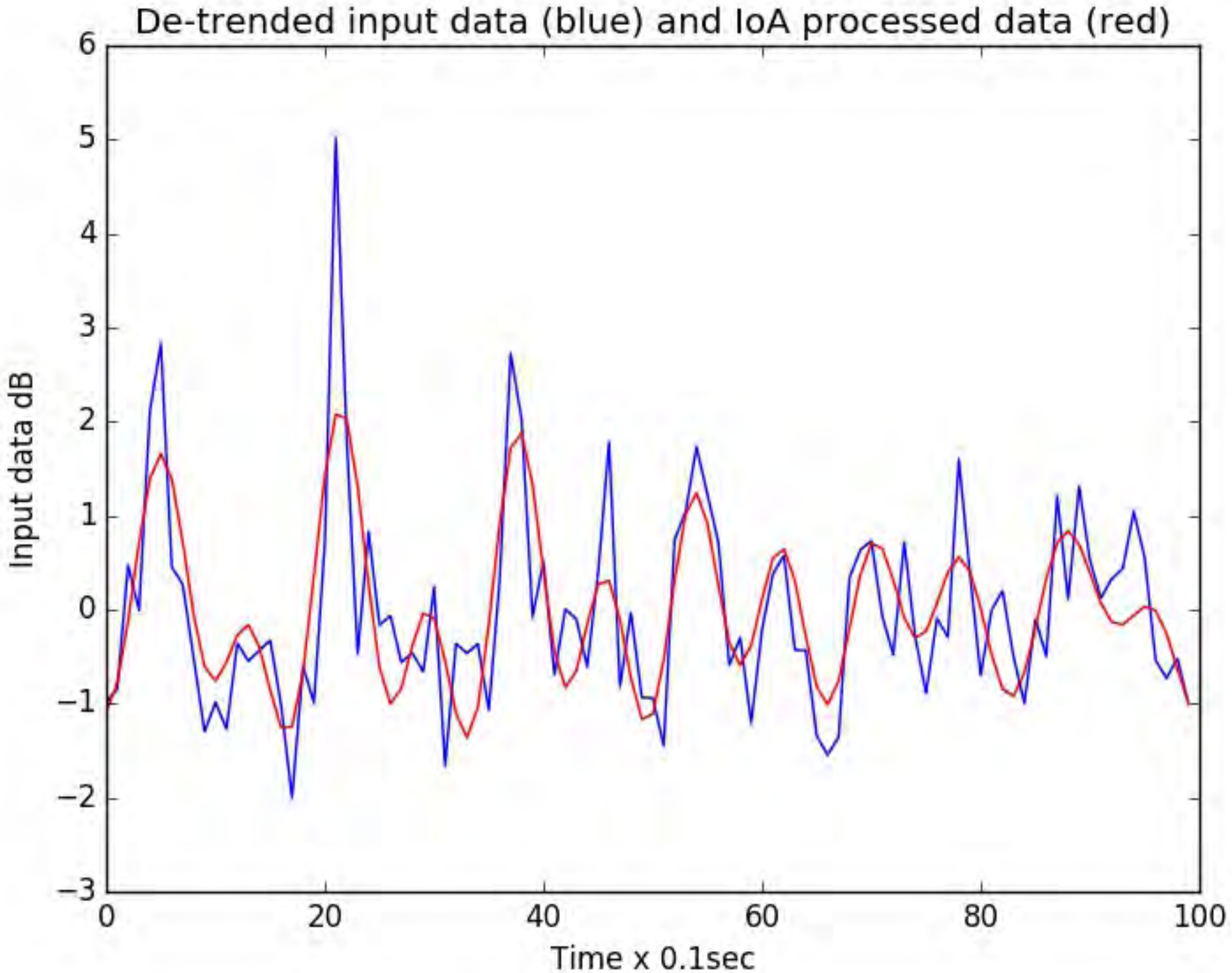

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

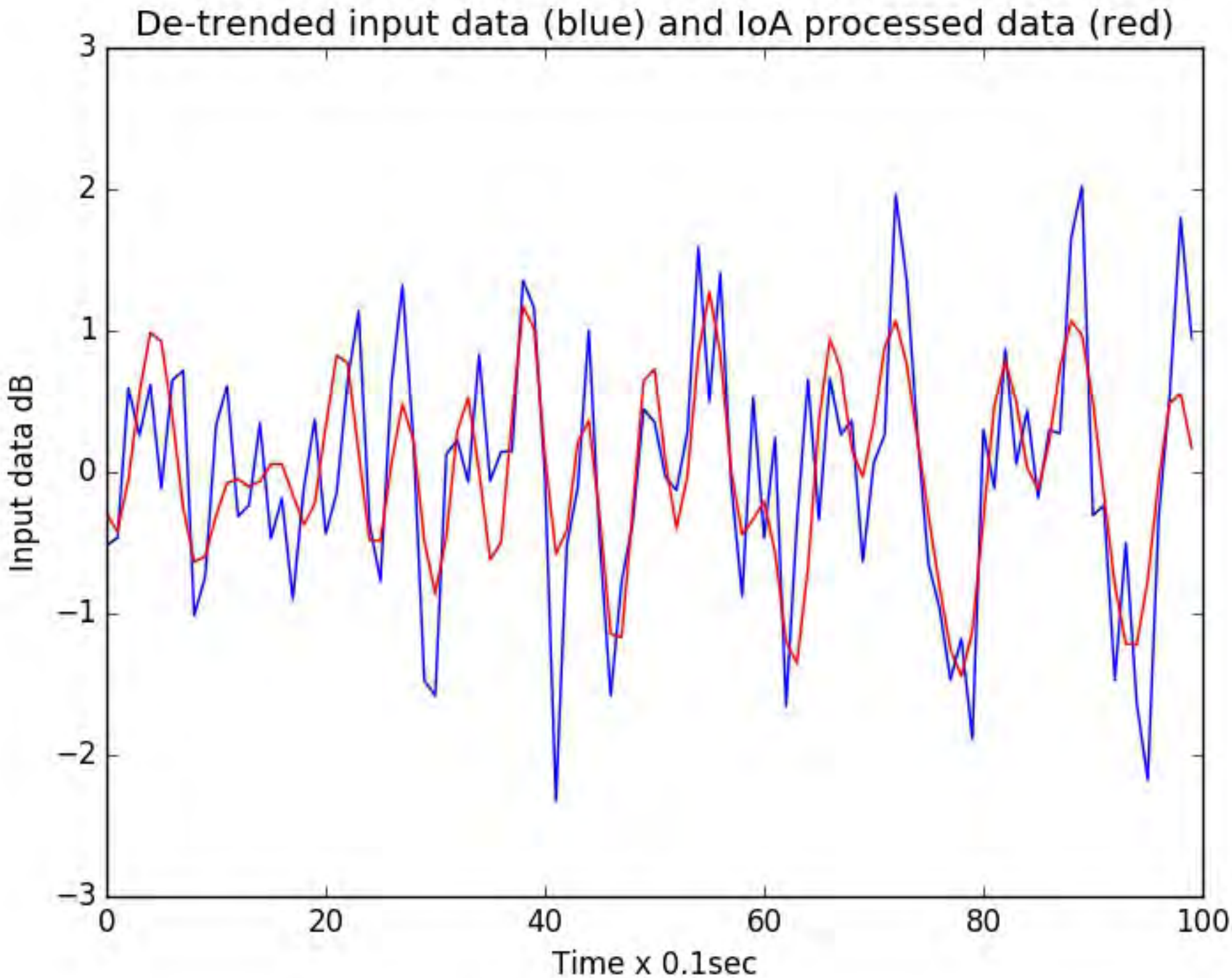

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

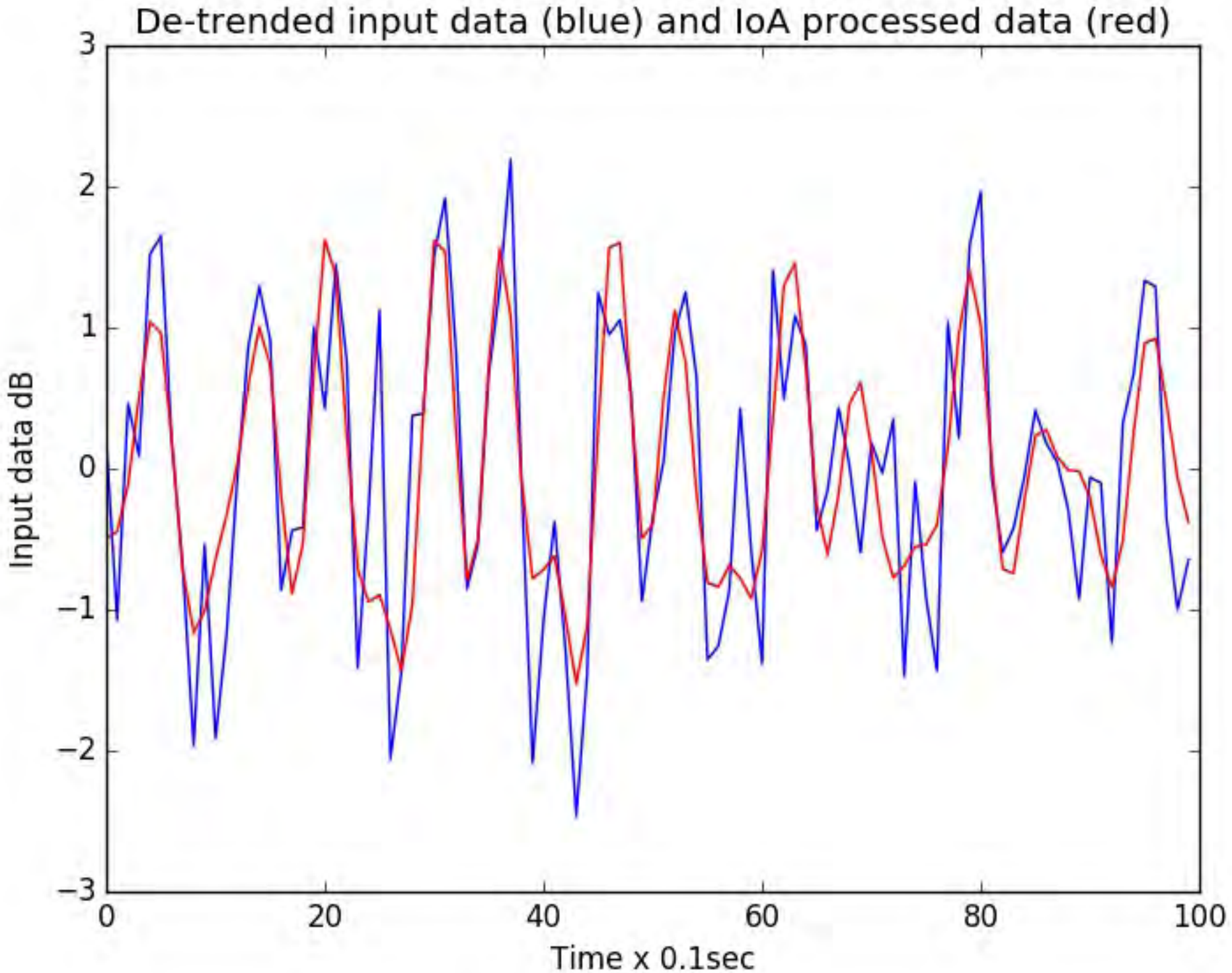

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
20
40
60
80
100

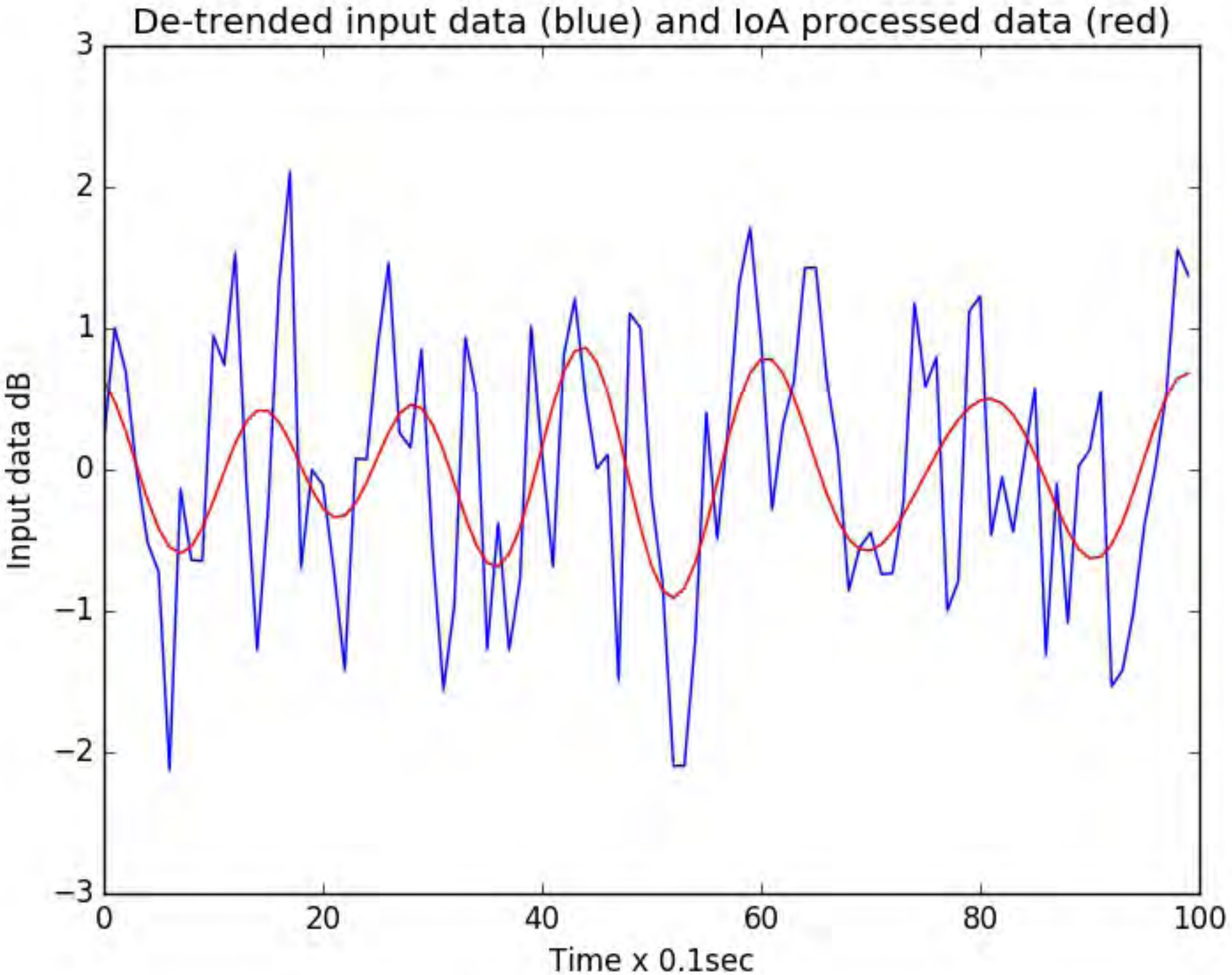

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
0
20
40
60
80
100

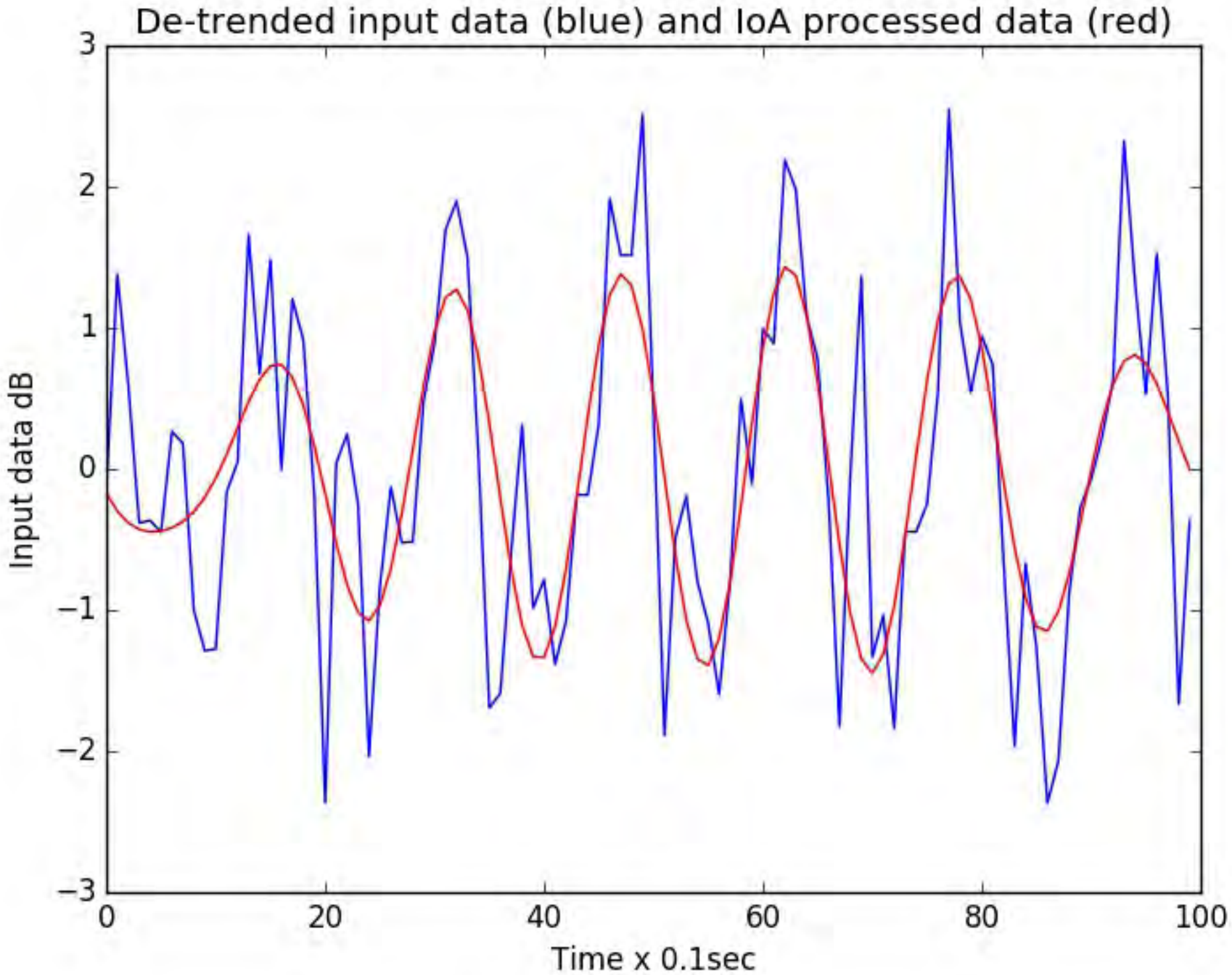

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

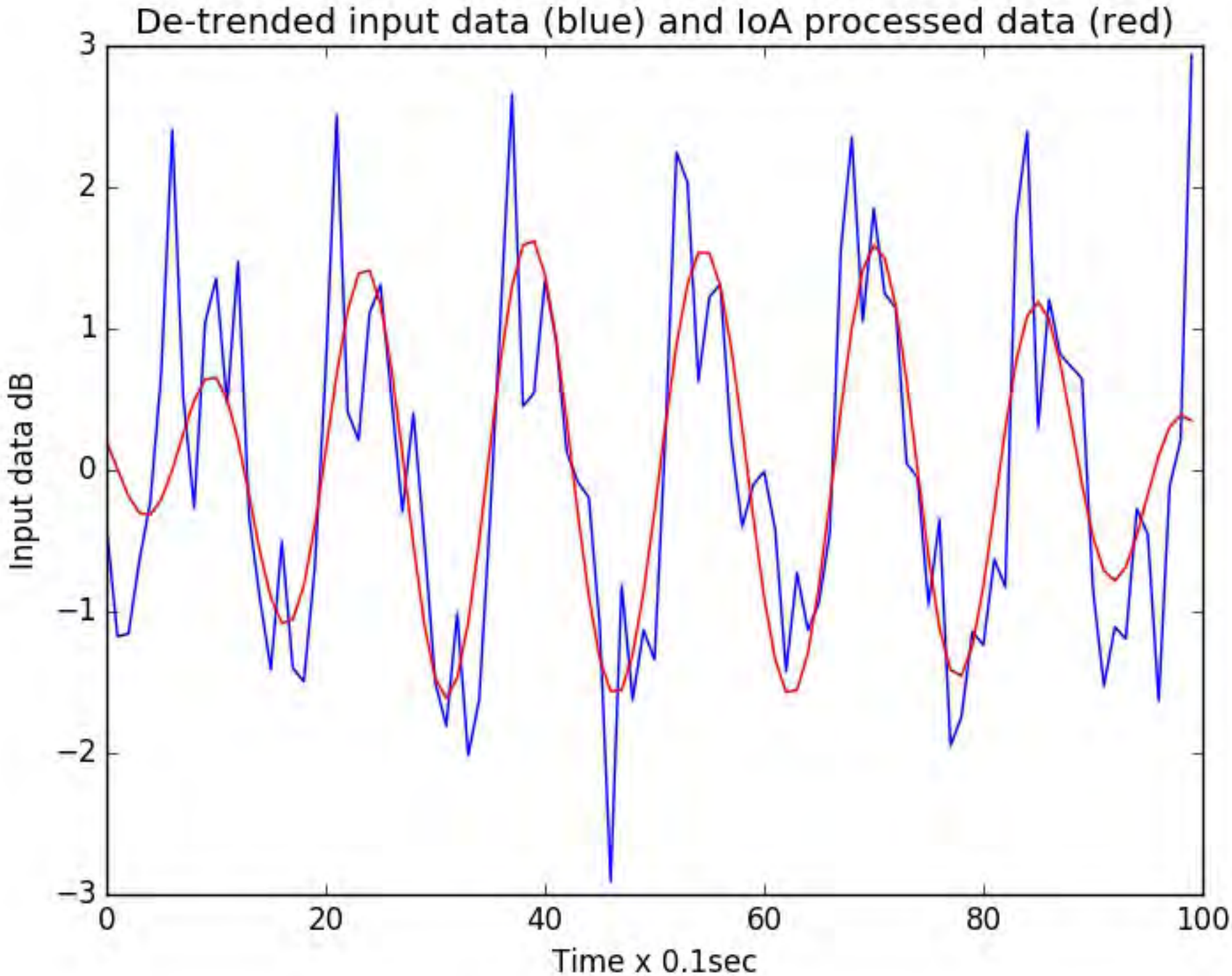

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

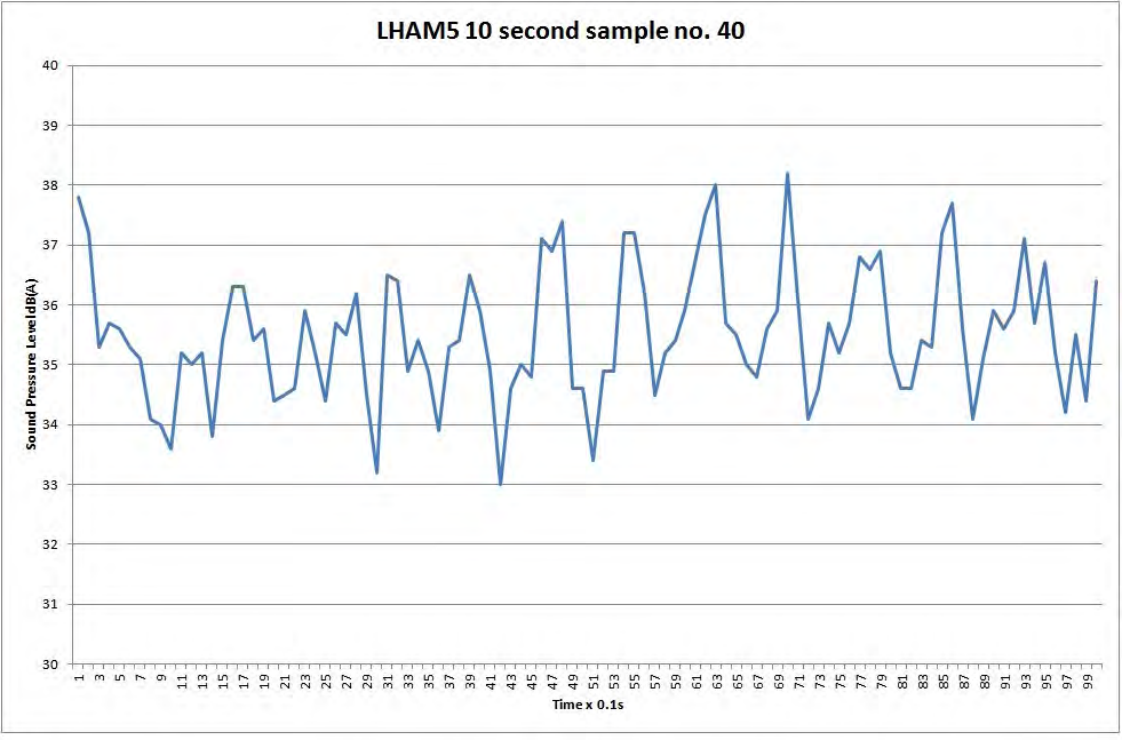

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

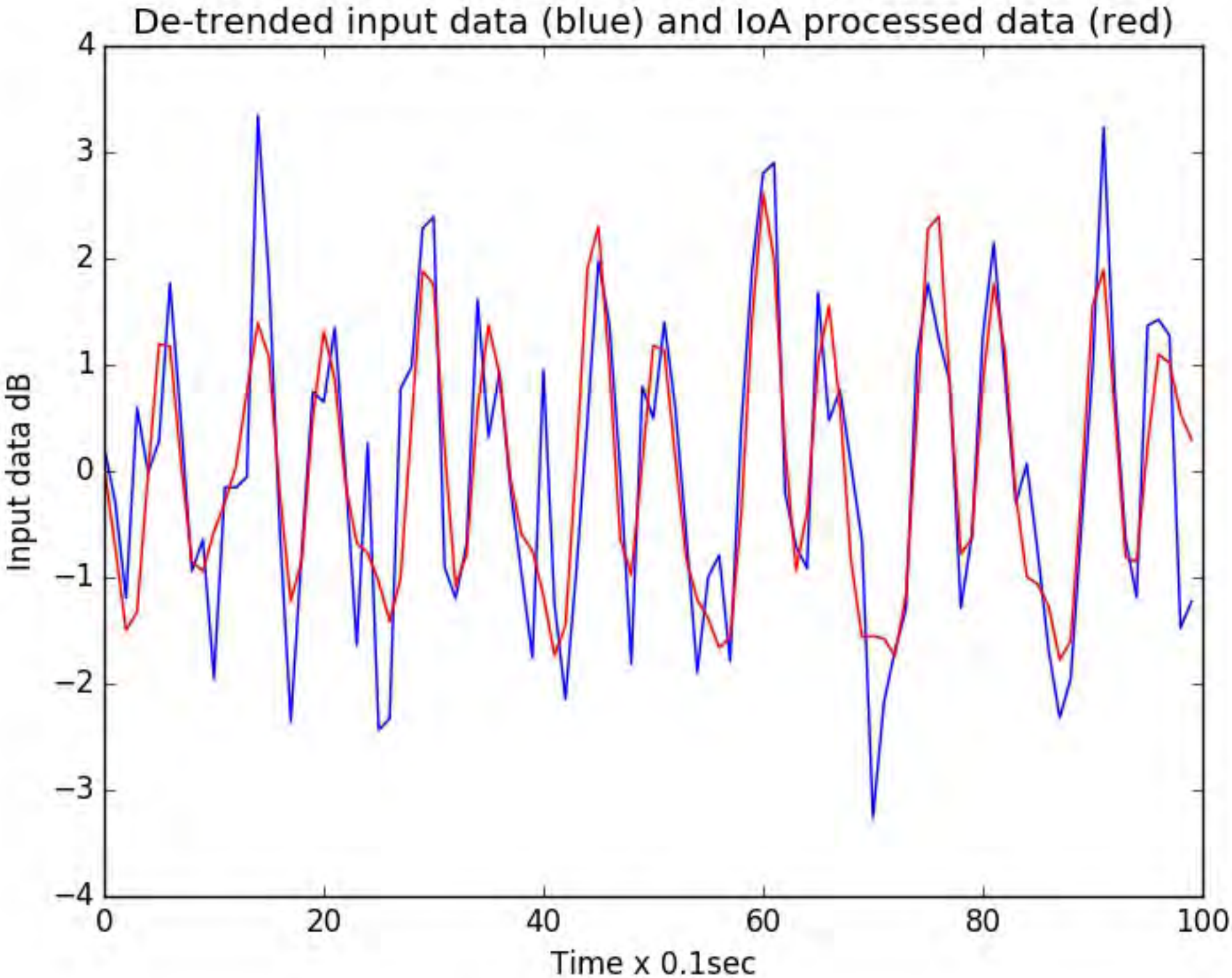

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

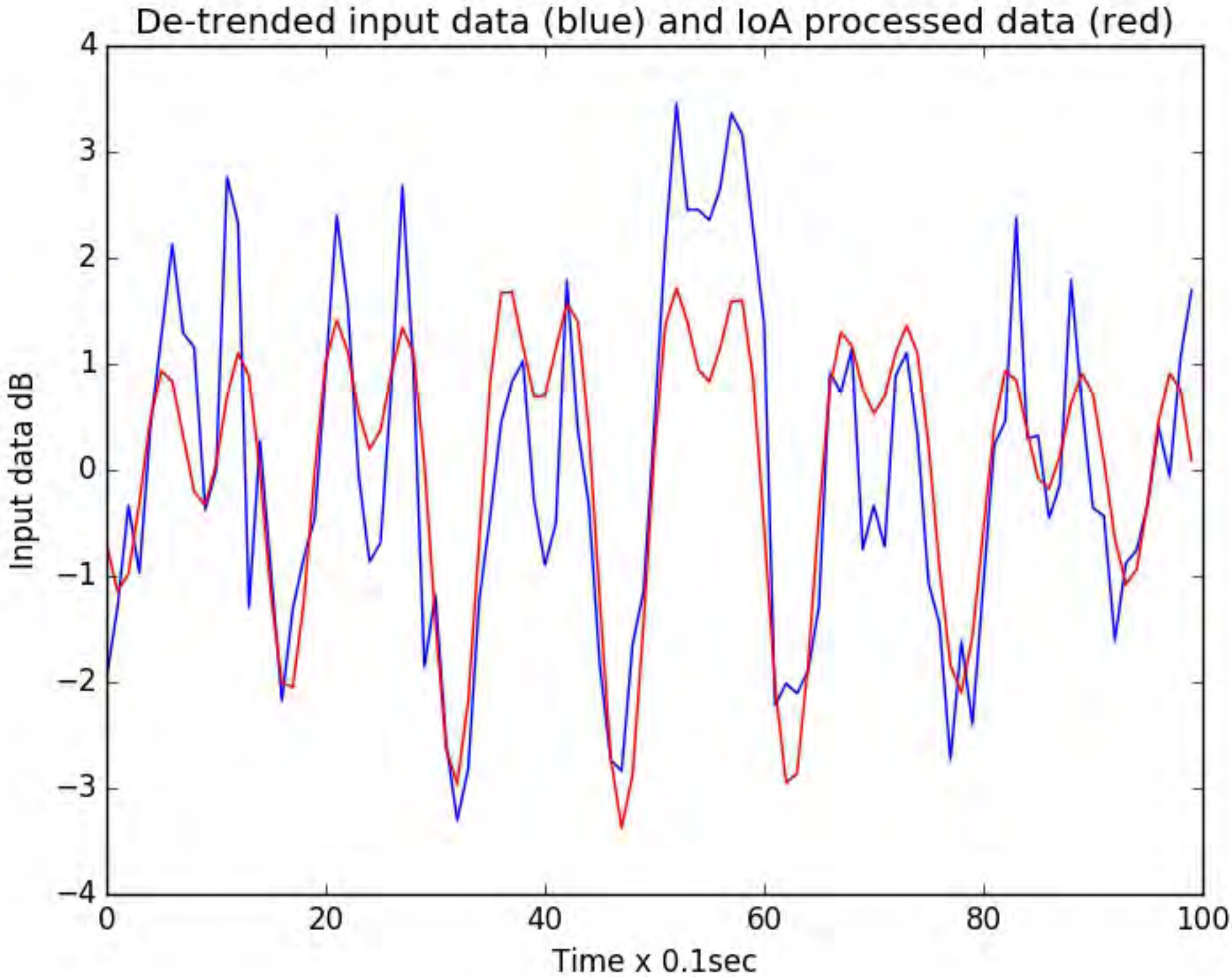

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

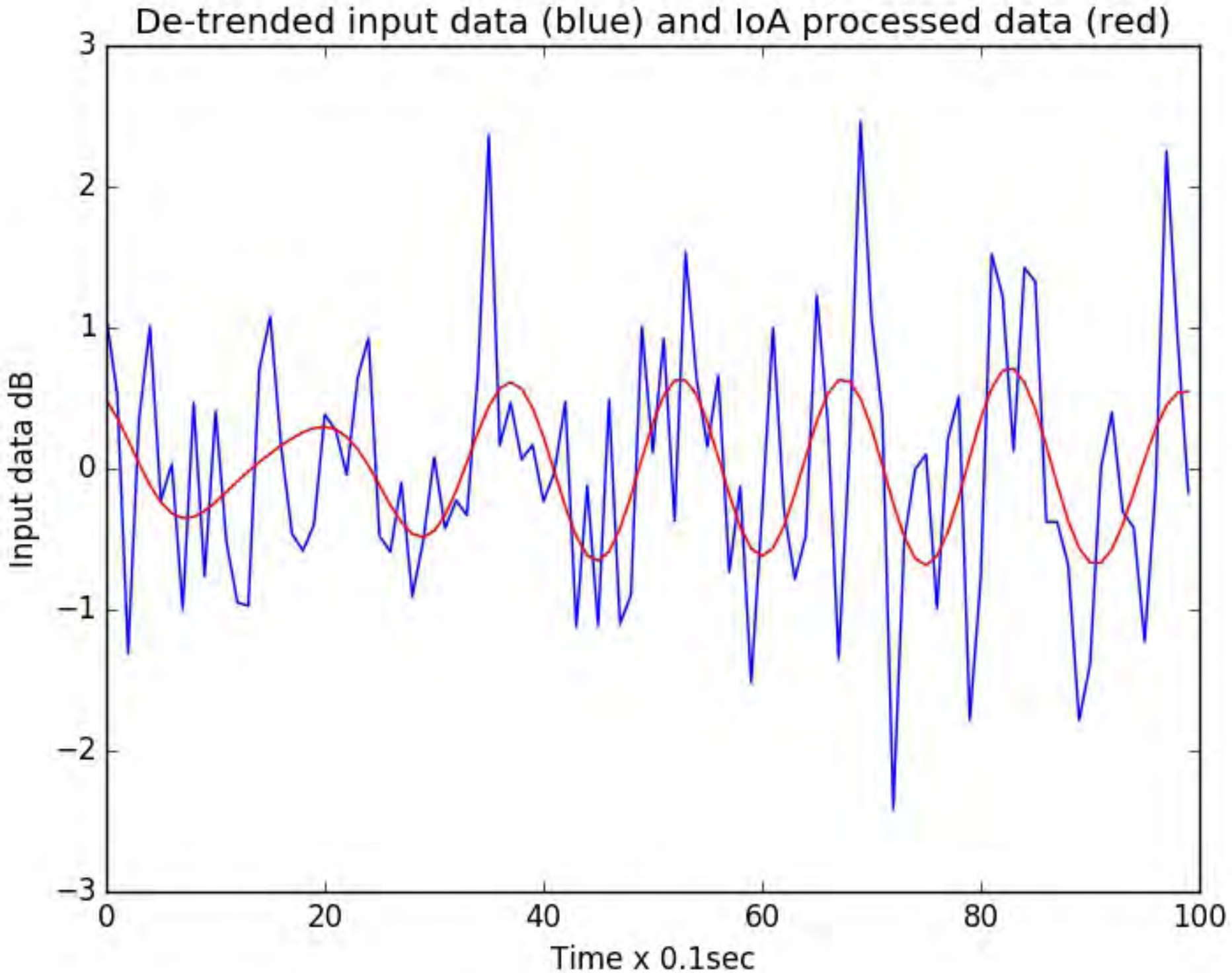

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

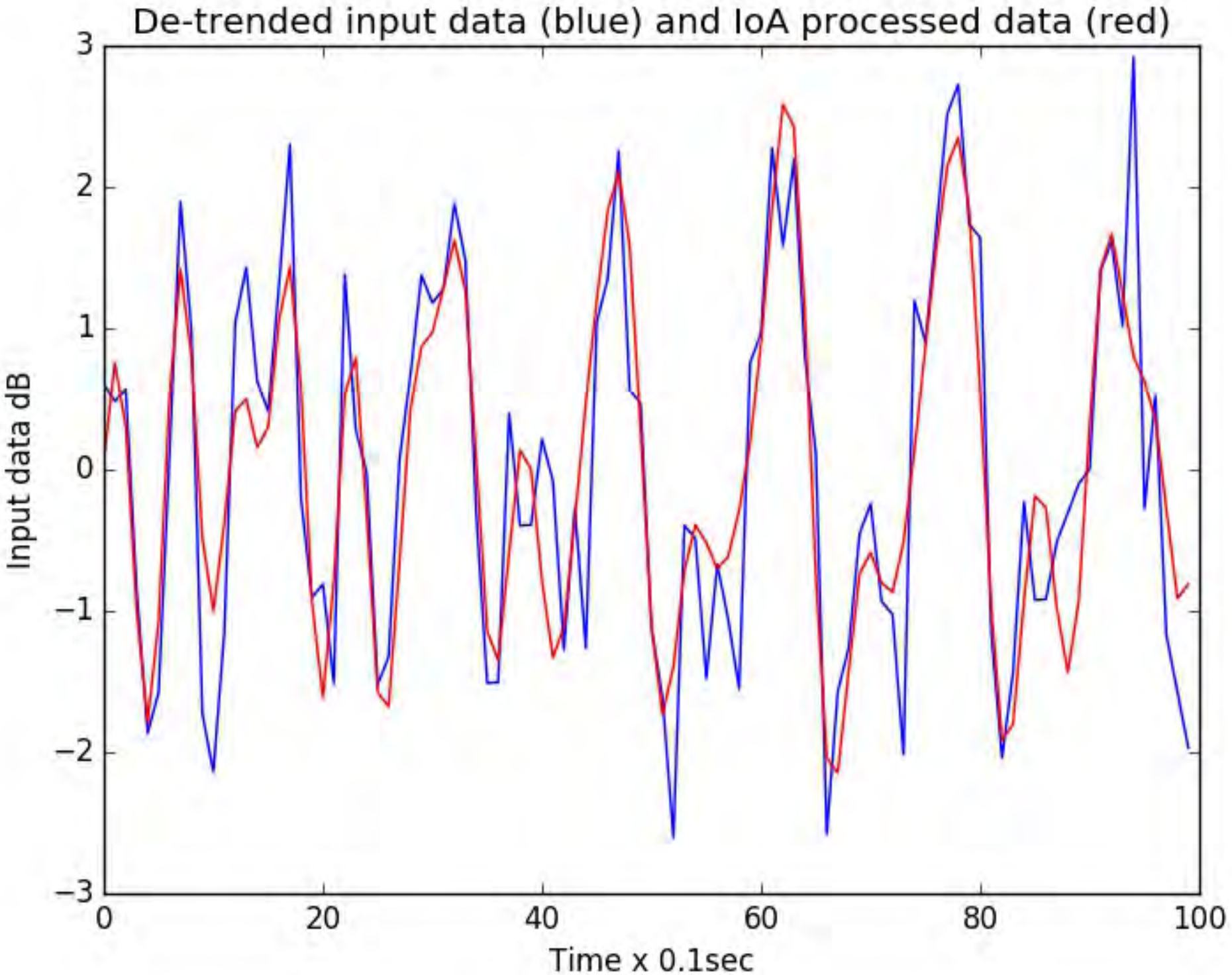

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

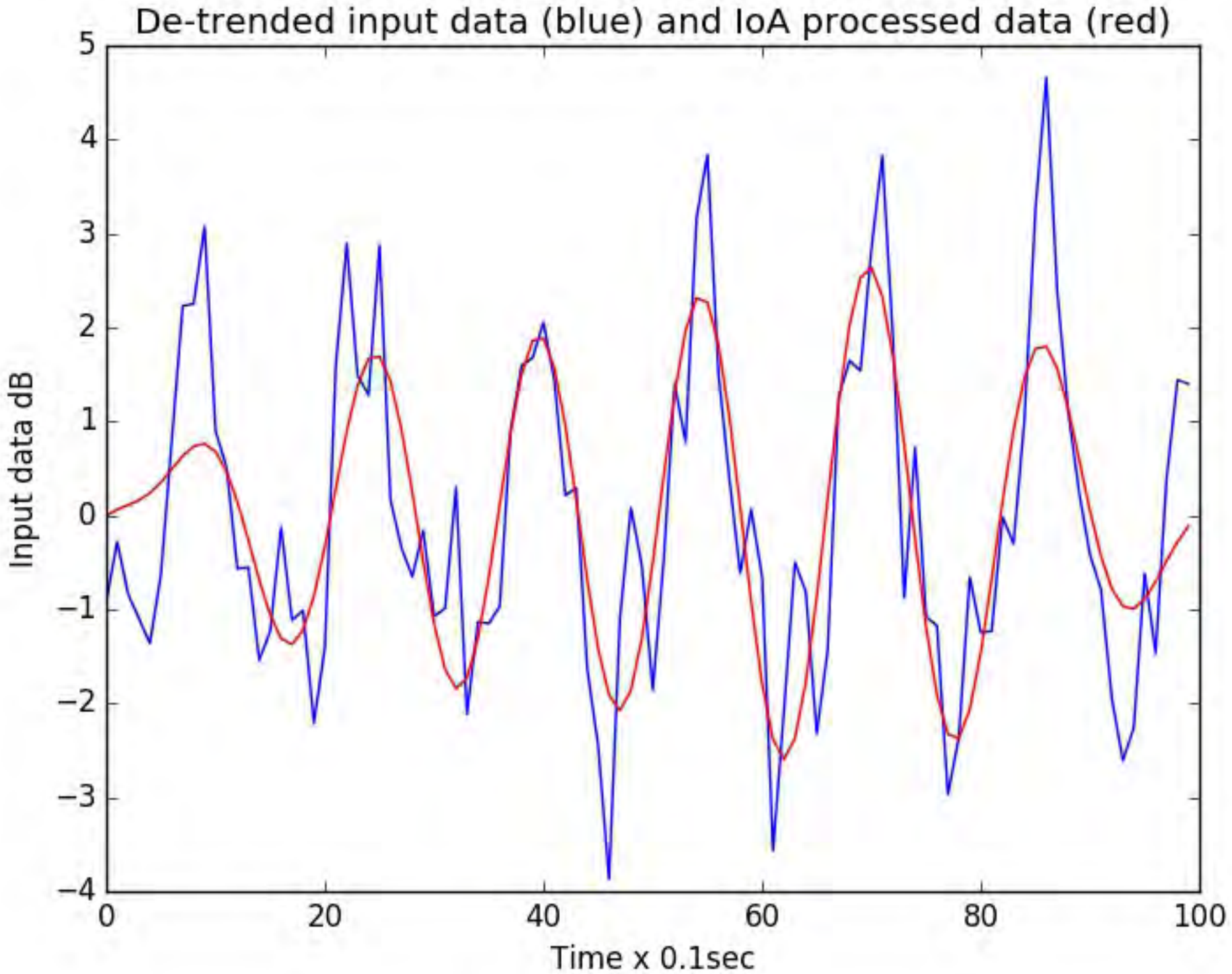

LHAM5 10 second sample no. 40
Sound Pressure LevelldB(A)
40
39
38
37
36
35
34
33
32
31
30
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Time x 0.1s

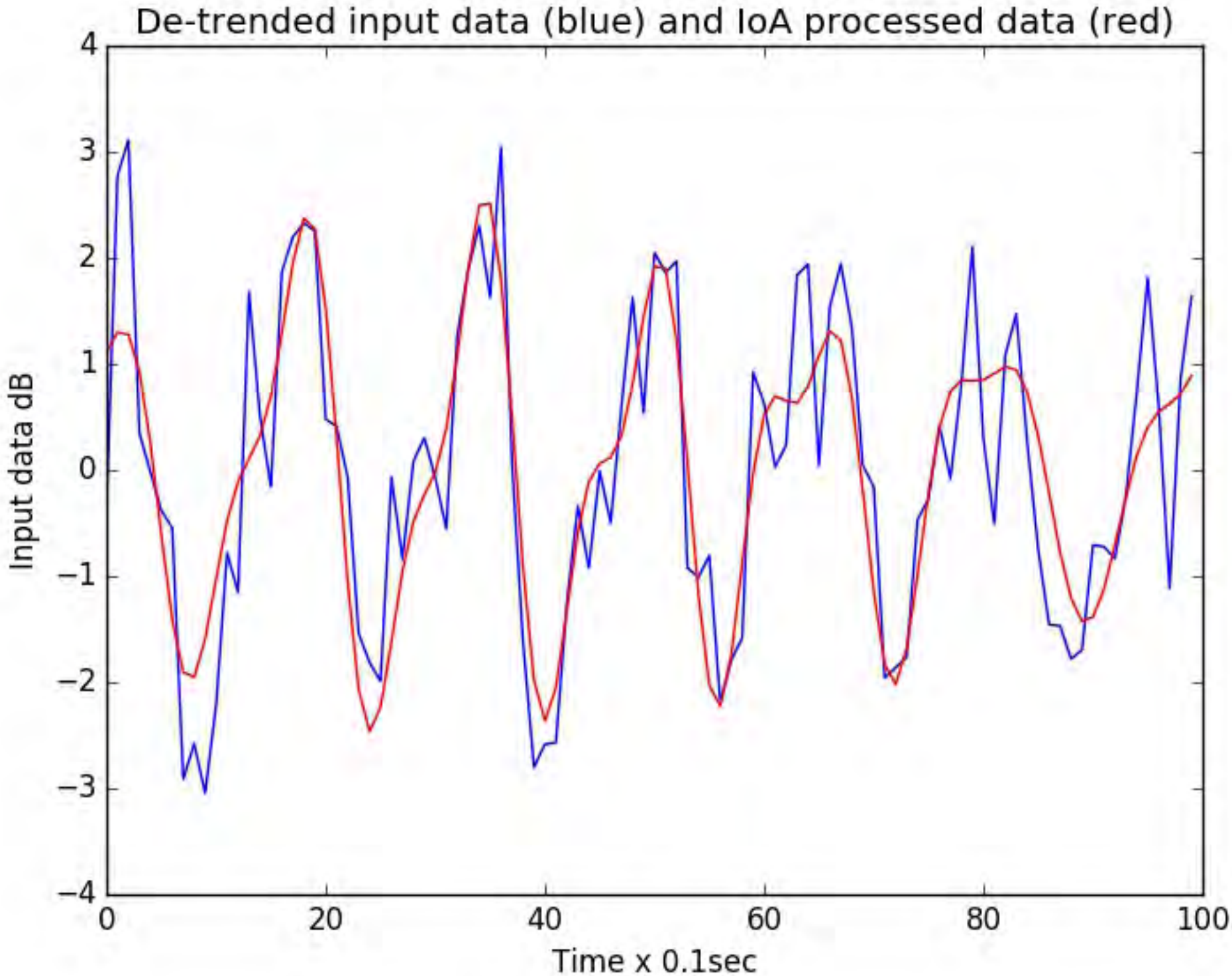

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

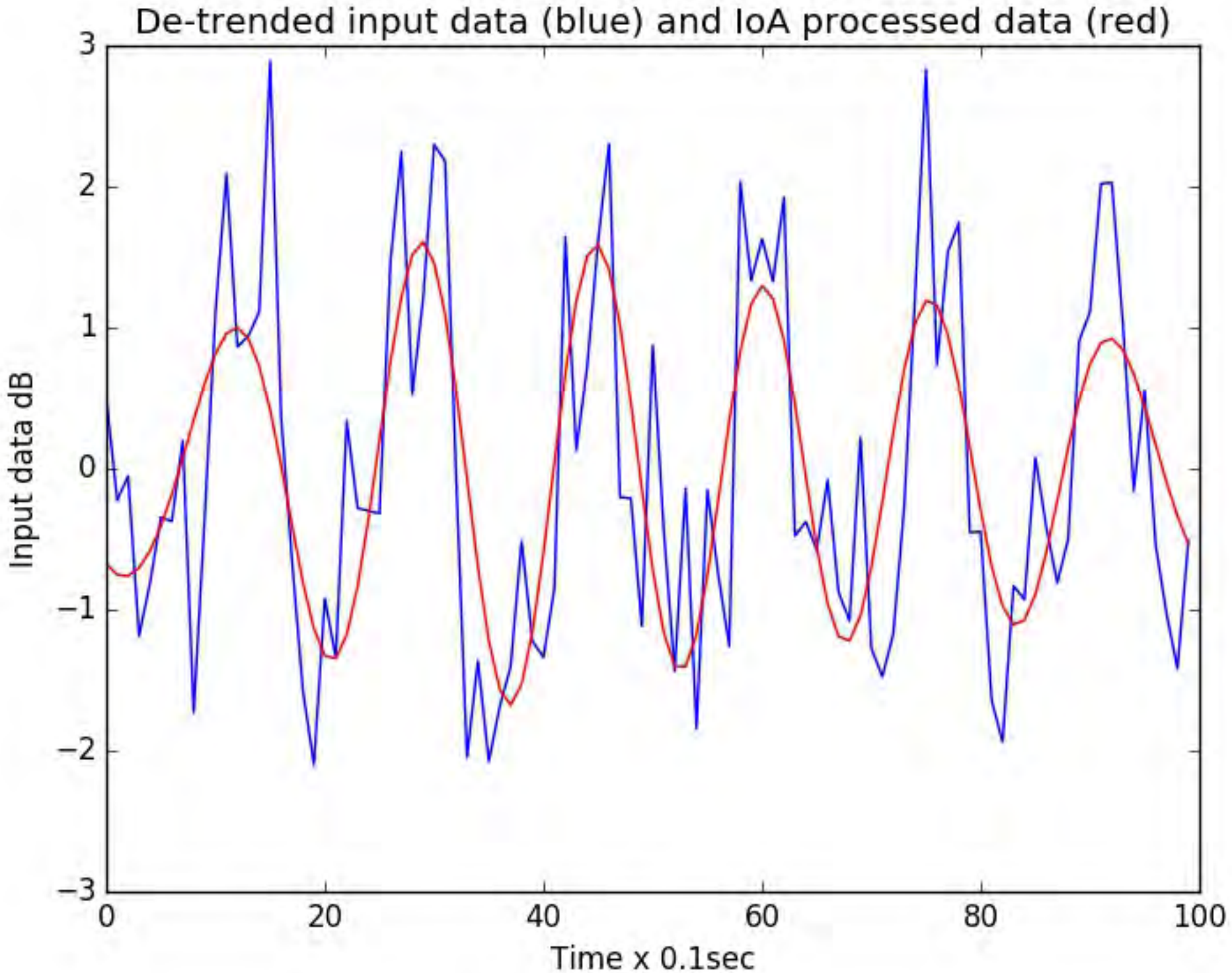

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

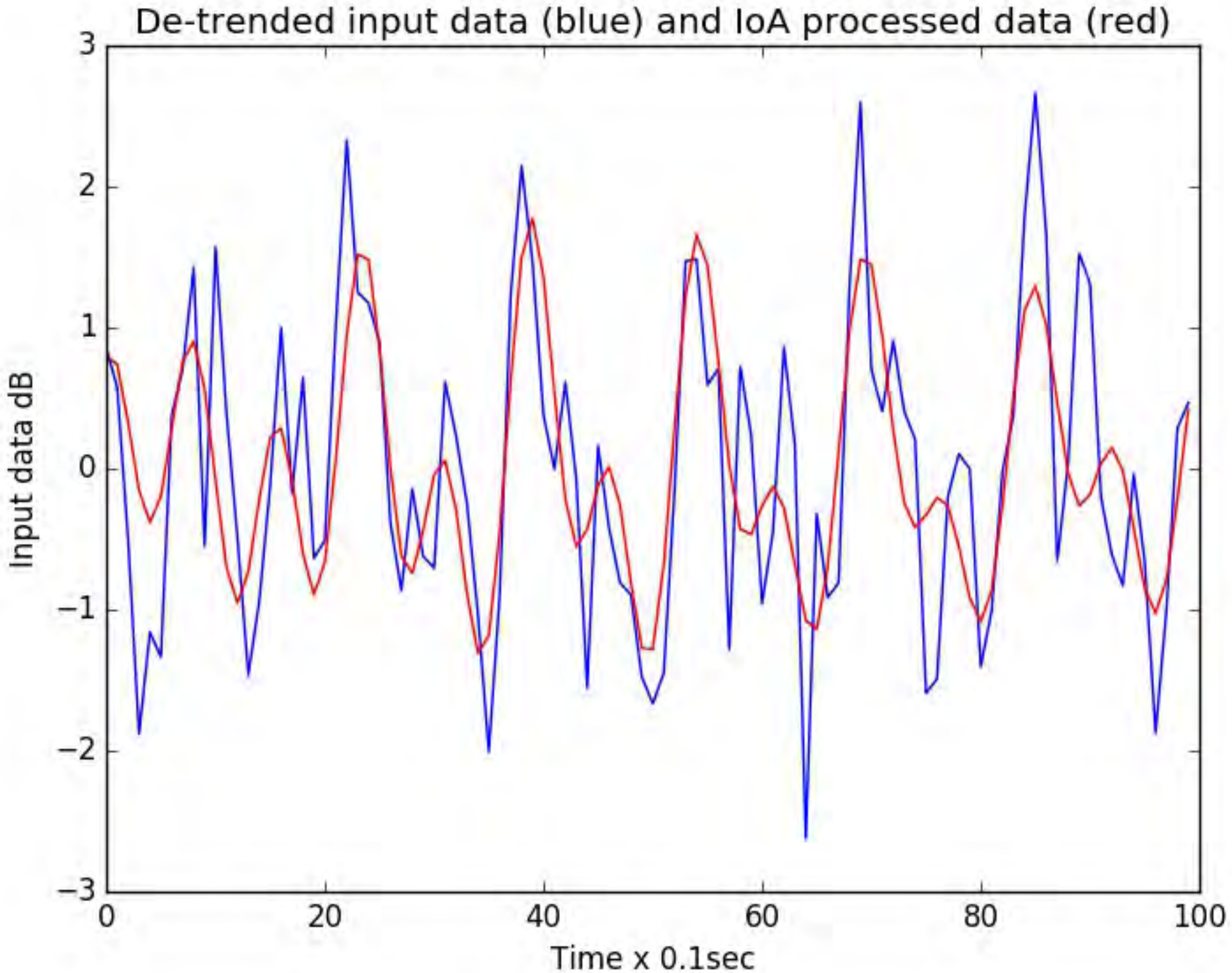

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

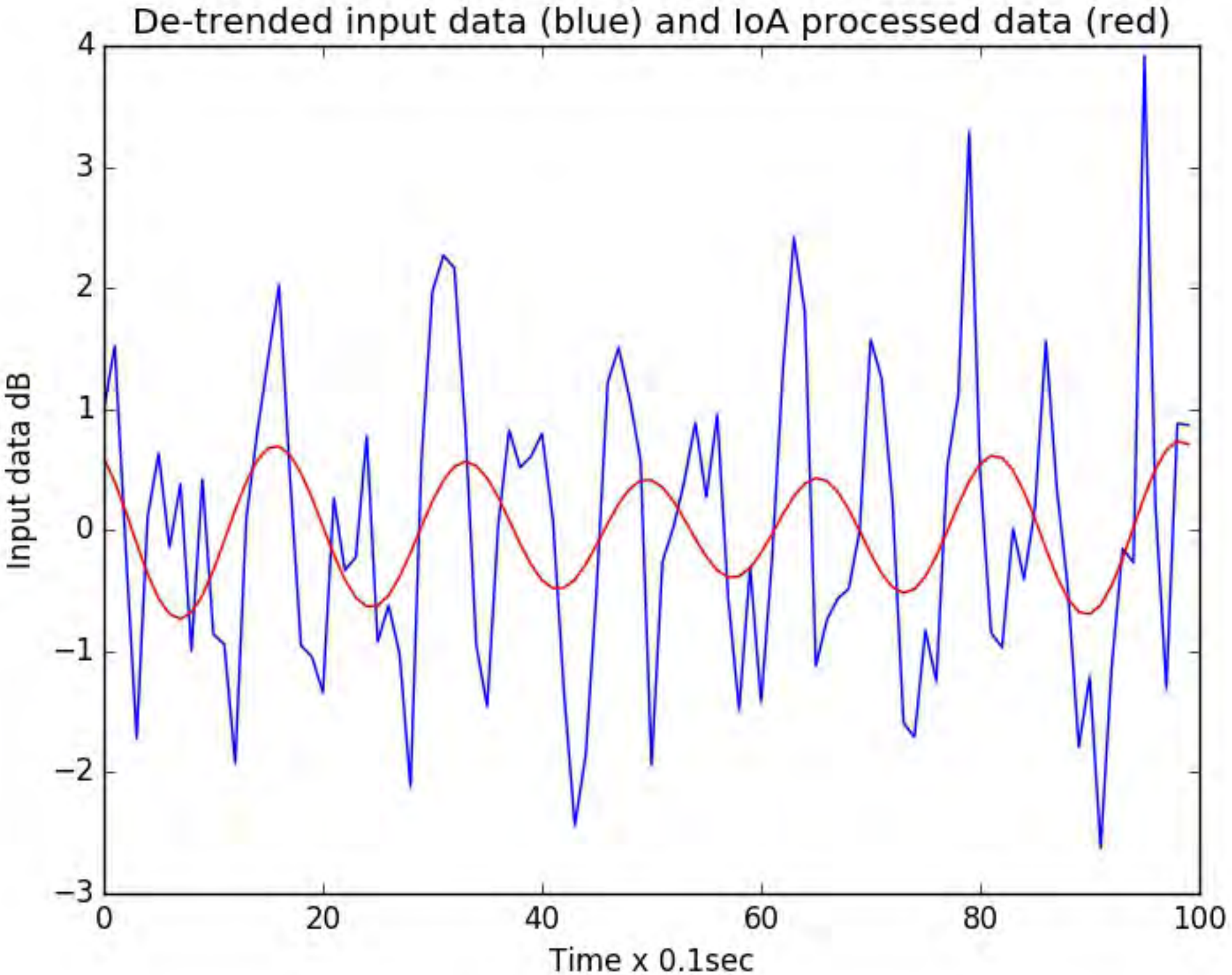

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

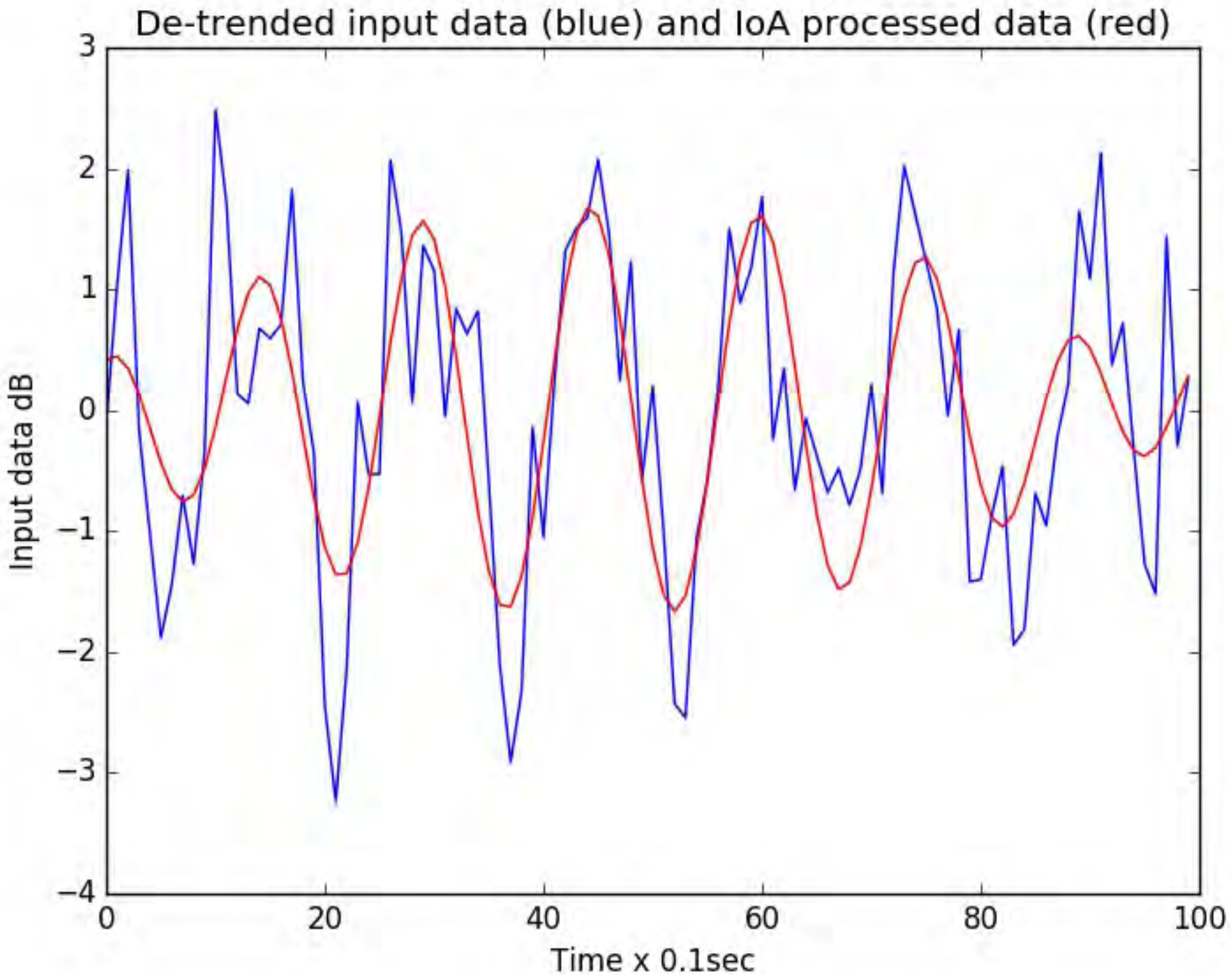

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

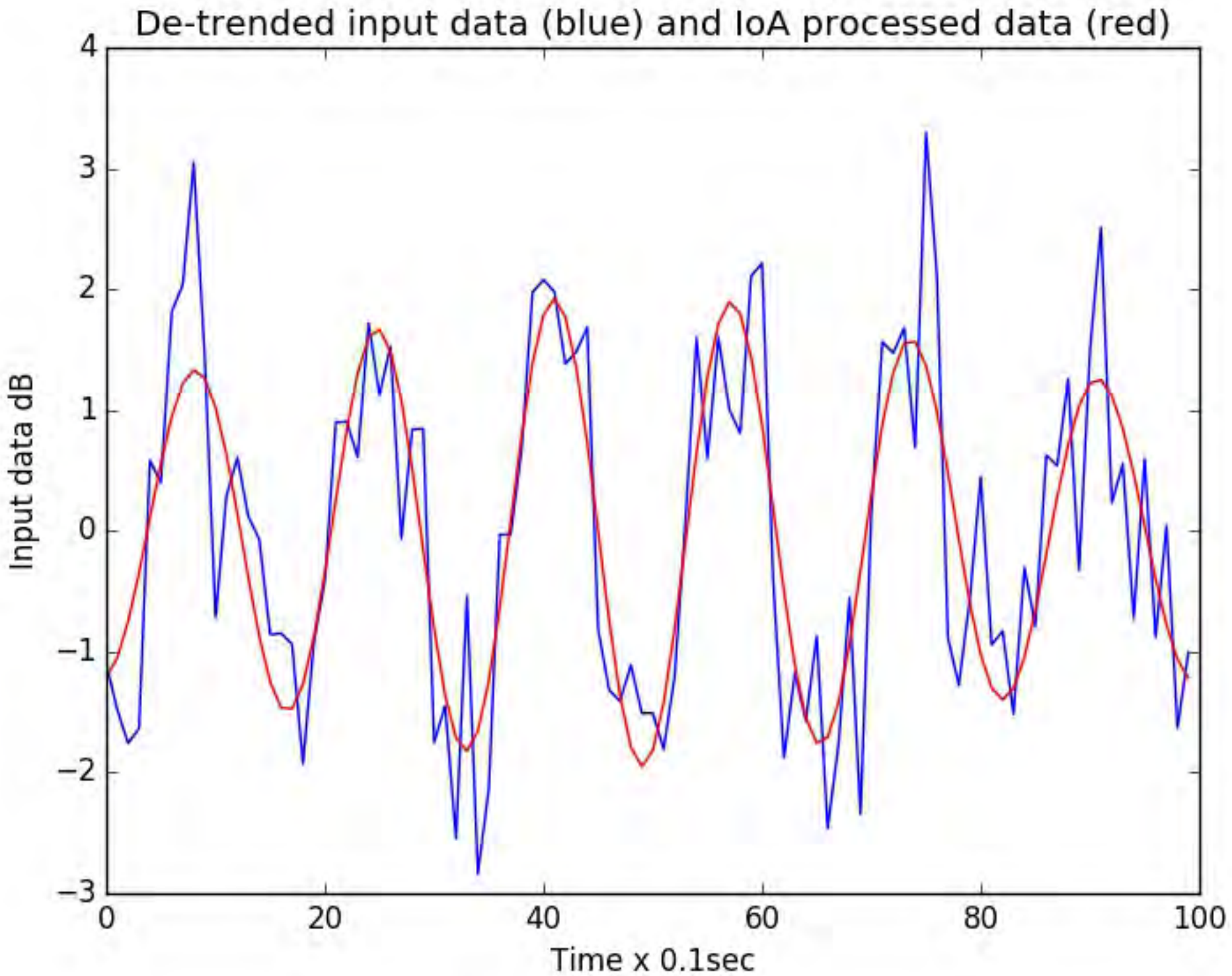

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

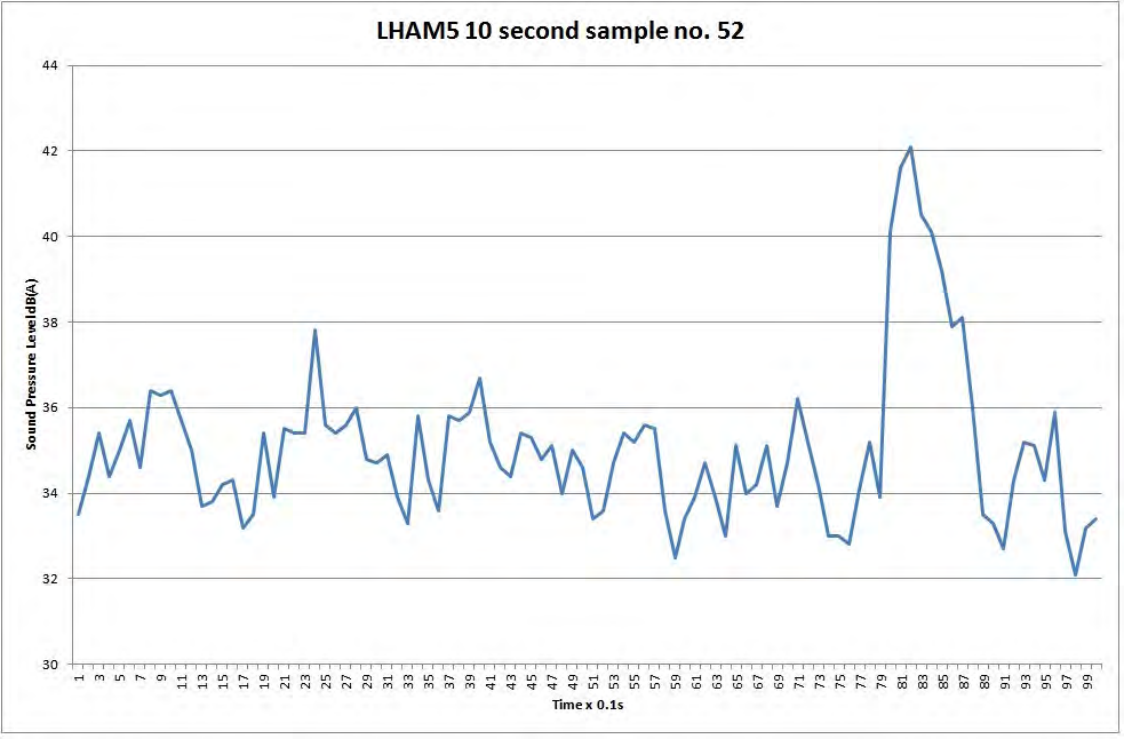

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

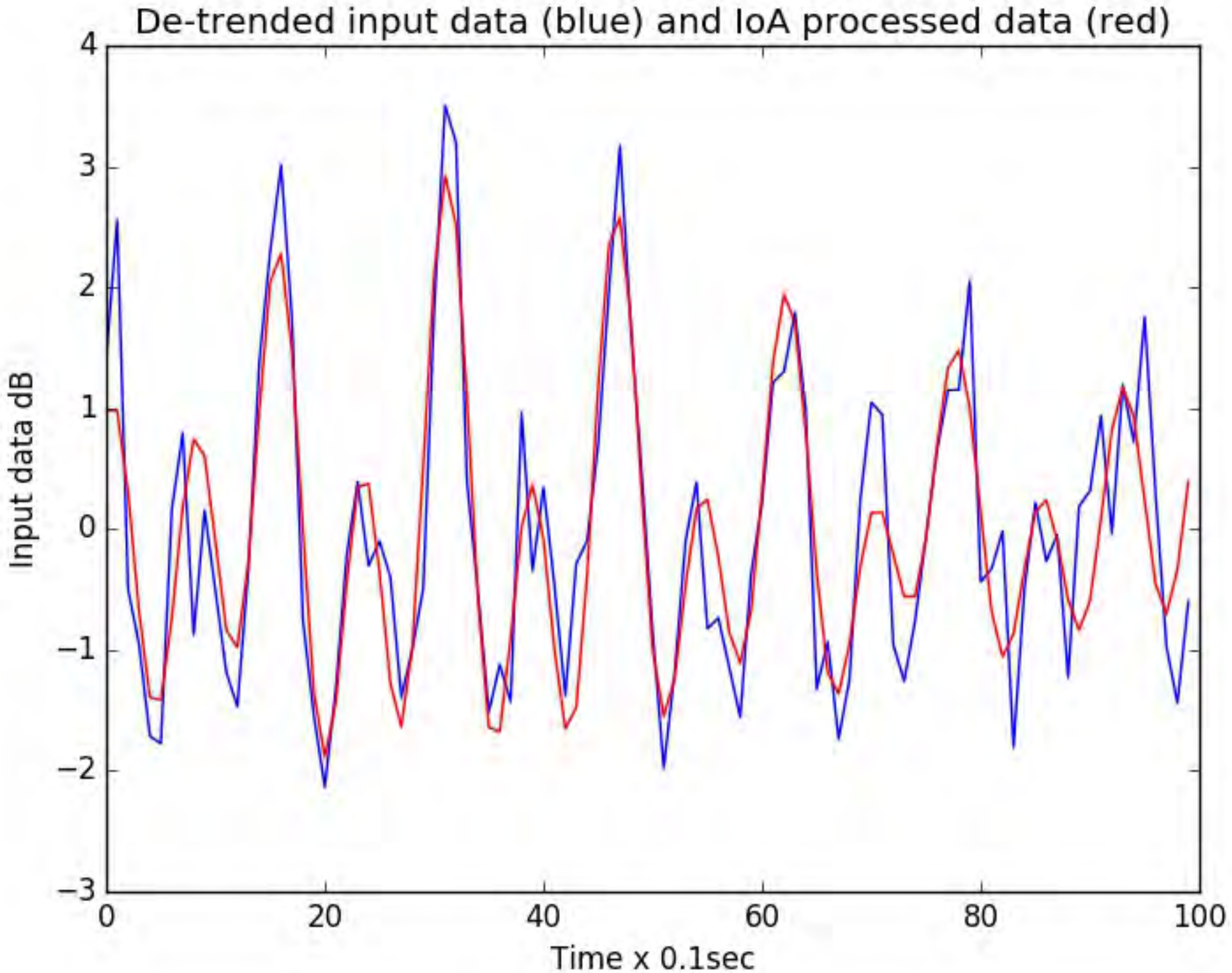

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

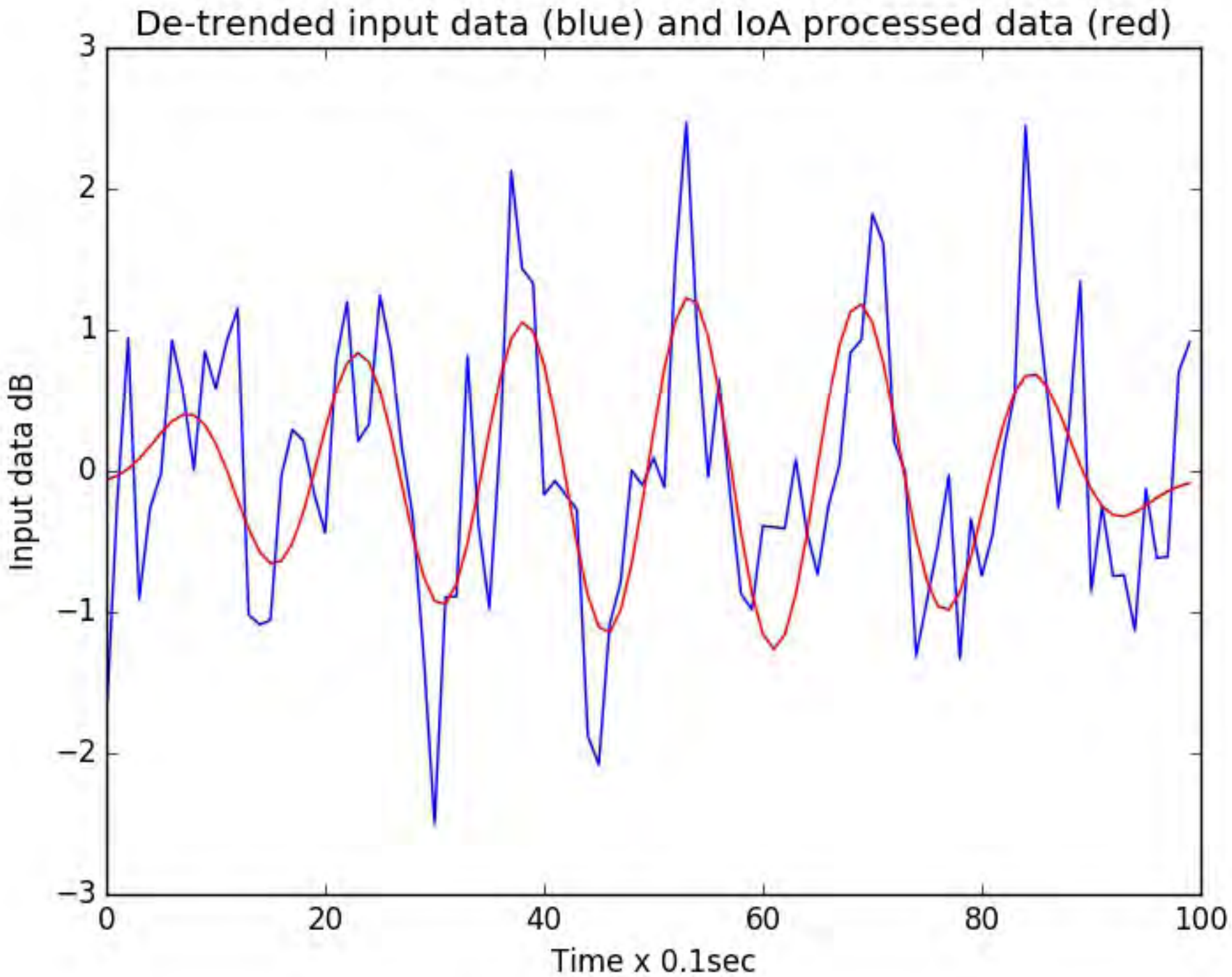

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

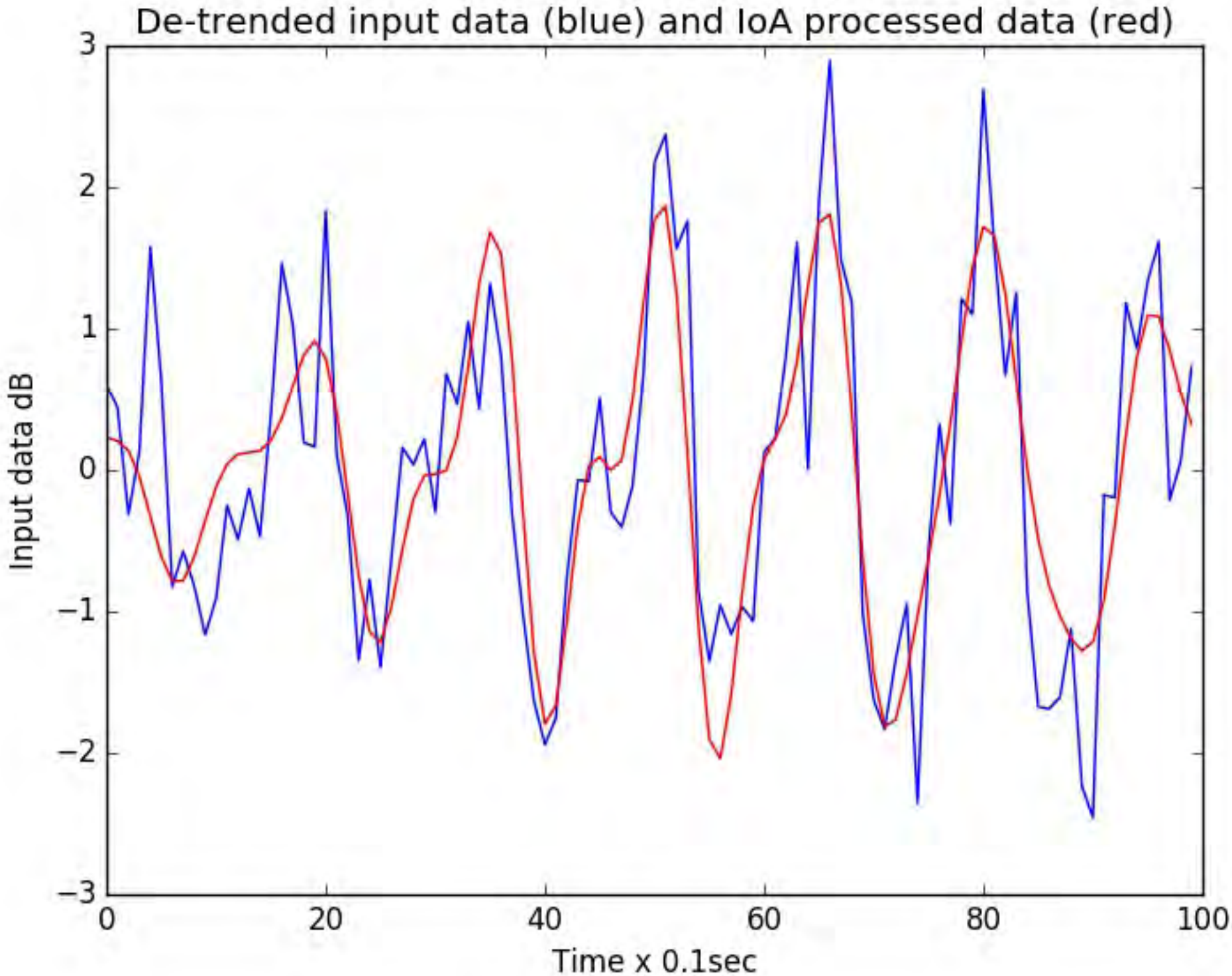

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

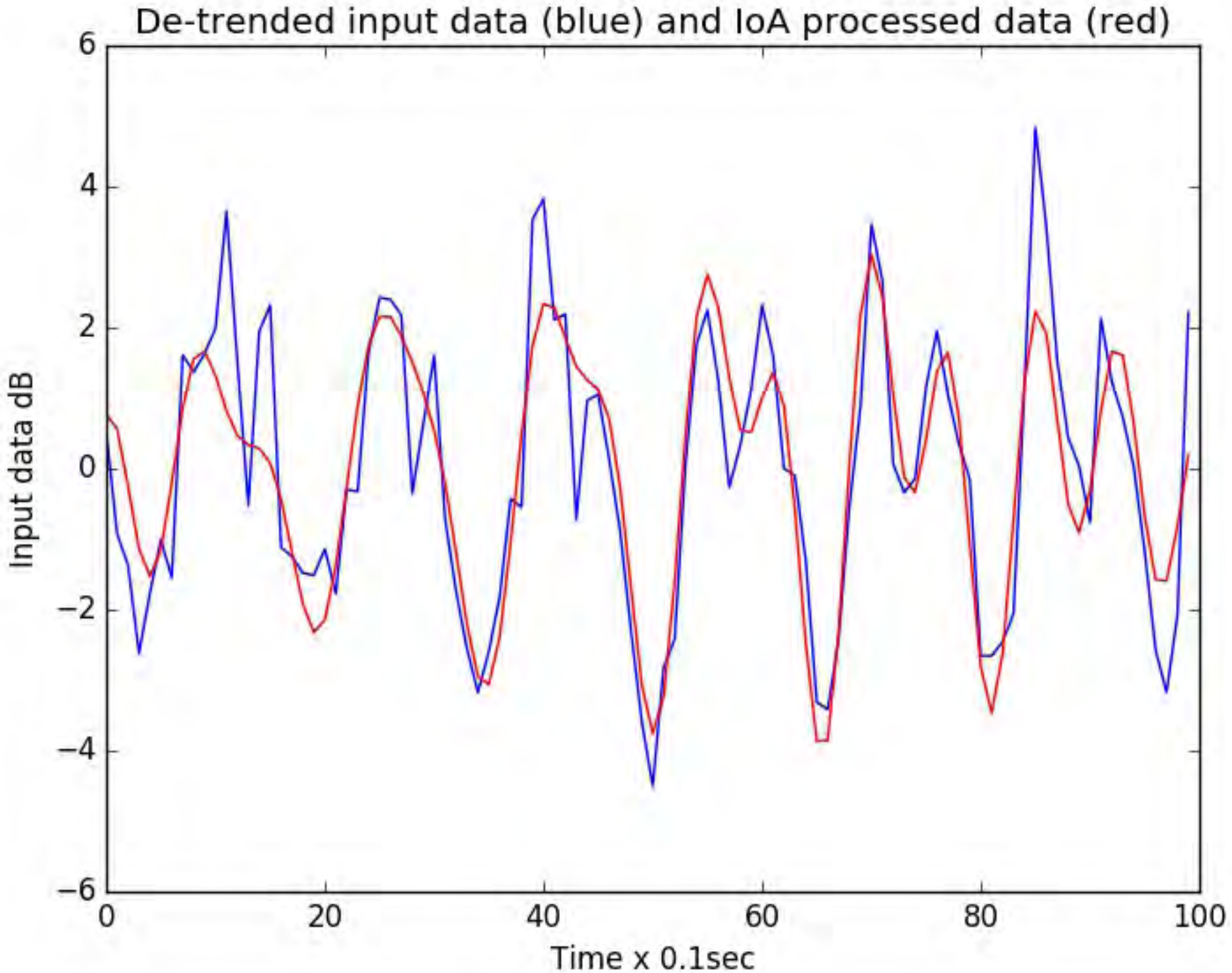

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

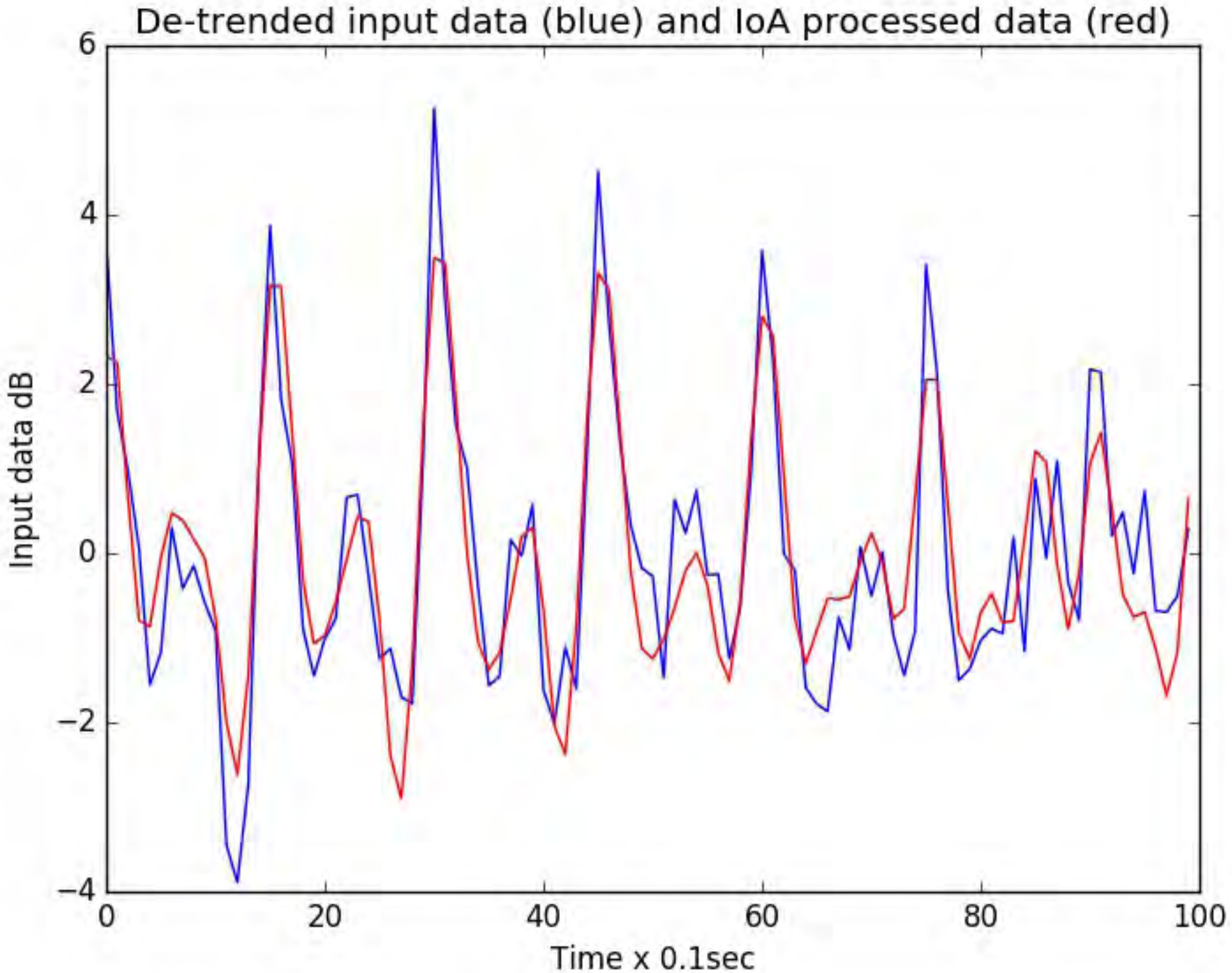

LHAM5 10 second sample no. 52
Sound Pressure LevelldB(A)
Time x 0.1s

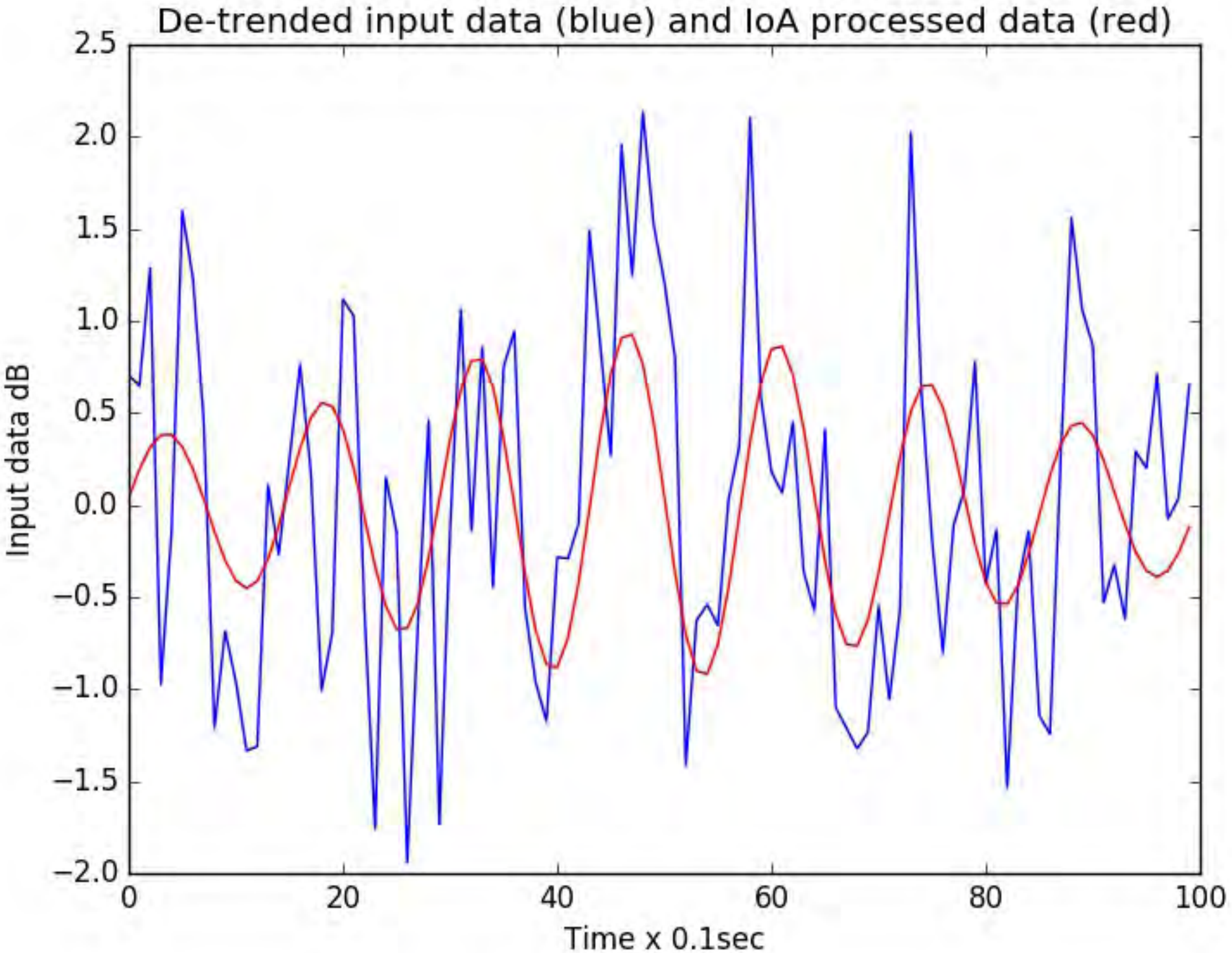

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

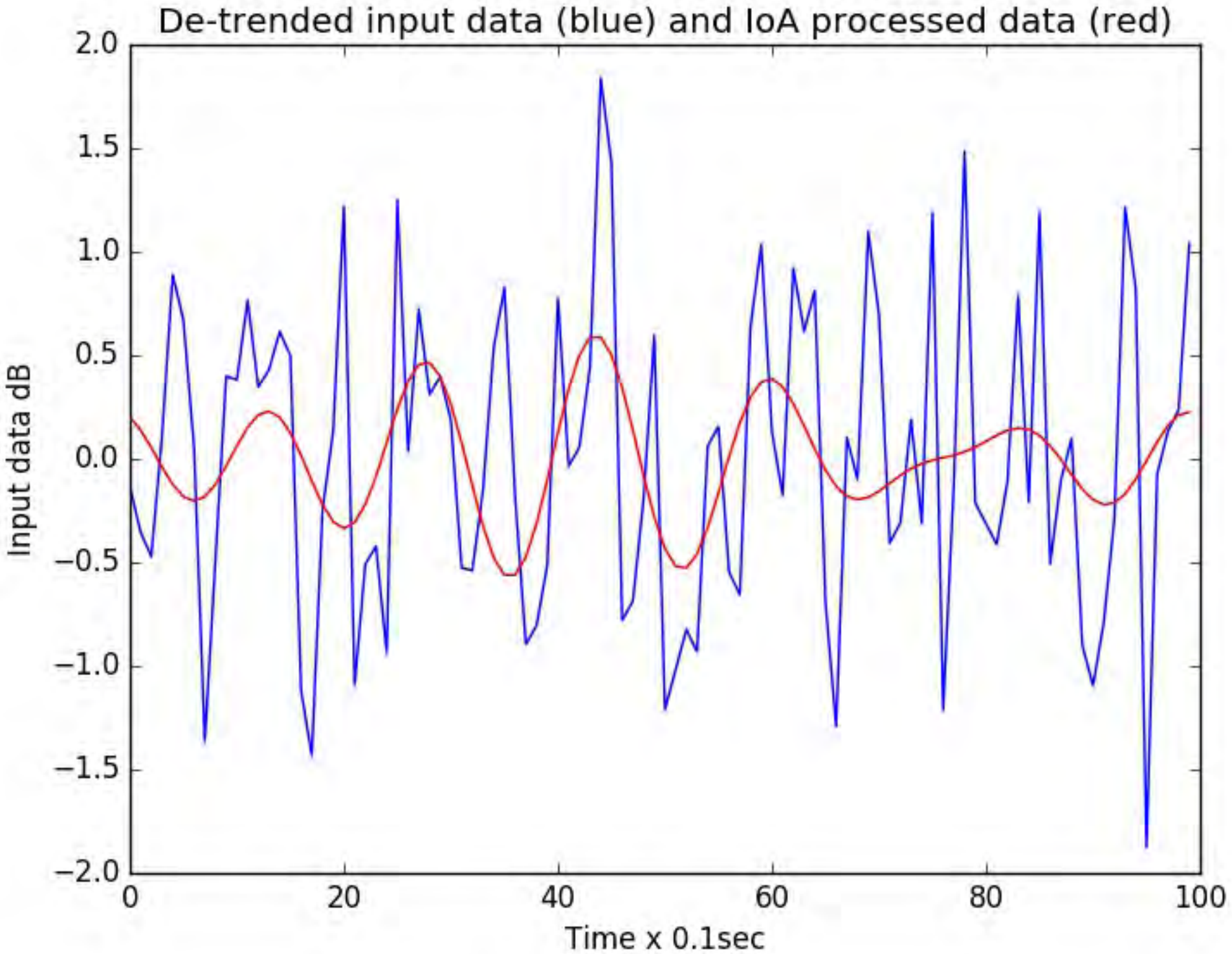

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

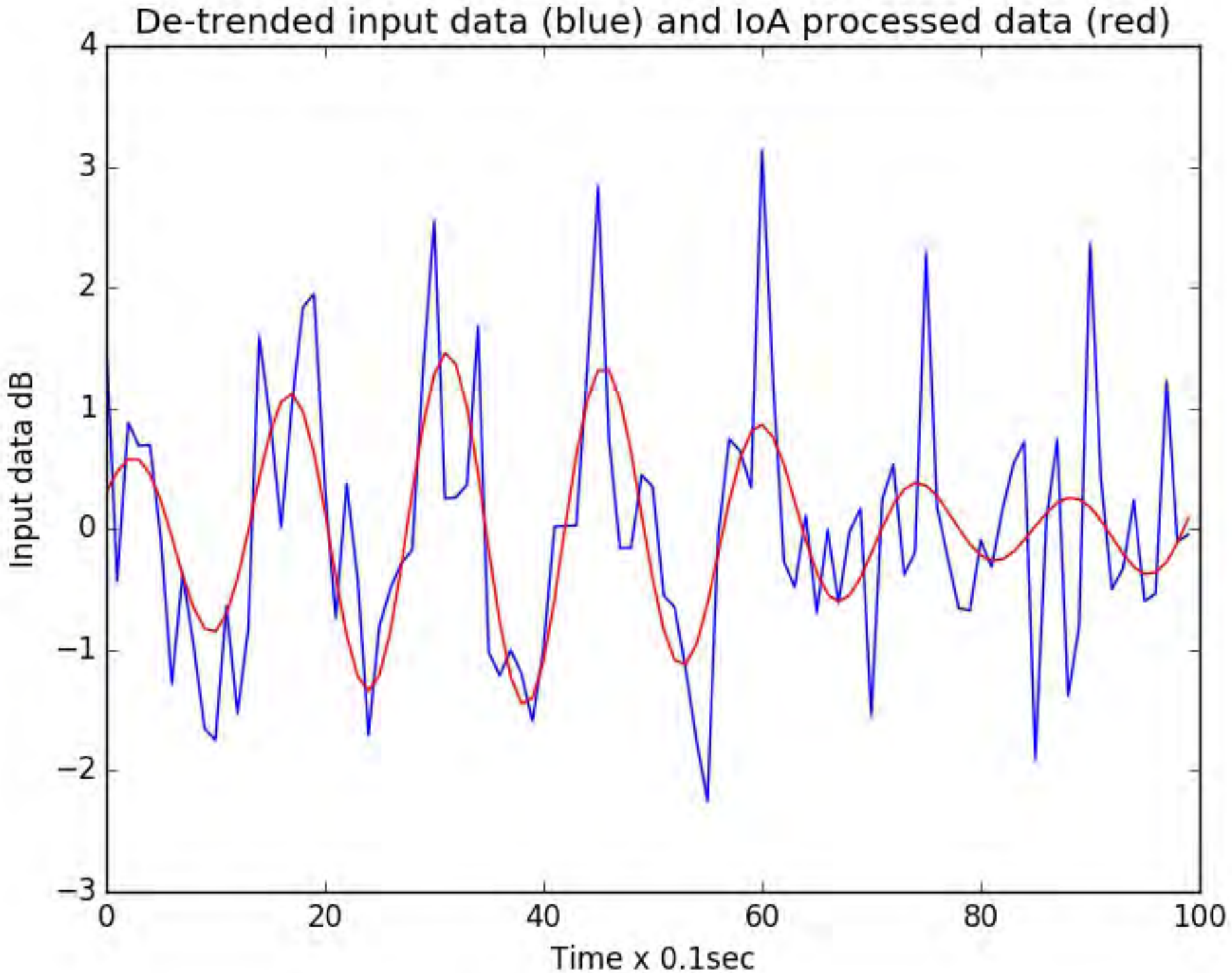

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
3
2
1
0
−1
−2
−3
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
20
40
60
80
100

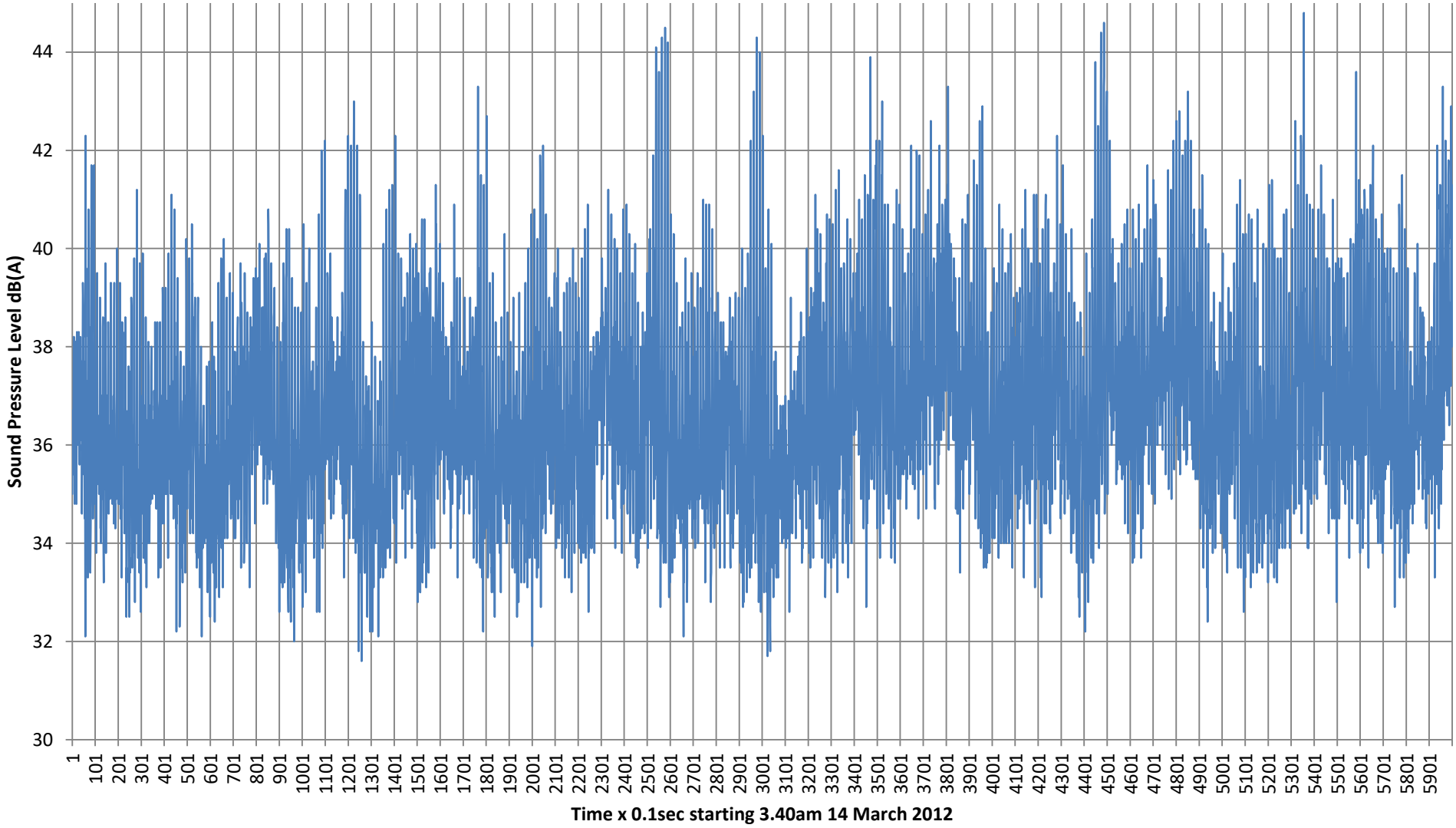

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

Input File name: LHAM5.txt
Frequency range for modulation frequency: 0.4 to 0.9 Hz
10 minute results
10 min Block No. 10 min AM Rating (dB)
10s results

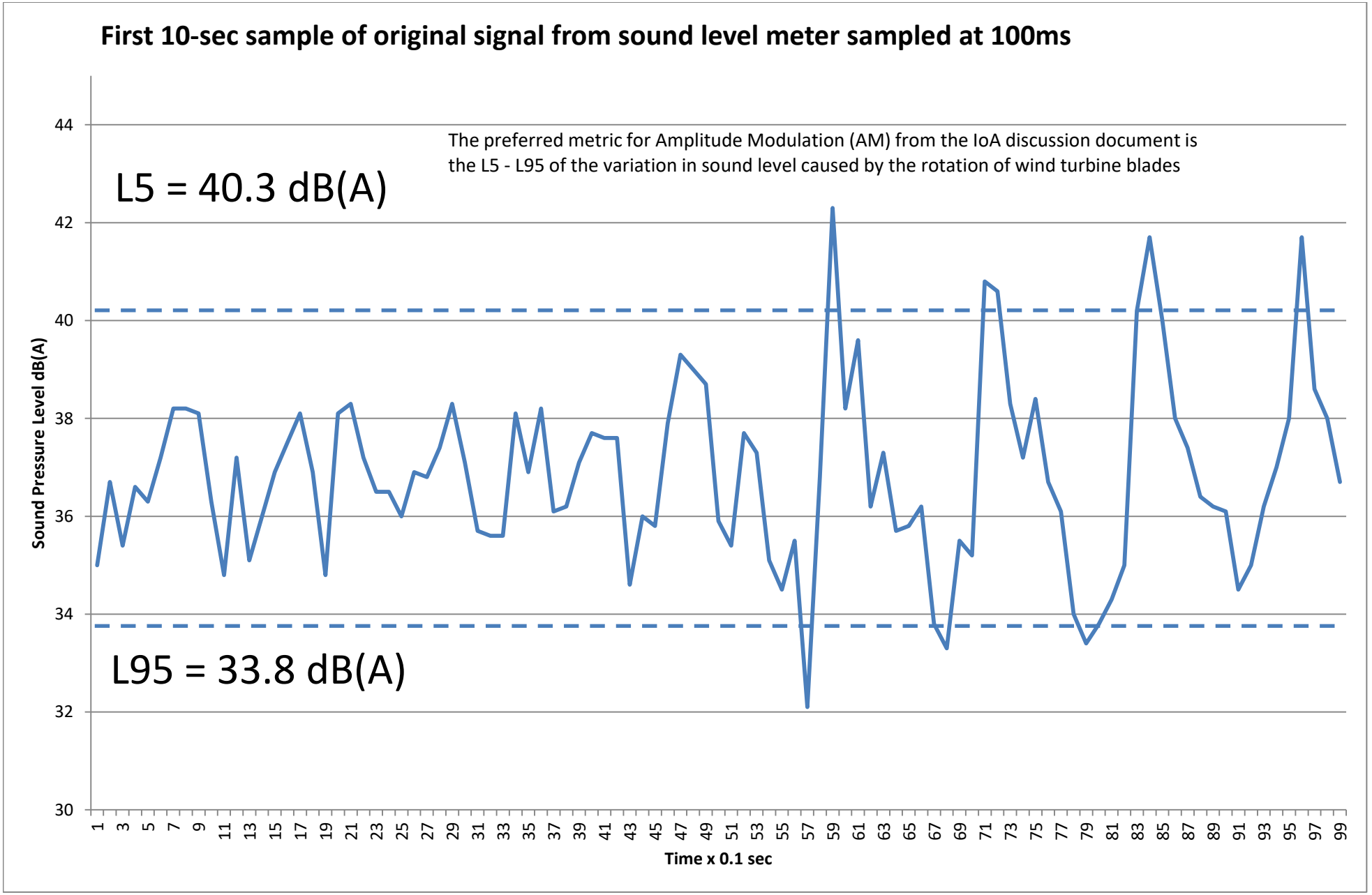
10 sec Block No.	Prominence	Fundamental Mod Freq (Hz)	10 sec AM rating (dB)	10 sec unprocessed AM (dB)
0	67.43	0.6	4.22	4.31
1	19.55	0.6	1.21	3.32
2	137.84	0.6	4.44	5.51
3	103.92	0.6	4.42	5.33
4	124.49	0.6	6.88	7.71
5	216.42	0.6	5.21	6.21
6	80.86	0.6	4.37	5.32
7	91.9	0.6	5.09	5.41
8	56.33	0.6	3.99	5.12
9	10.08	0.7	2.26	4.3
10	232.61	0.6	4.21	5.6
11	3.45			
12	95.71	0.6	4.48	5.11
13	79.45	0.6	4.79	5.61
14	496.3	0.6	5.35	5.82
15	30.27	0.6	3.78	4.51
16	110.28	0.6	5.19	5.61
17	319.64	0.6	5.54	6.42
18	146.81	0.6	5.81	6.21
19	85.48	0.6	5.55	5.81
20	141.11	0.6	5.04	5.61
21	334.76	0.6	4.5	5.8
22	323.46	0.6	4.31	5
23	84.19	0.6	4.72	5.71
24	65.13	0.6	3.74	4.2
25	42.61	0.6	2.99	4.31
26	782.65	0.6	4.08	5.11

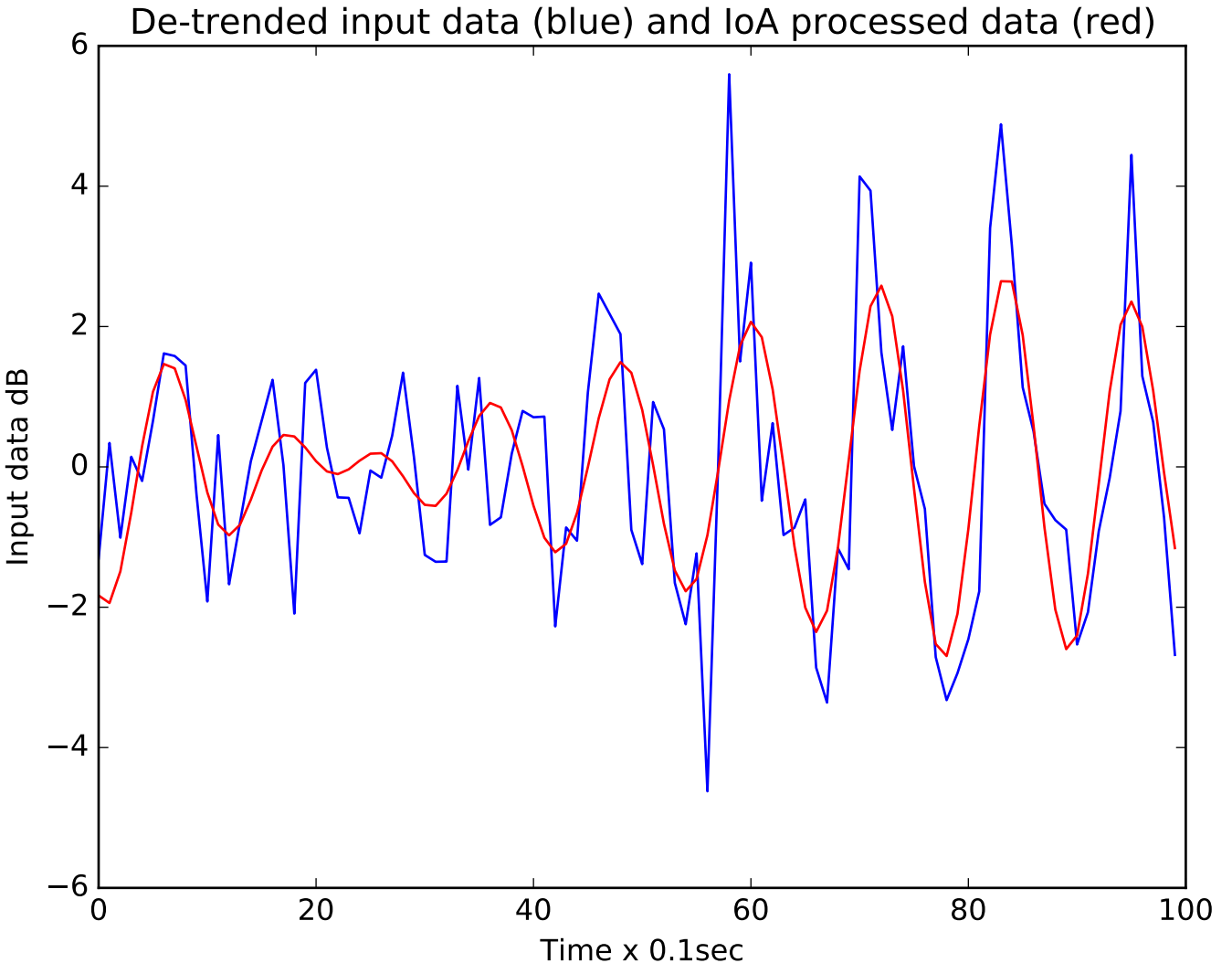
27	56.08	0.6	2.82	3.81
28	16.47	0.6	2.57	3.1
29	58.39	0.6	3	3.43
30	8.88	0.6	1.08	3.21
31	5.87	0.7	1.19	3.1
32	32.69	0.6	2.9	4.2
33	23.42	0.6	2.54	3.01
34	12.27	0.6	2.18	3
35	10.38	0.6	2.59	3.6
36	7.33	0.6	1.36	3.01
37	20.99	0.6	2.63	3.8
38	33.45	0.7	2.98	4.1
39	3.12			
40	11.27	0.6	3.48	4.51
41	8.9	0.6	4.29	5.21
42	26.44	0.6	1.24	2.81
43	33.37	0.6	3.59	4.31
44	14.94	0.6	4.12	5.71
45	35.01	0.6	3.97	4.91
46	21.06	0.6	2.77	4.01
47	11.14	0.6	2.57	3.91
48	14.25	0.6	1.25	3.91
49	14.63	0.7	2.95	4.3
50	93.21	0.6	3.43	4.2
51	2.55			
52	33.02	0.6	3.67	3.93
53	16.81	0.6	2.05	2.8
54	16.94	0.6	3.35	3.81
55	17.62	0.6	5.36	6.04
56	65.49	0.7	5.11	5.31
57	23.52	0.7	1.54	3.11
58	5.88	0.6	0.93	2.51
59	26.46	0.7	2.34	3.62

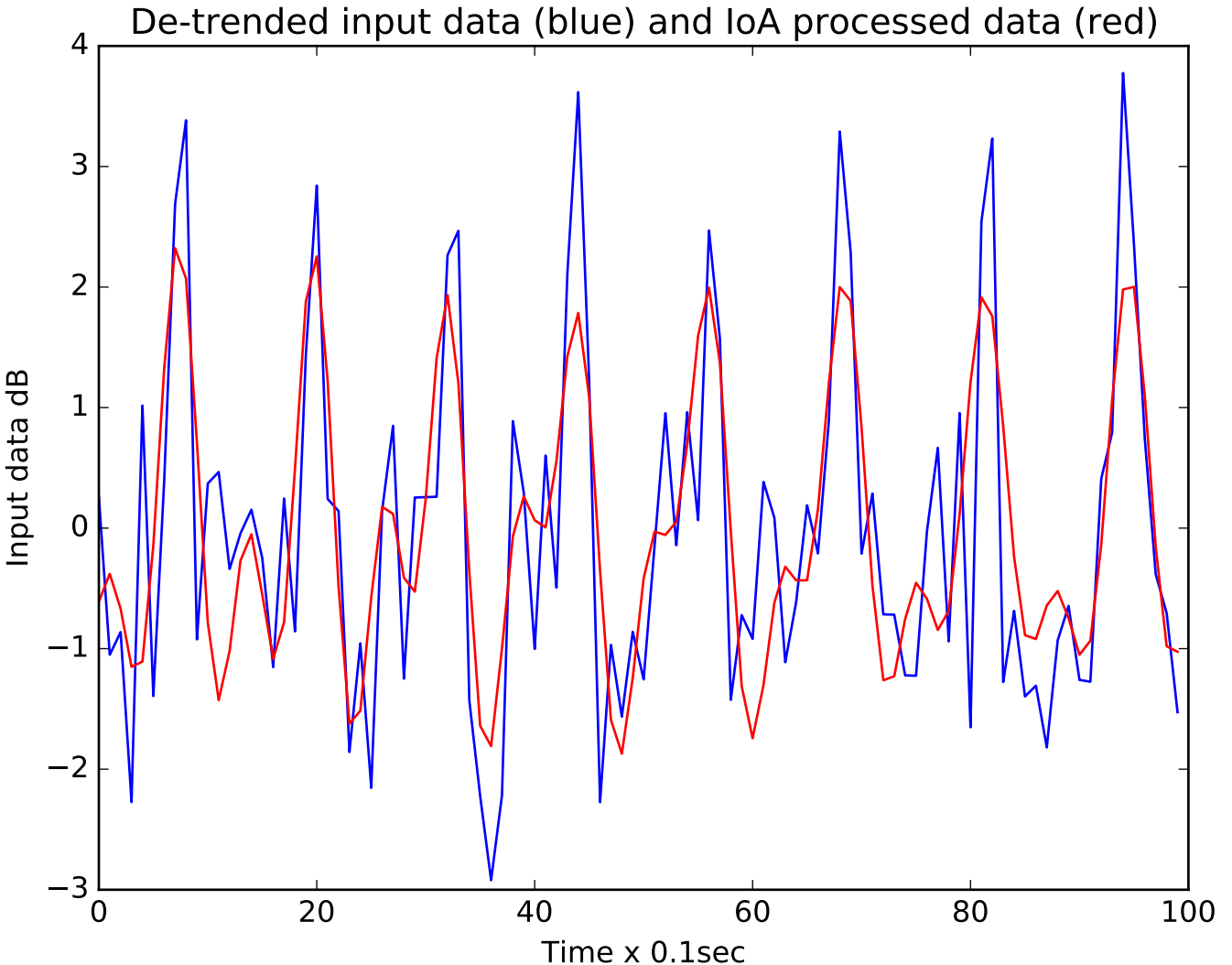
Leonards Hill Wind Farm outside nearest residence (Two MM82 turbines)
A-wt 100Hz to 400Hz one-third octave band limited sound pressure level

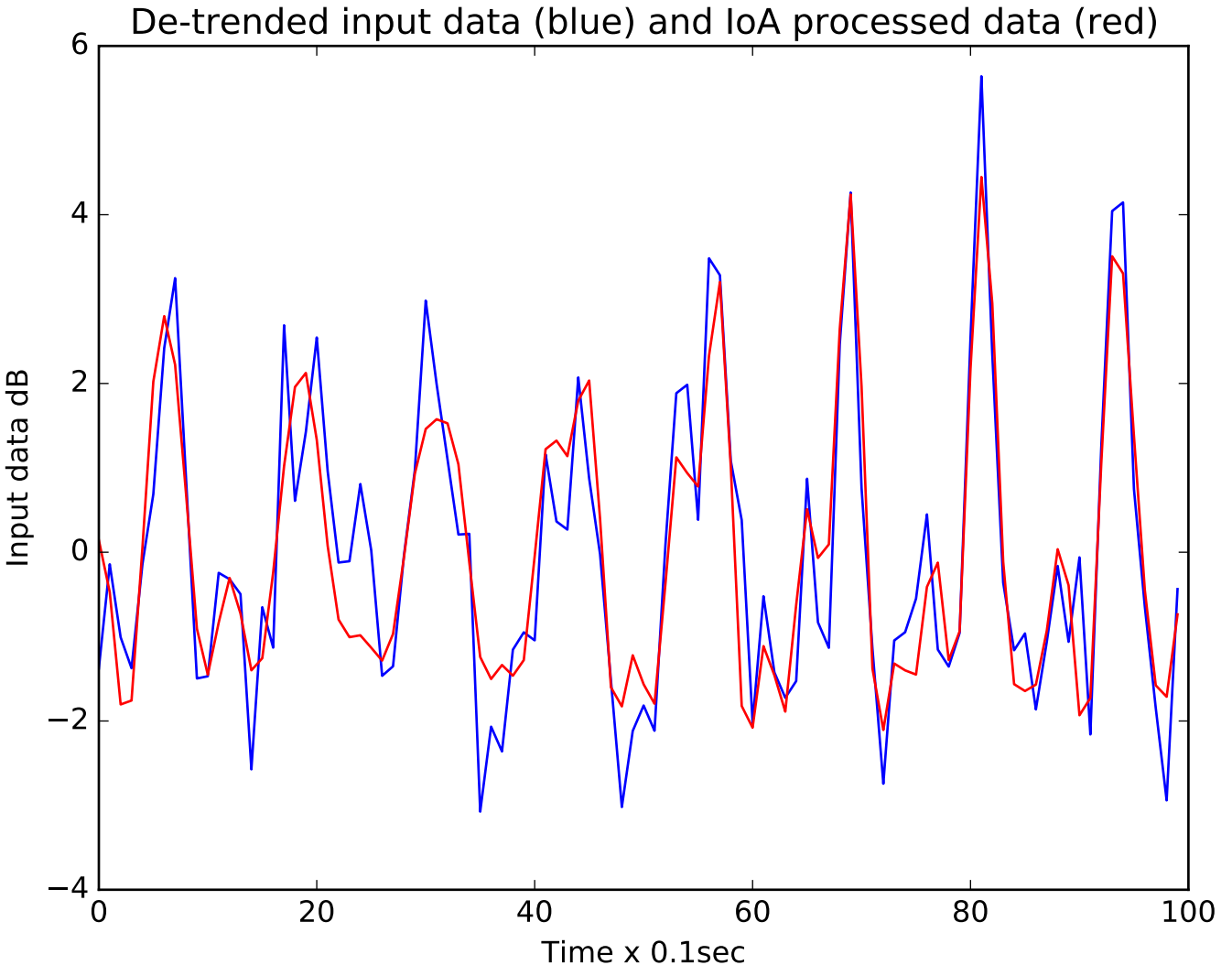


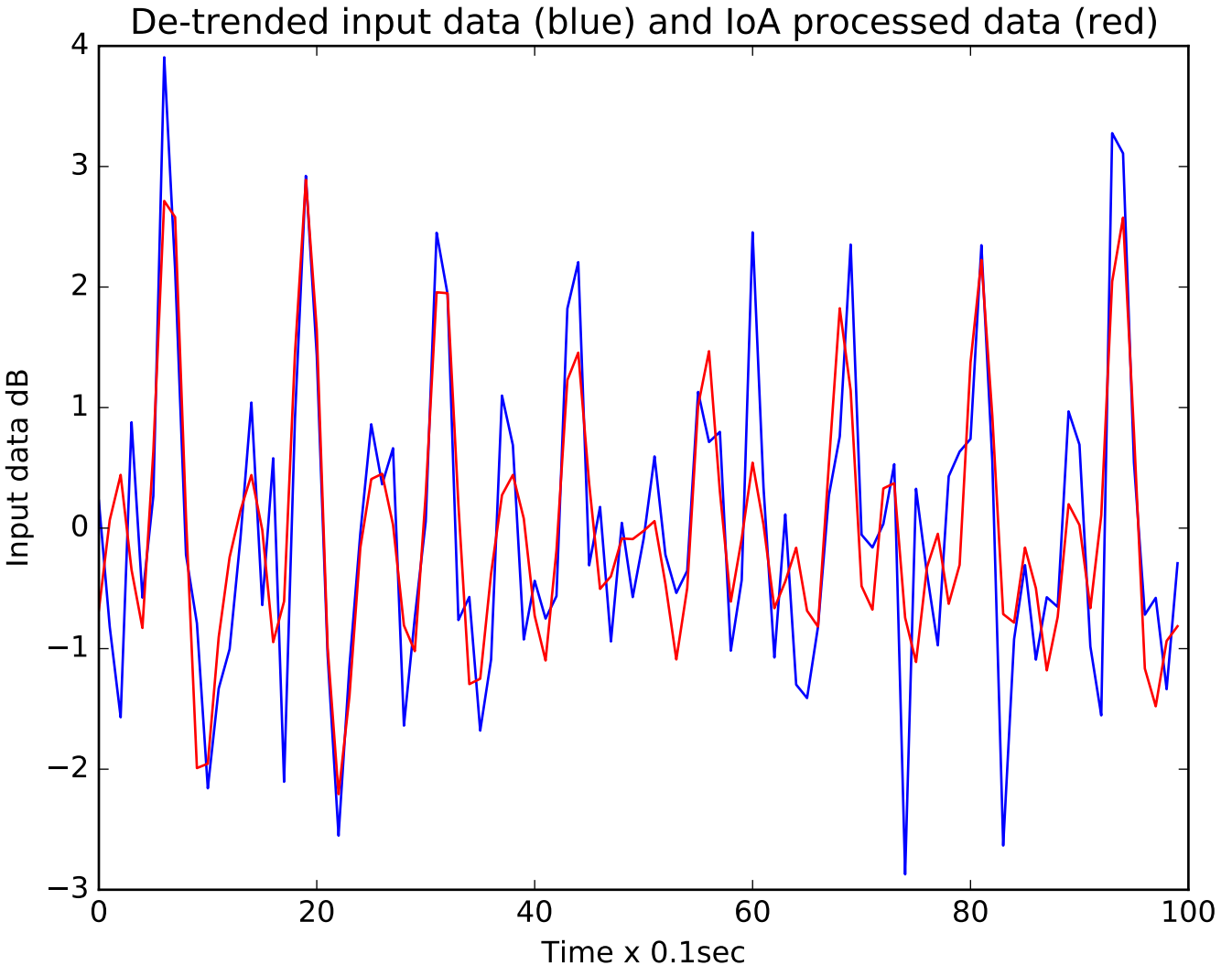
First 10-sec sample of original signal from sound level meter sampled at 100ms

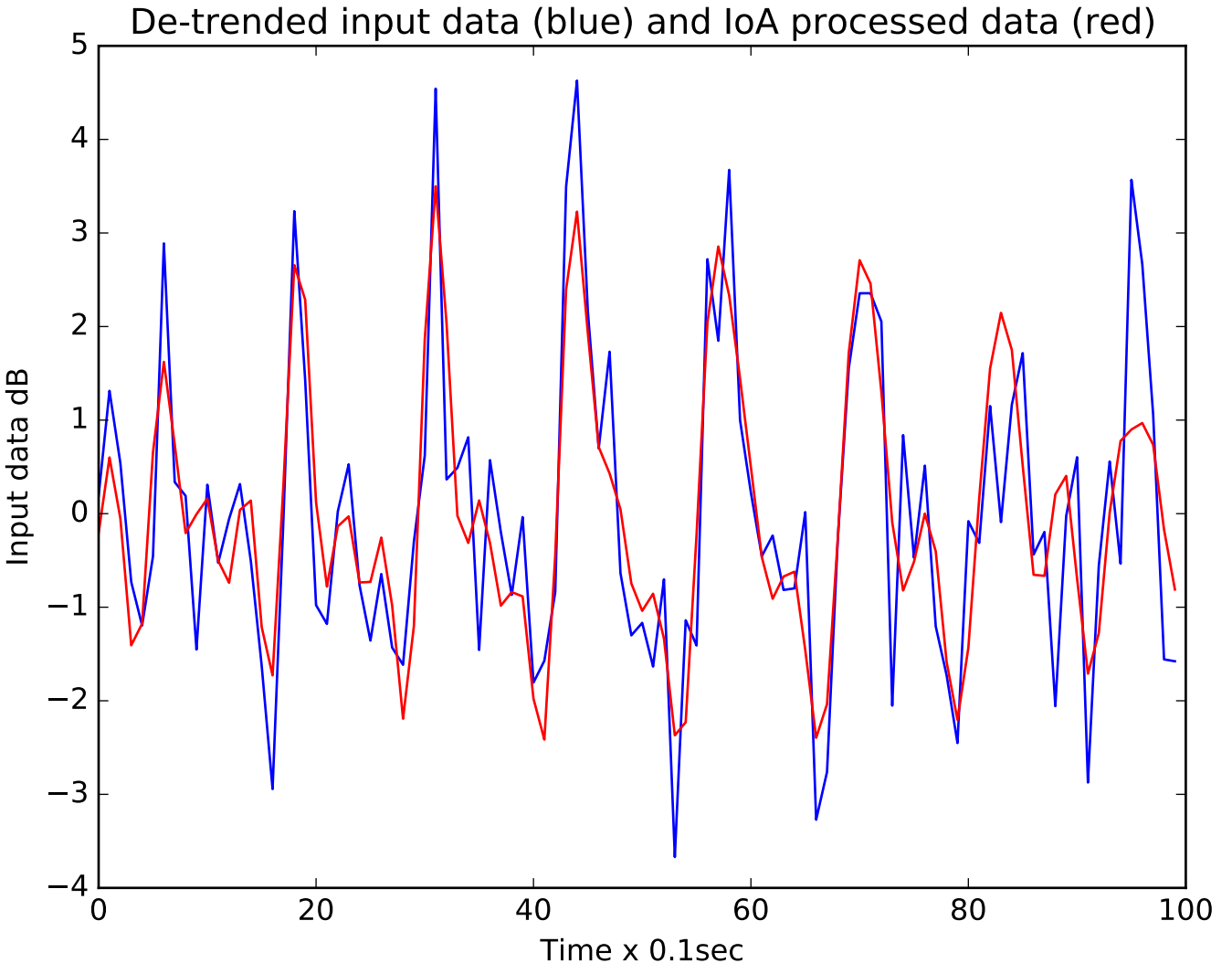


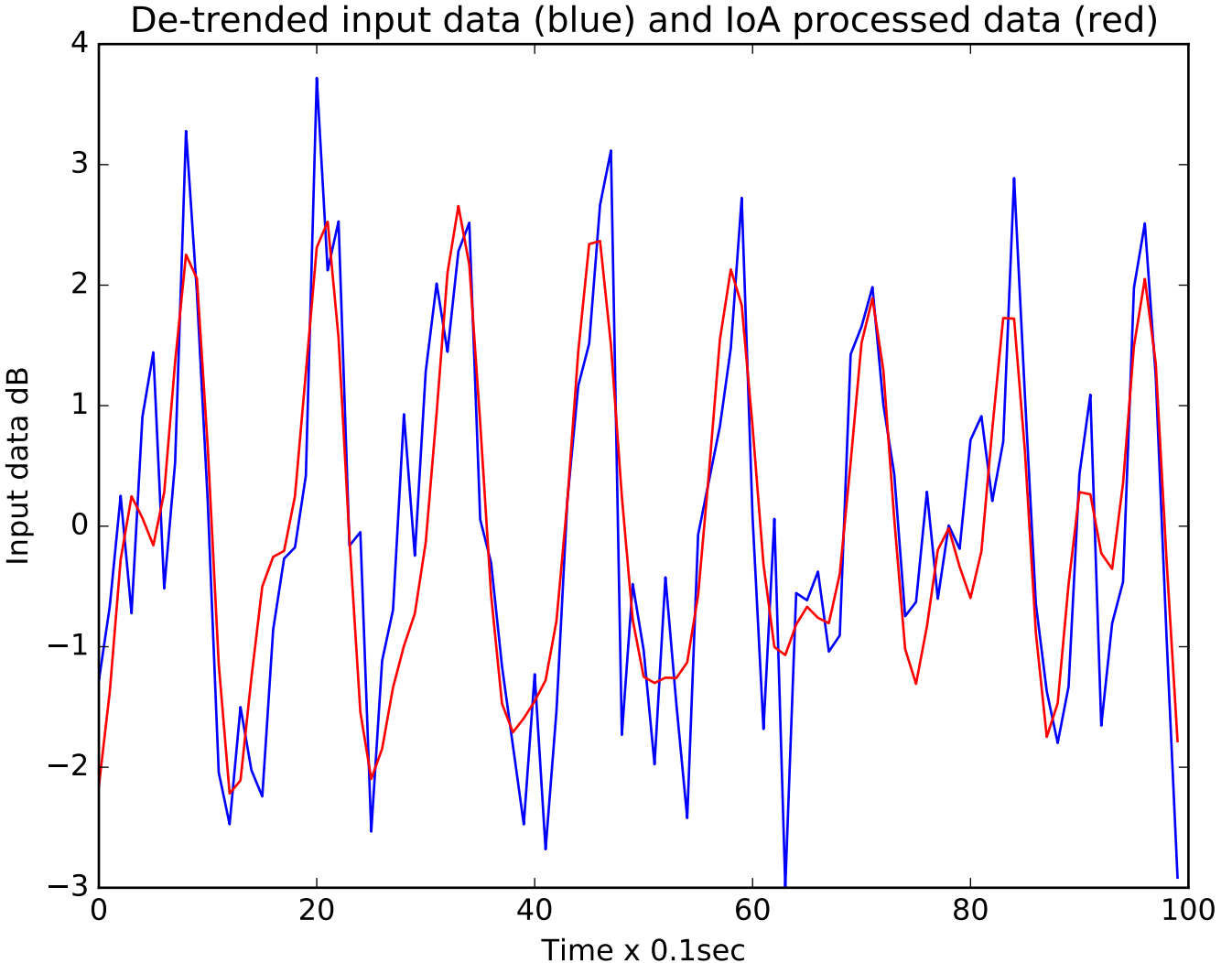

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100

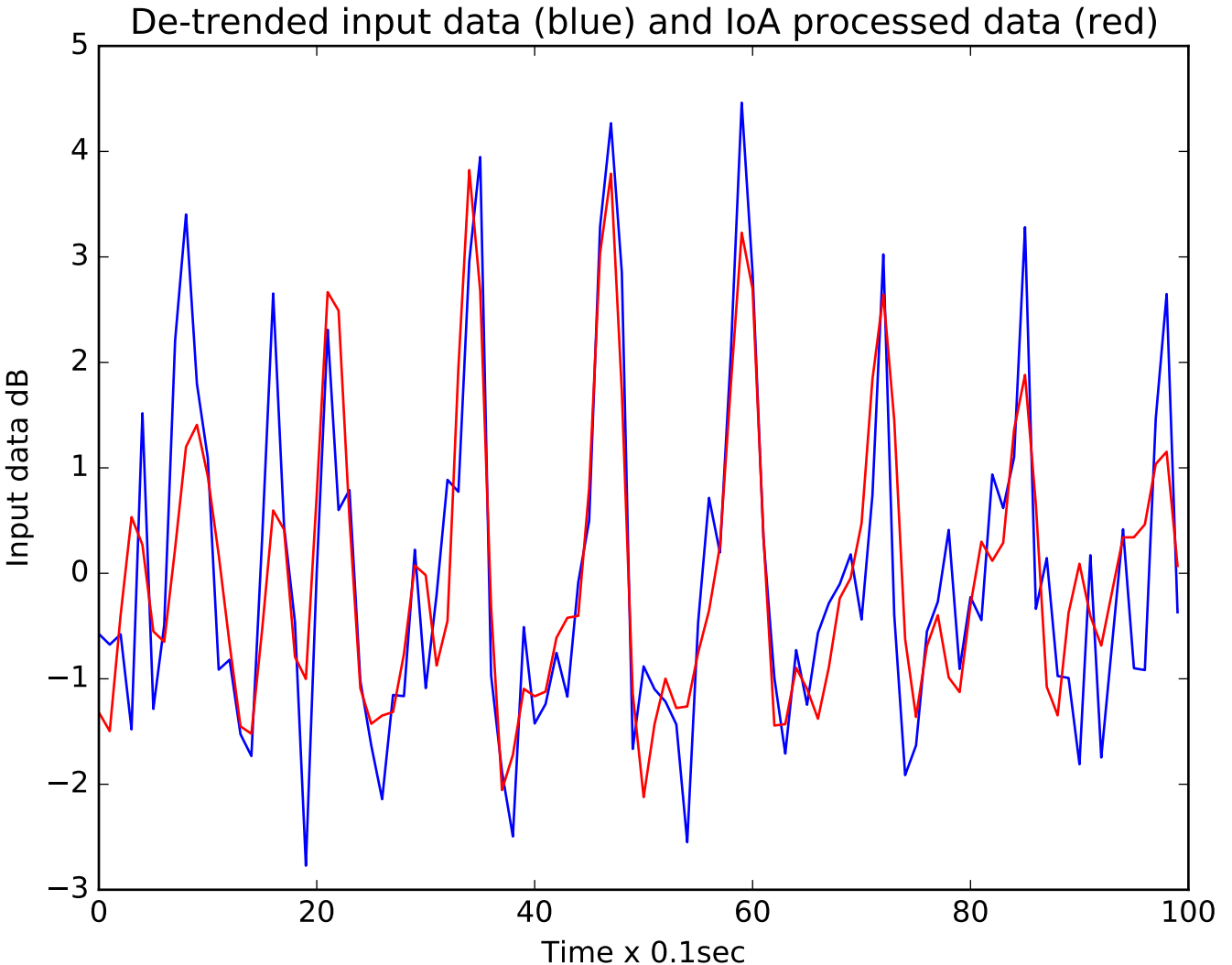

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

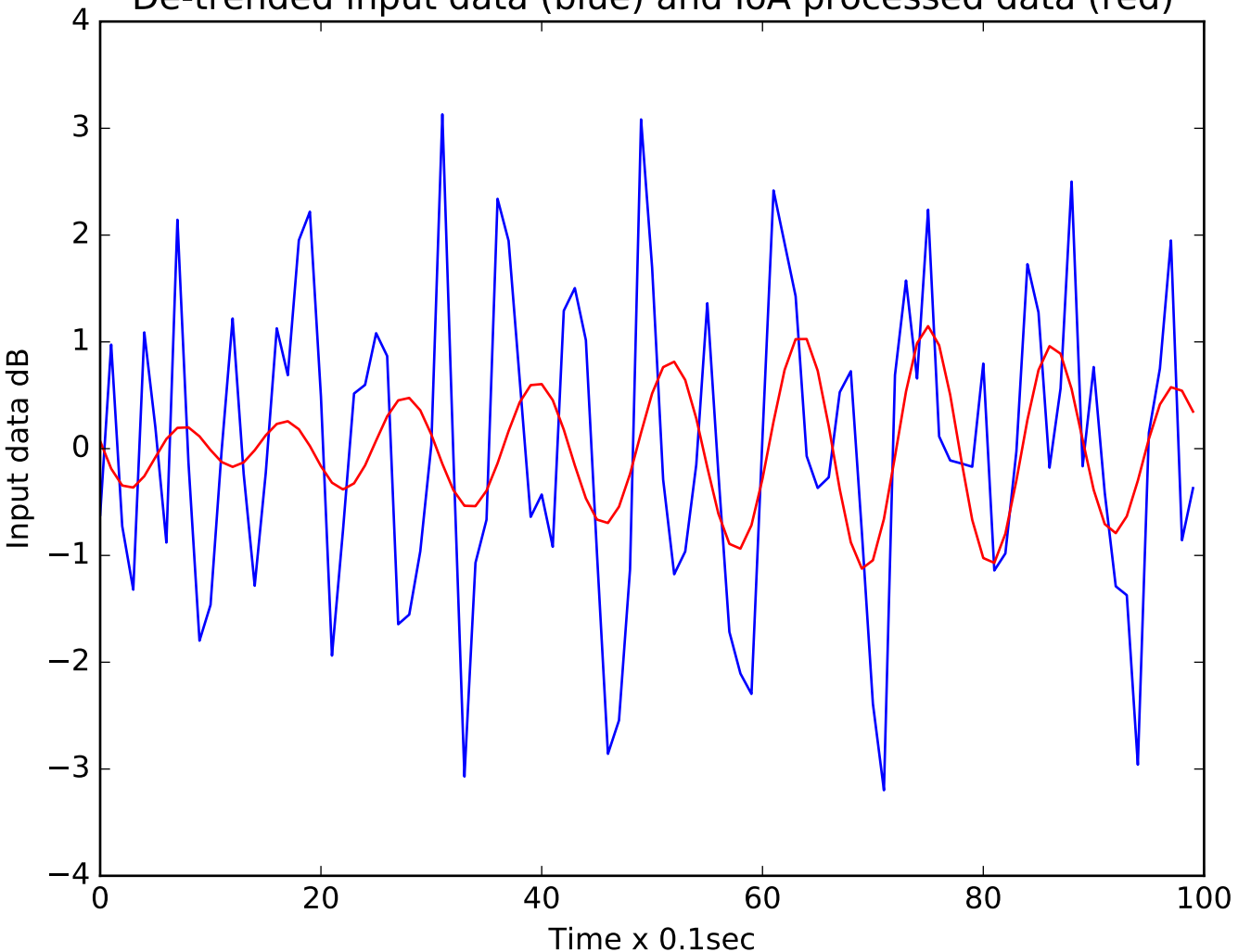

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100

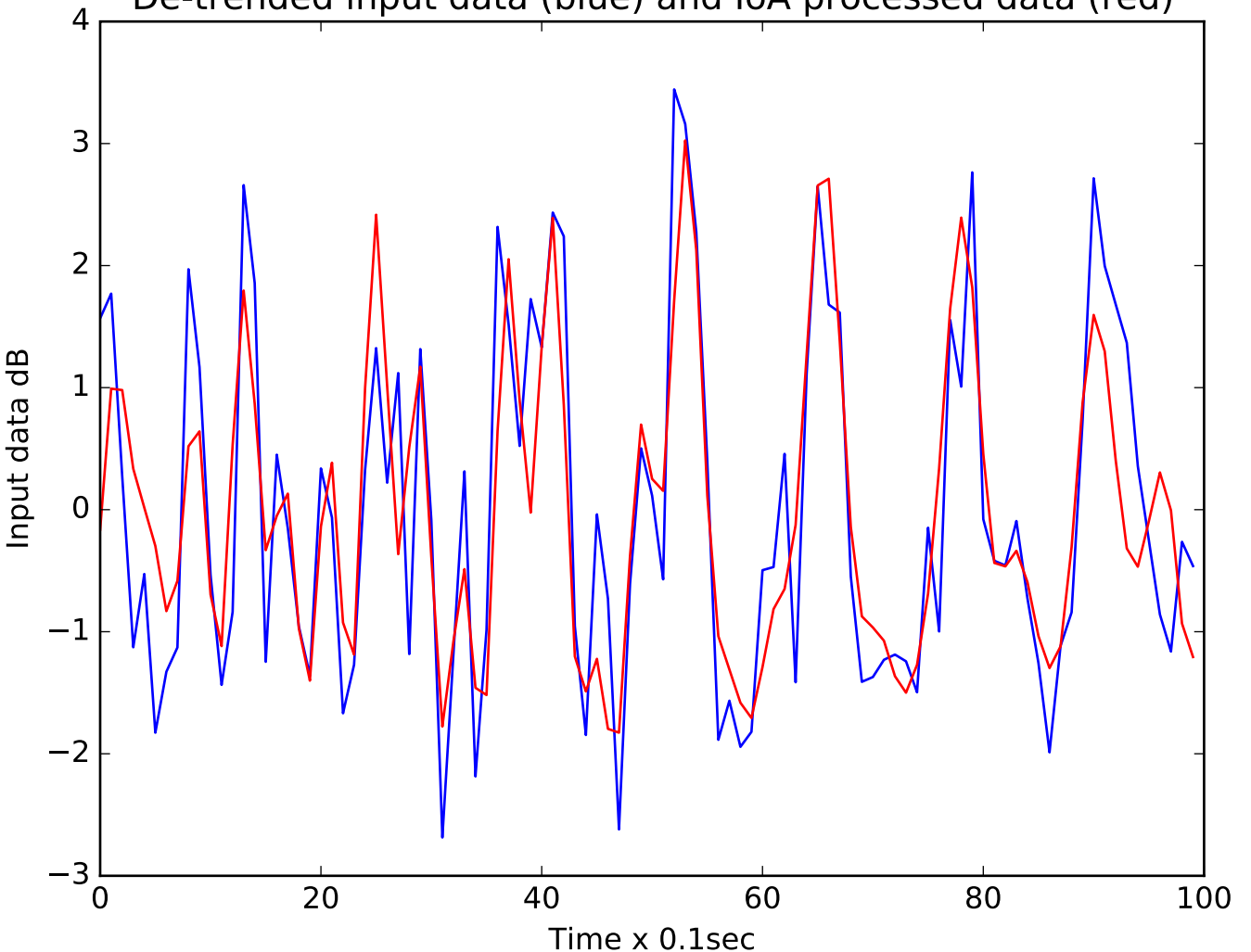

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

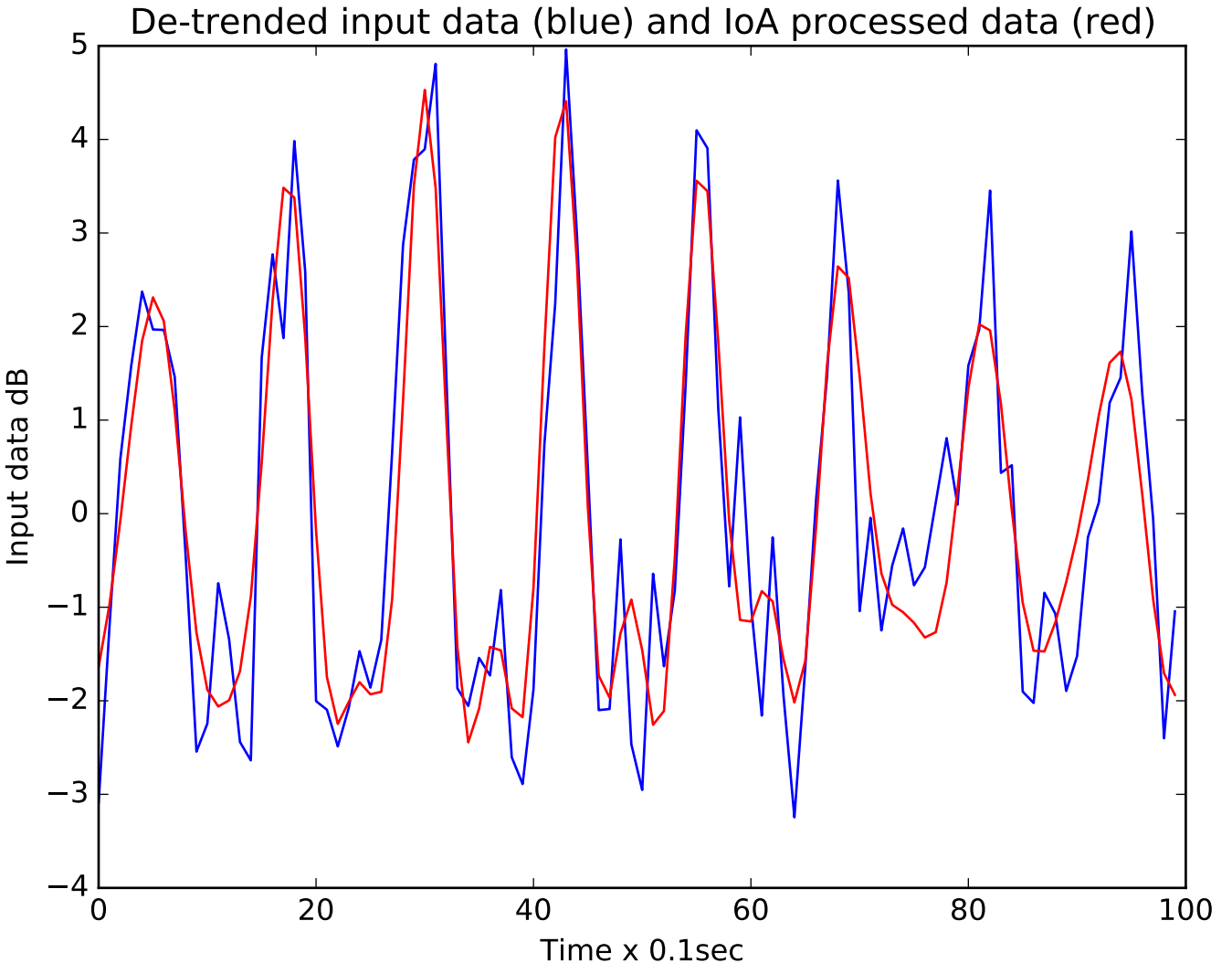

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

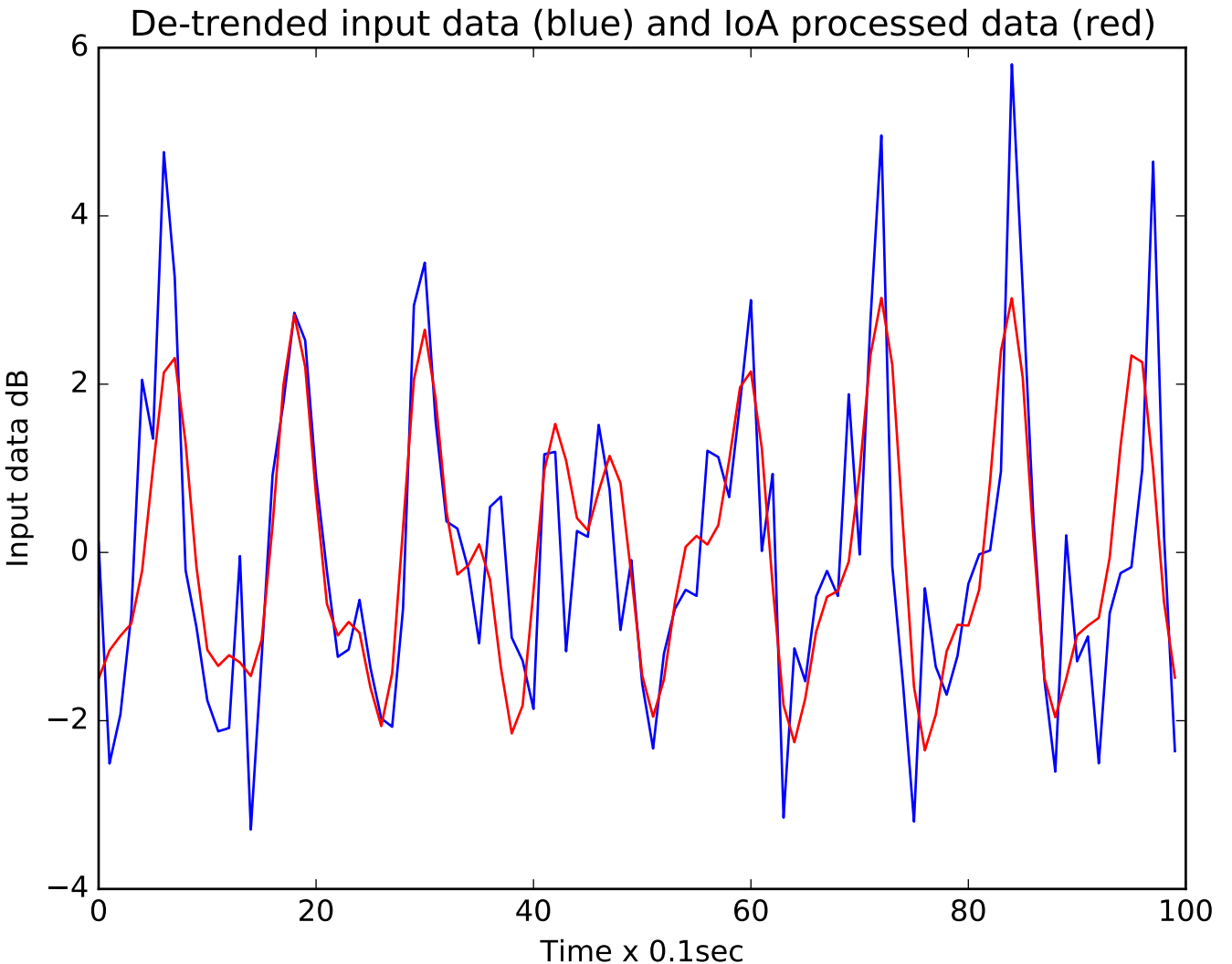

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

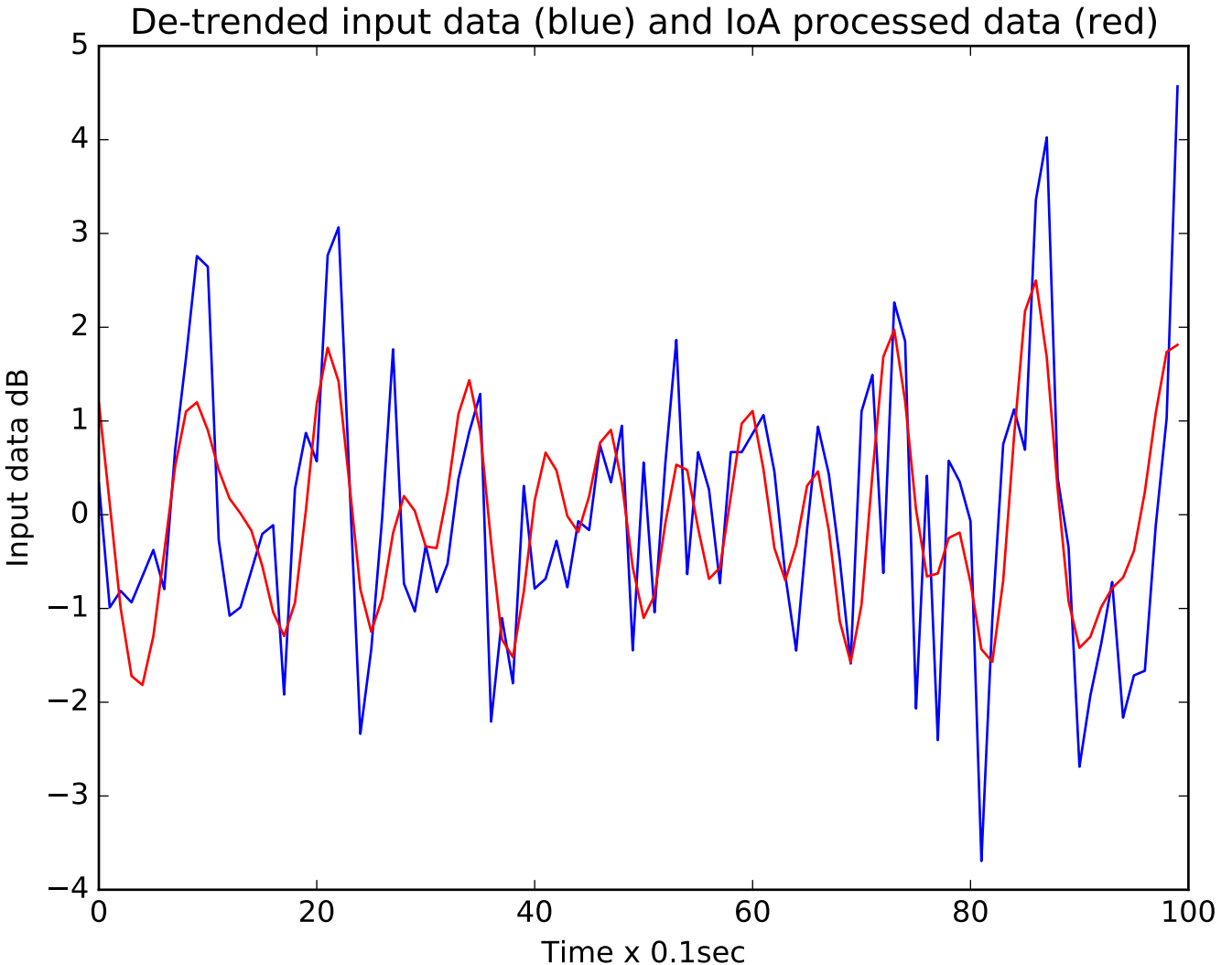

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100

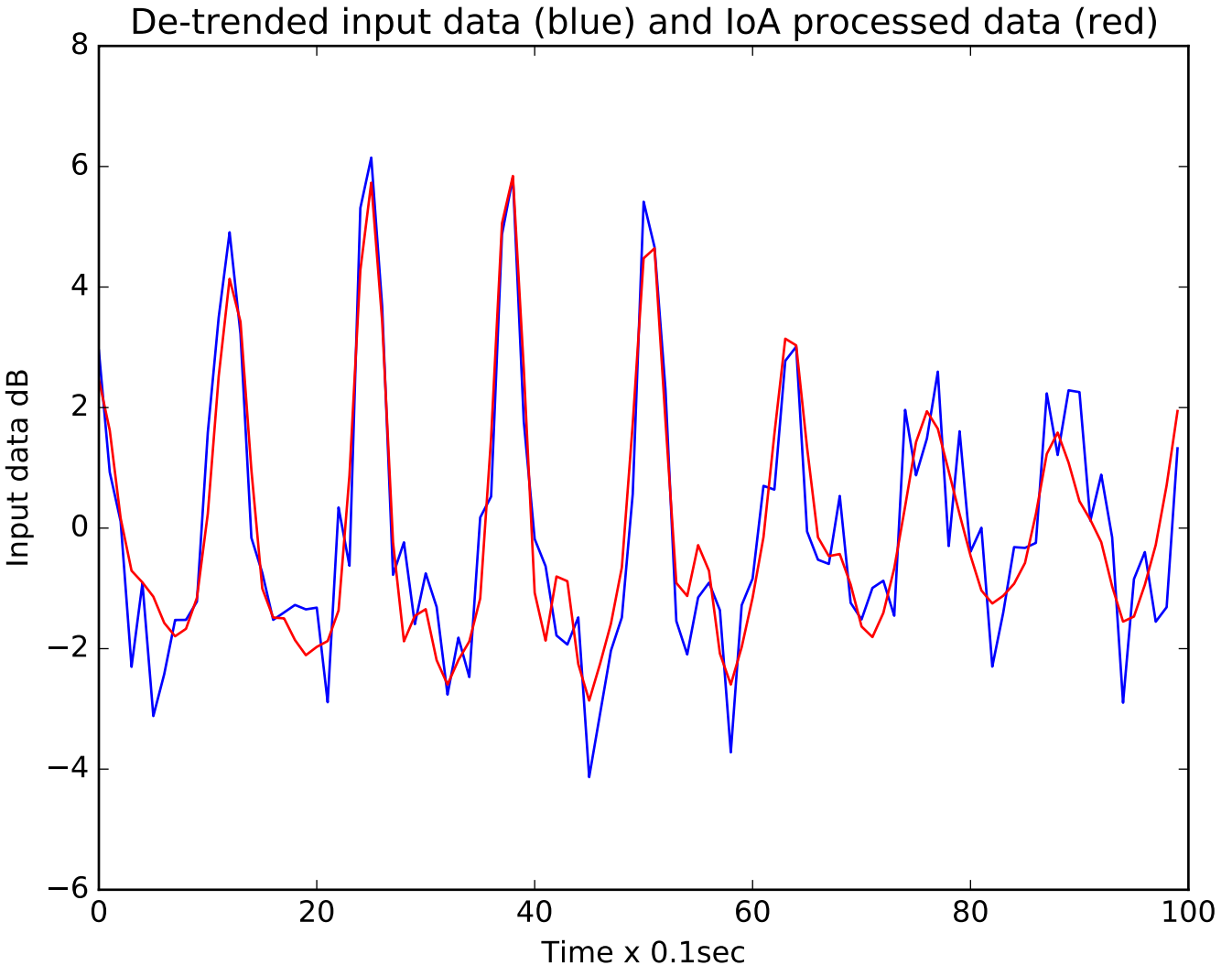

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100

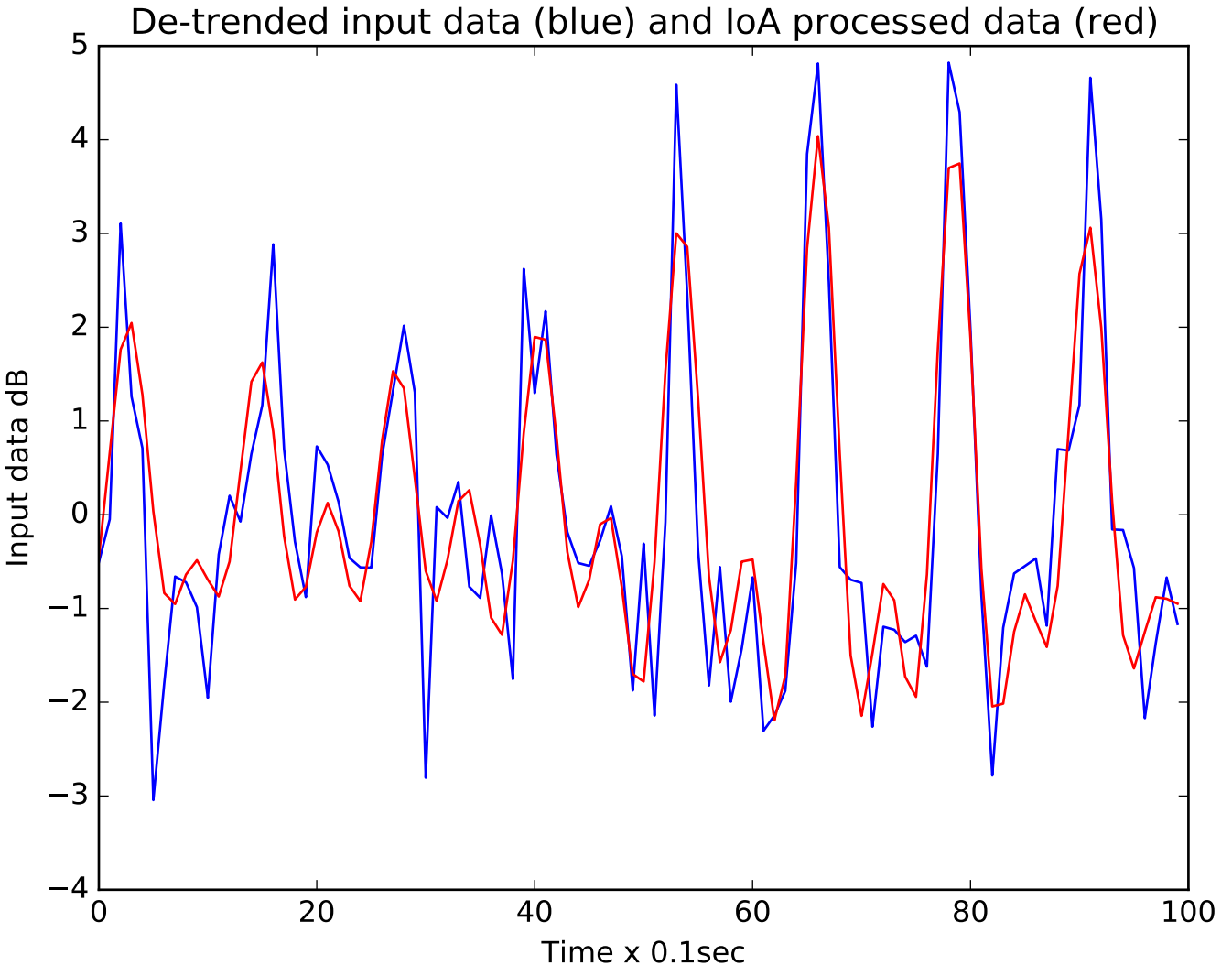

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
4
3
2
1
0
−1
−2
−3
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
8
6
4
2
0
−2
−4
−6
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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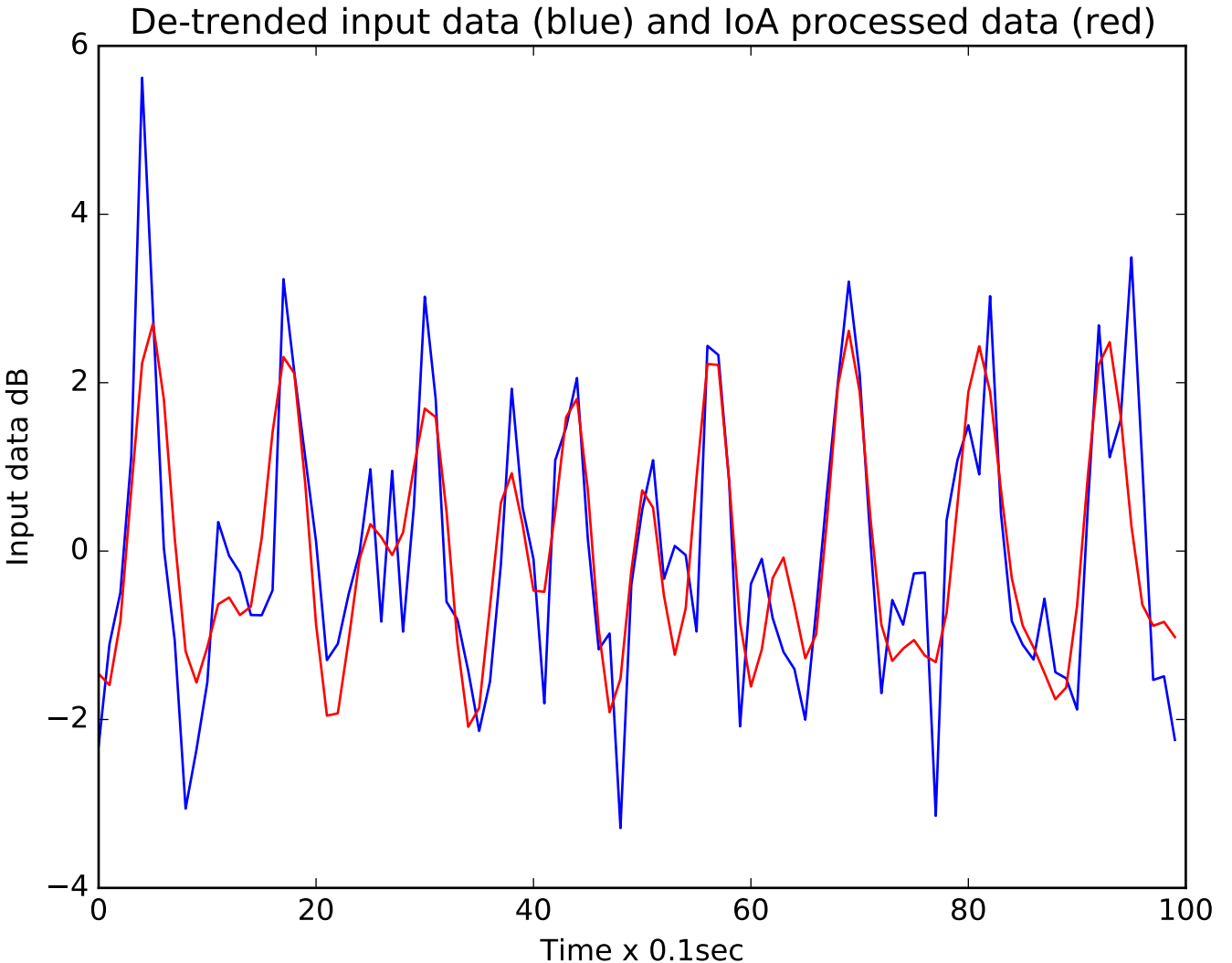
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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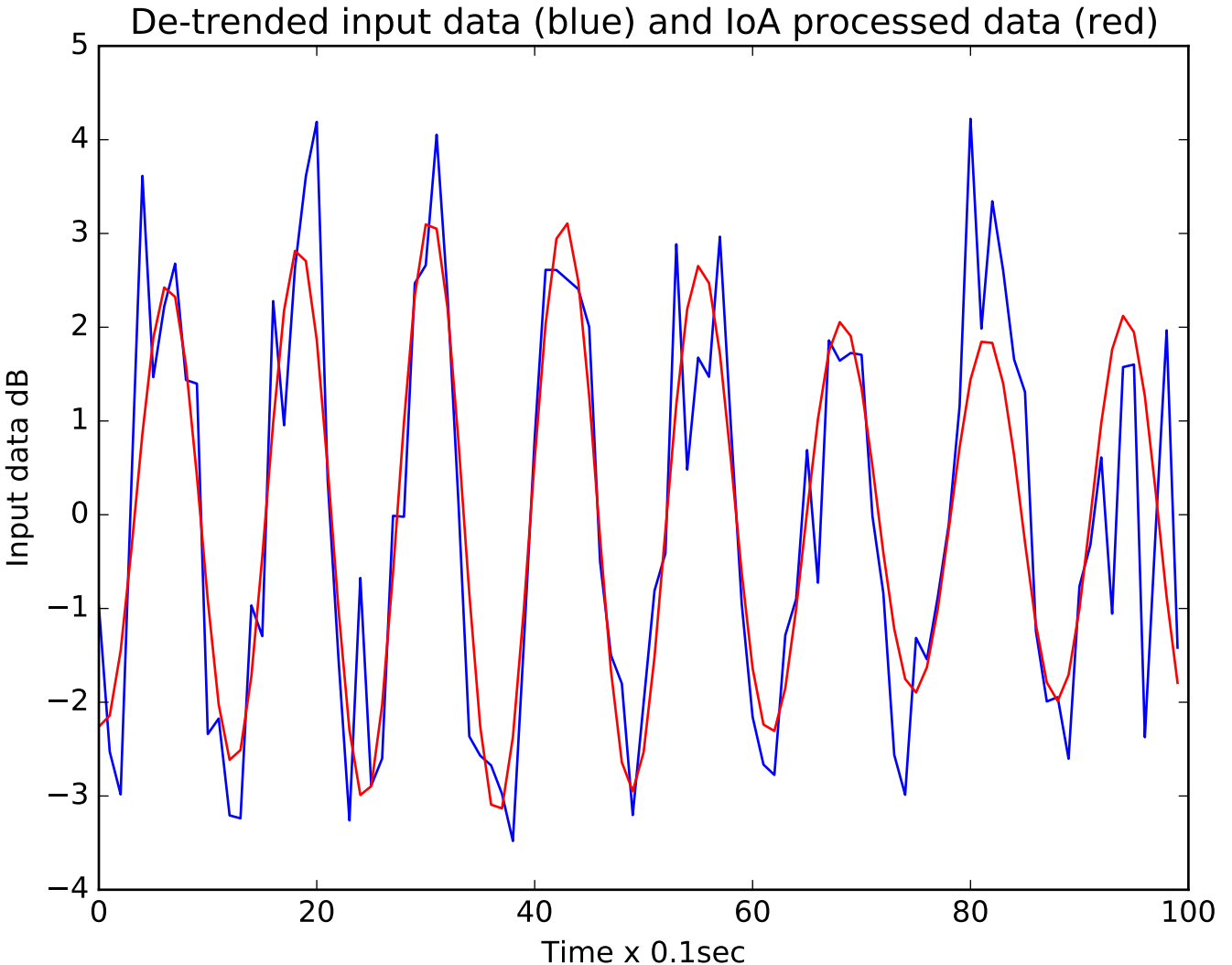
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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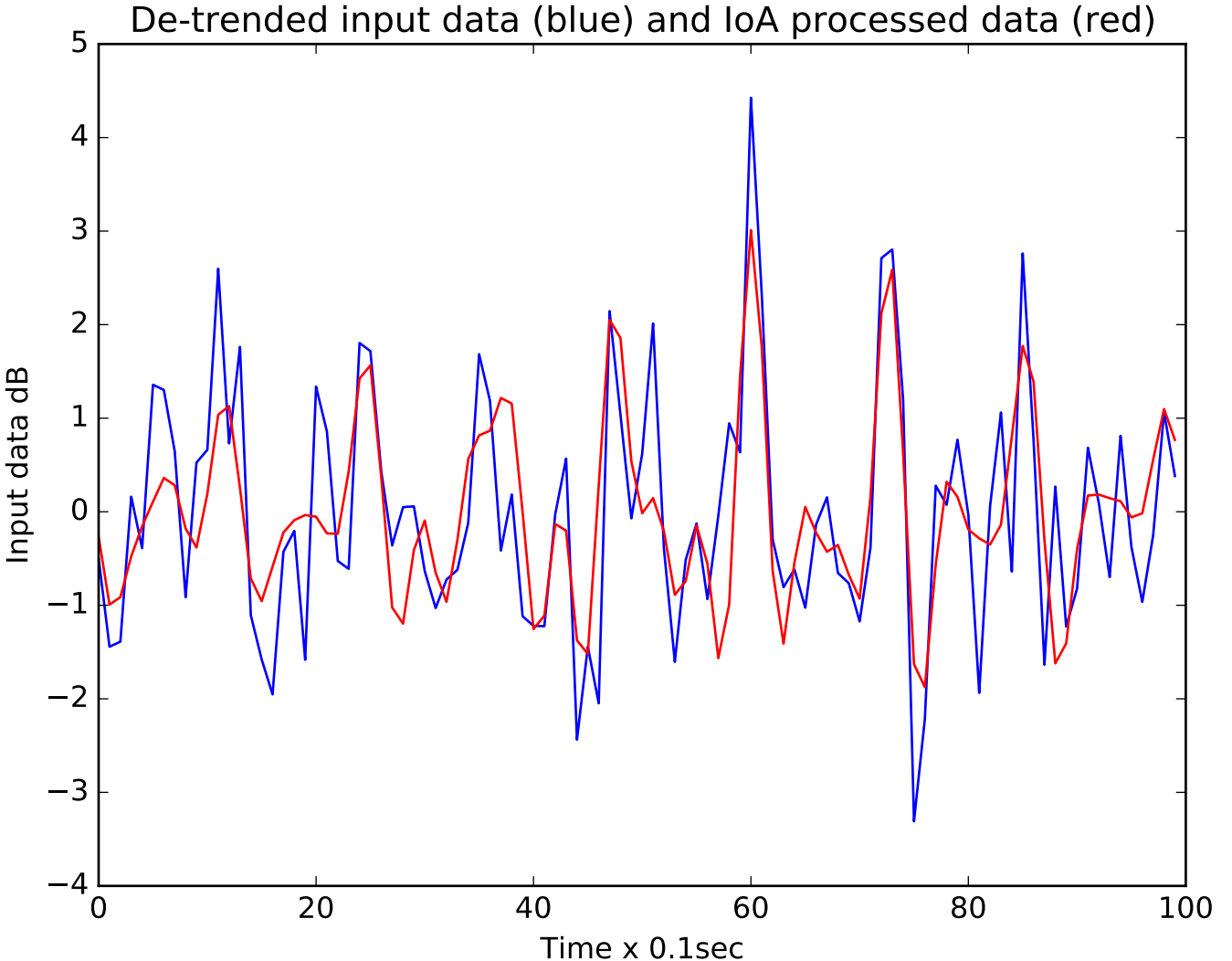
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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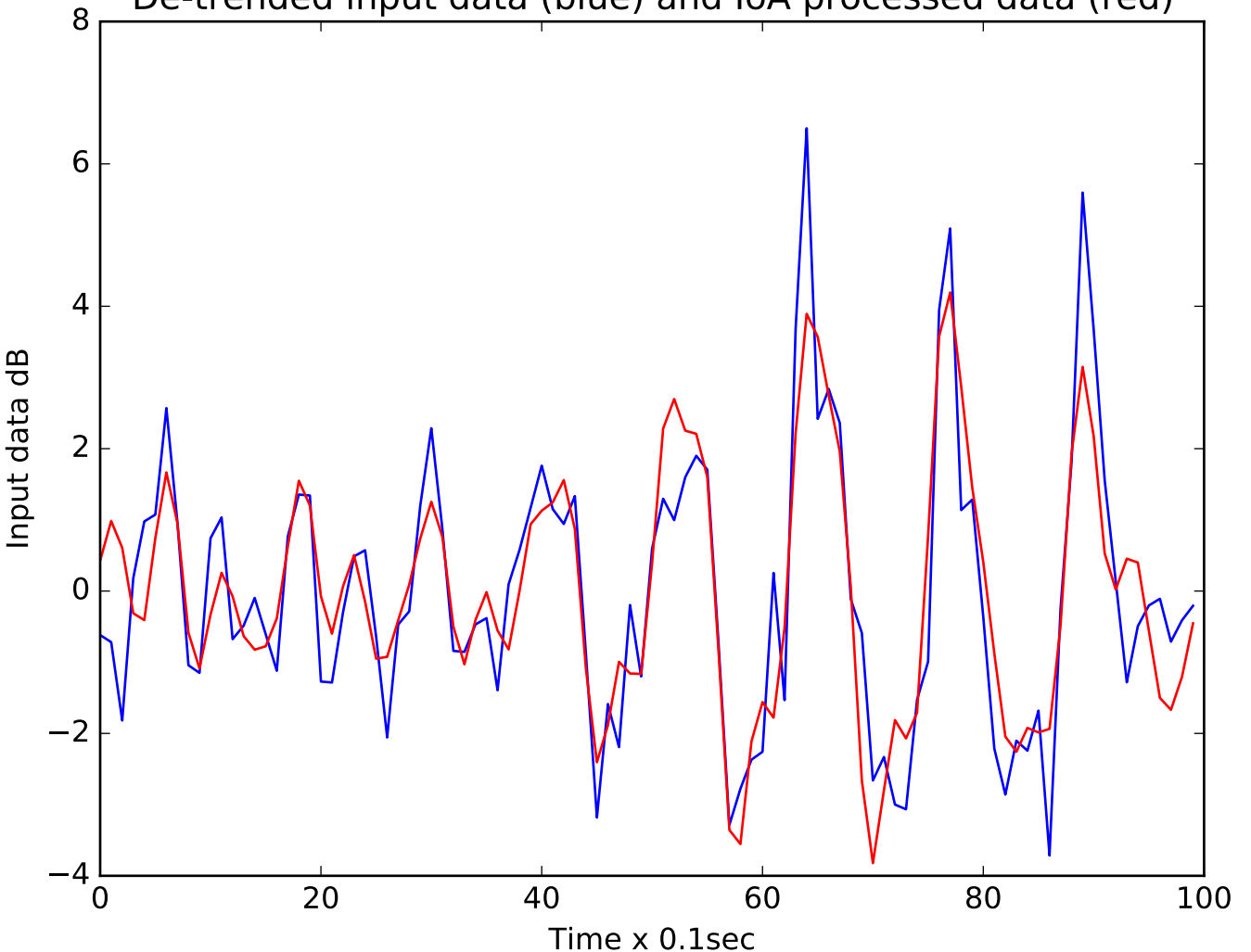
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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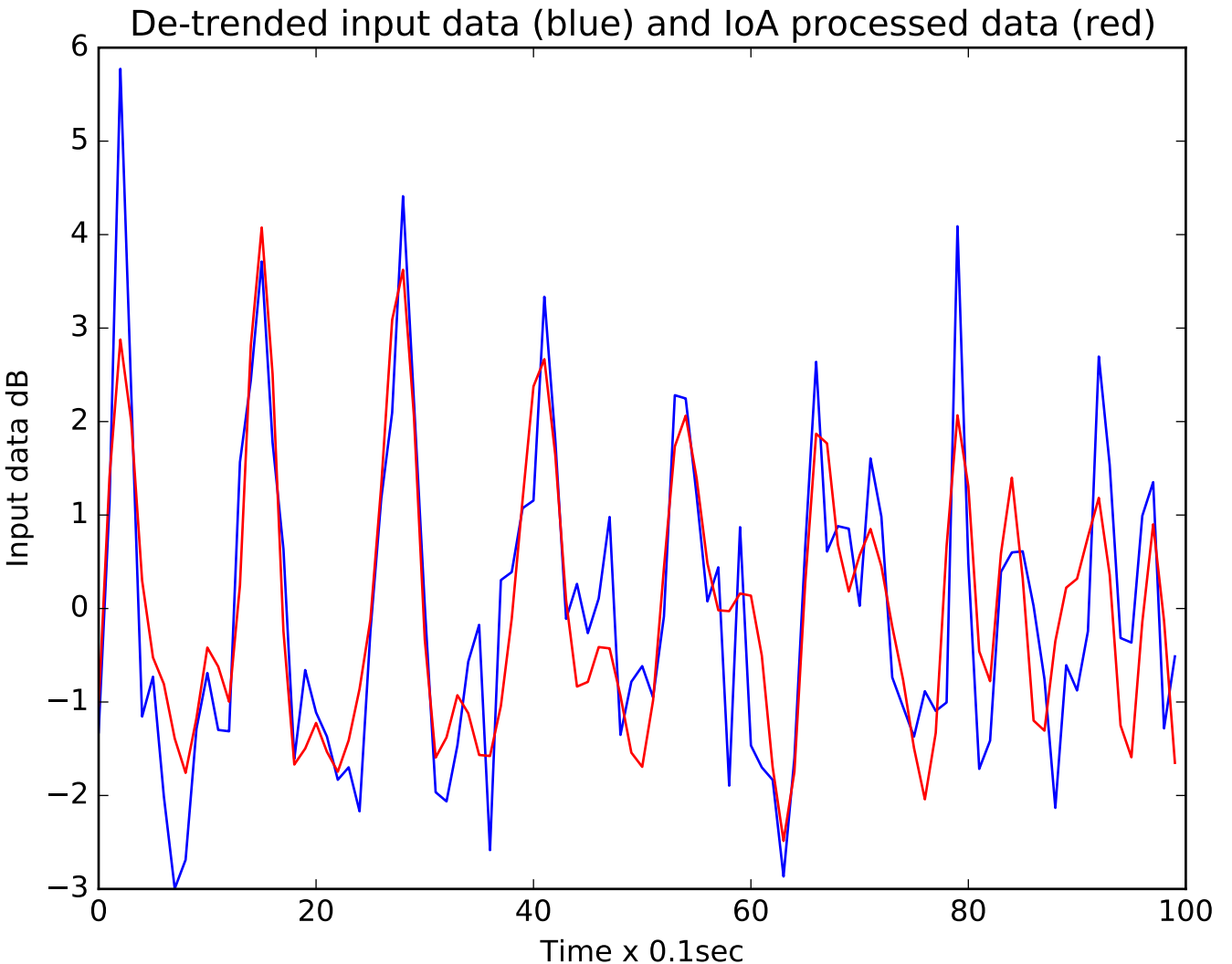
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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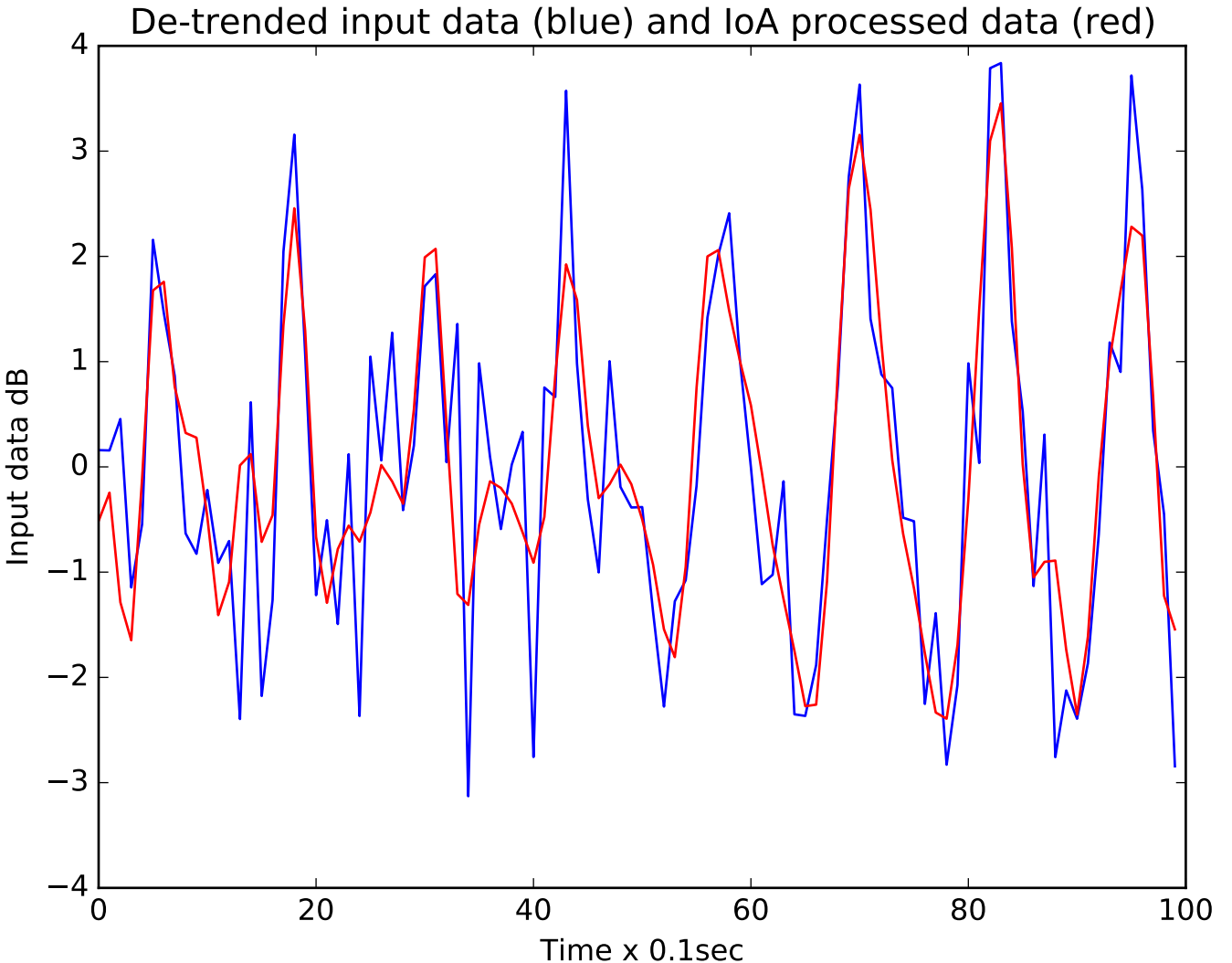
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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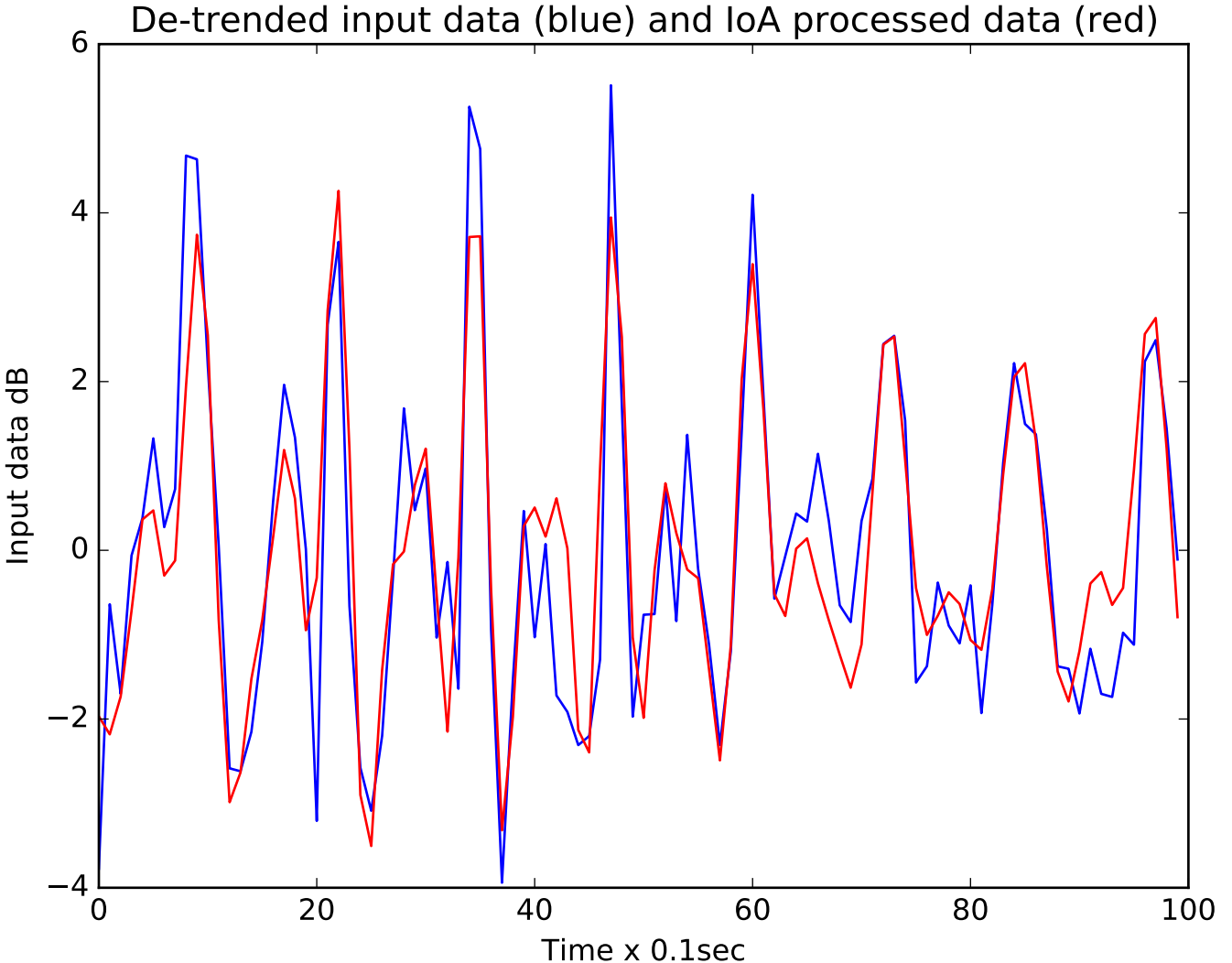
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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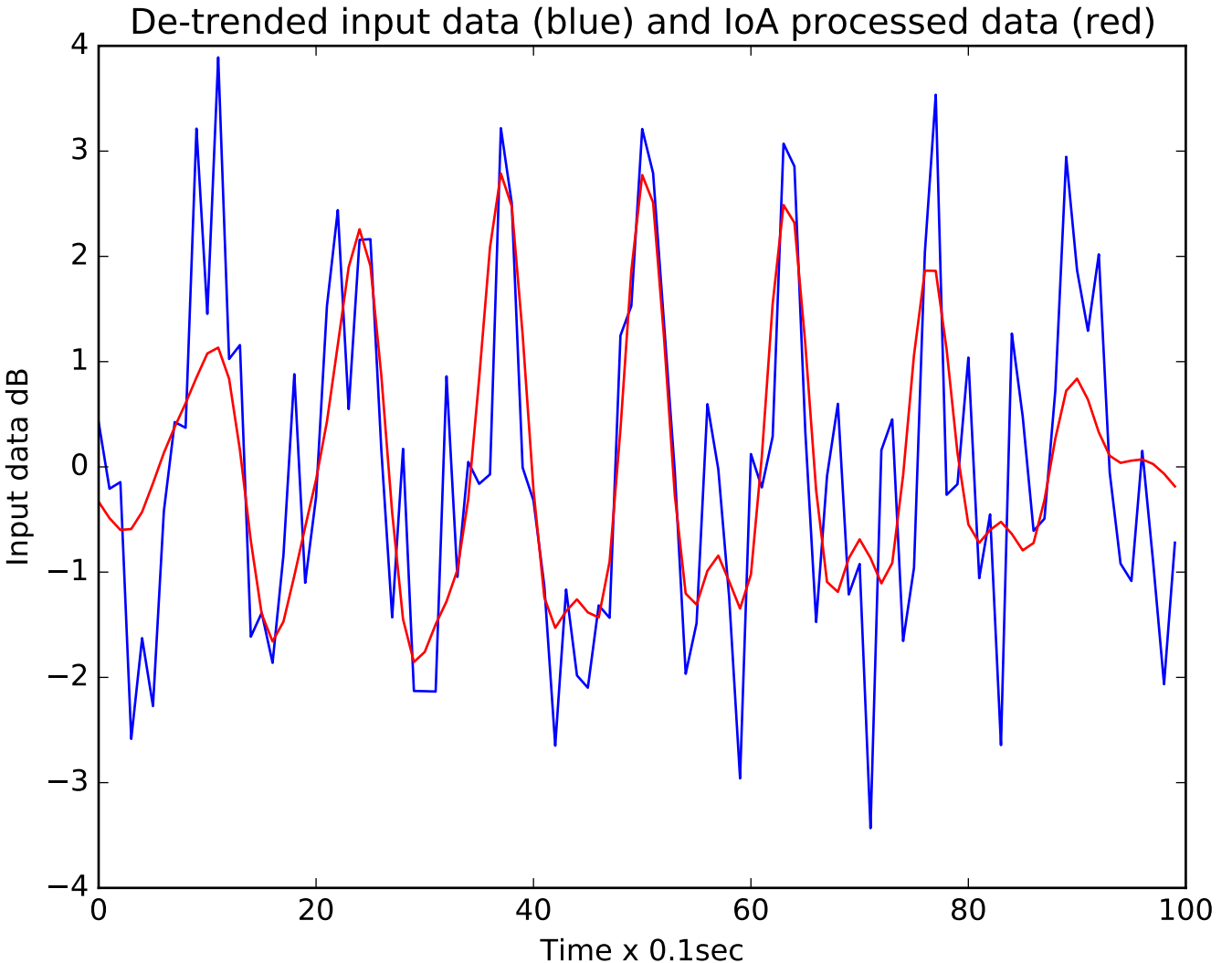
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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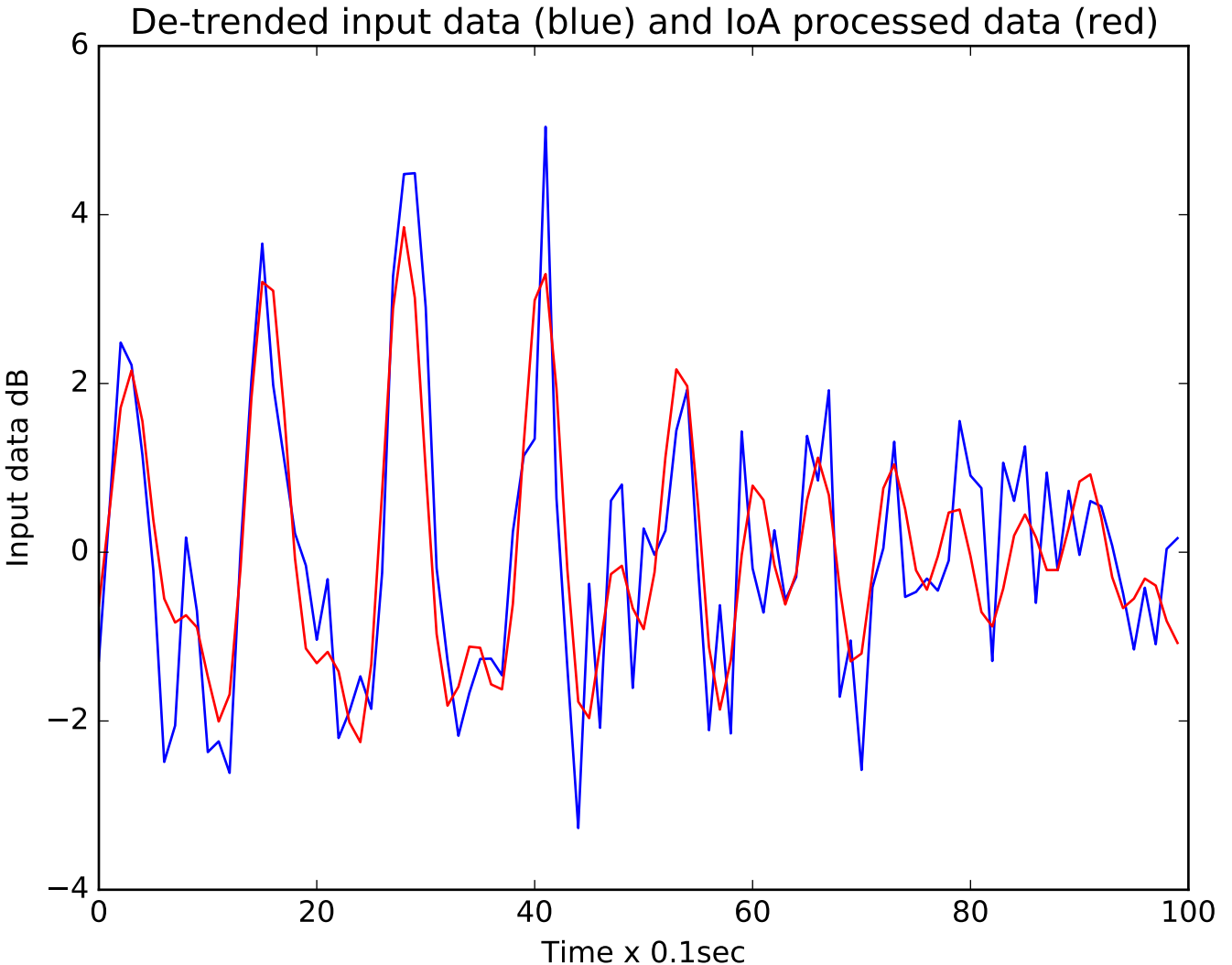
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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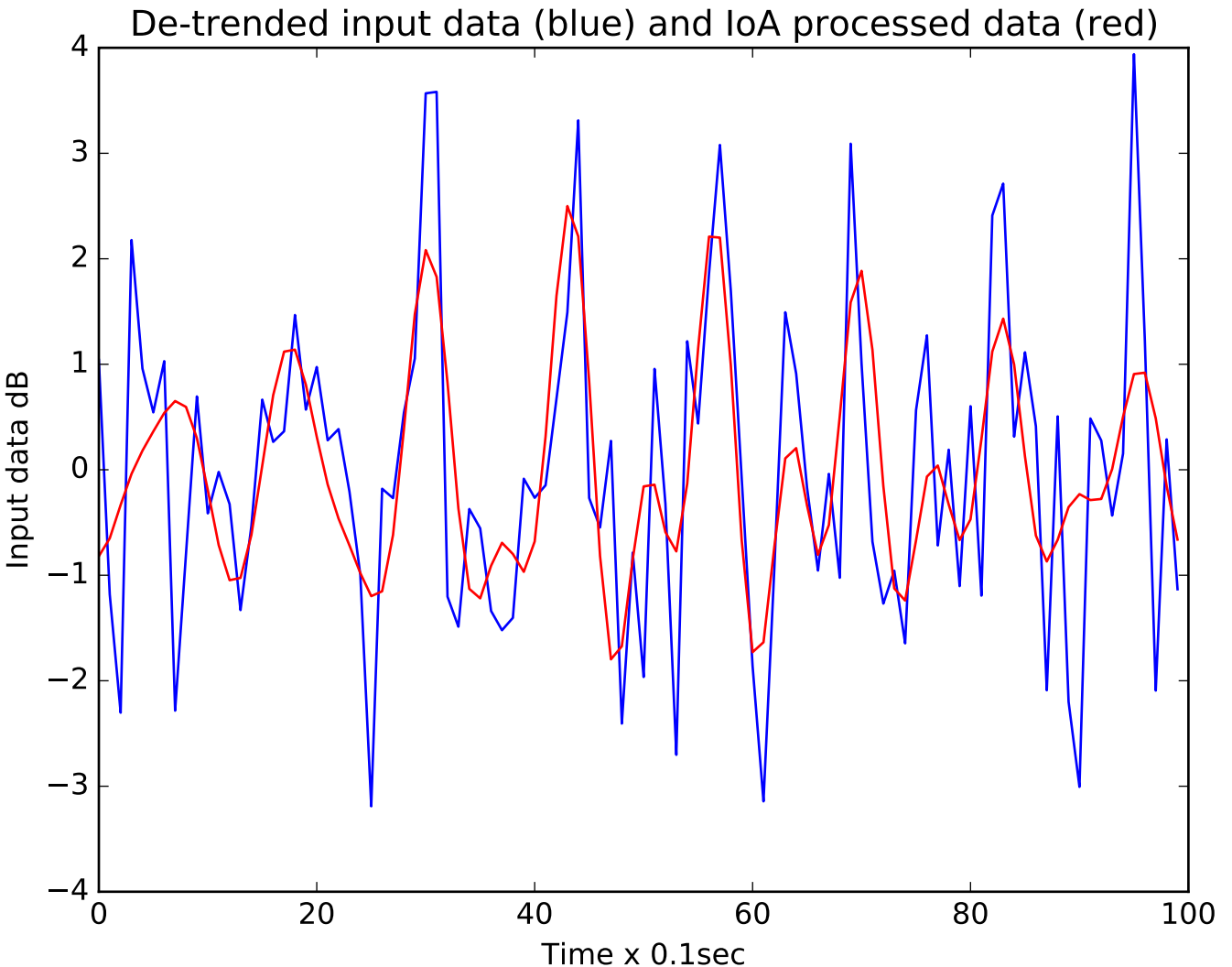
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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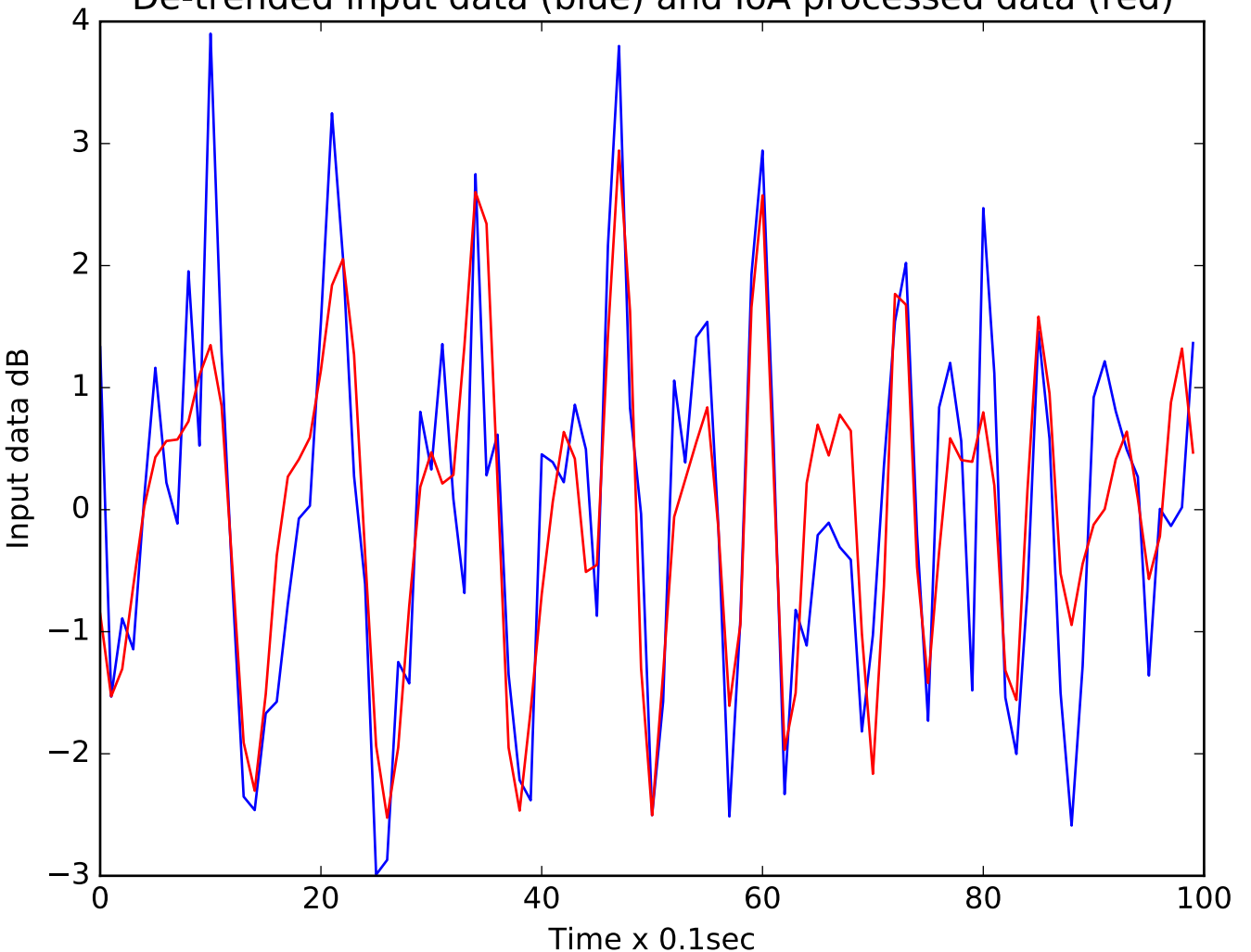
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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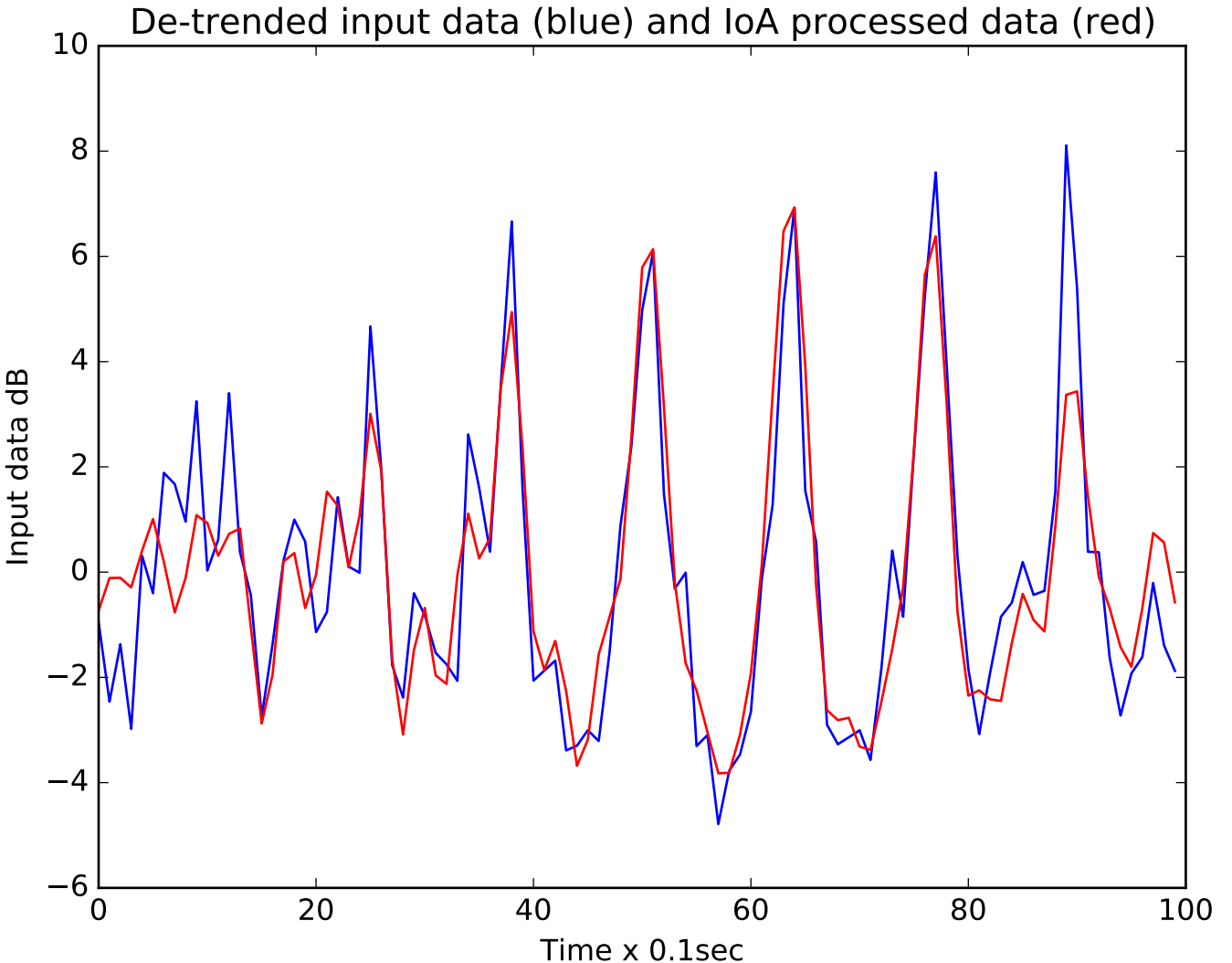
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
10
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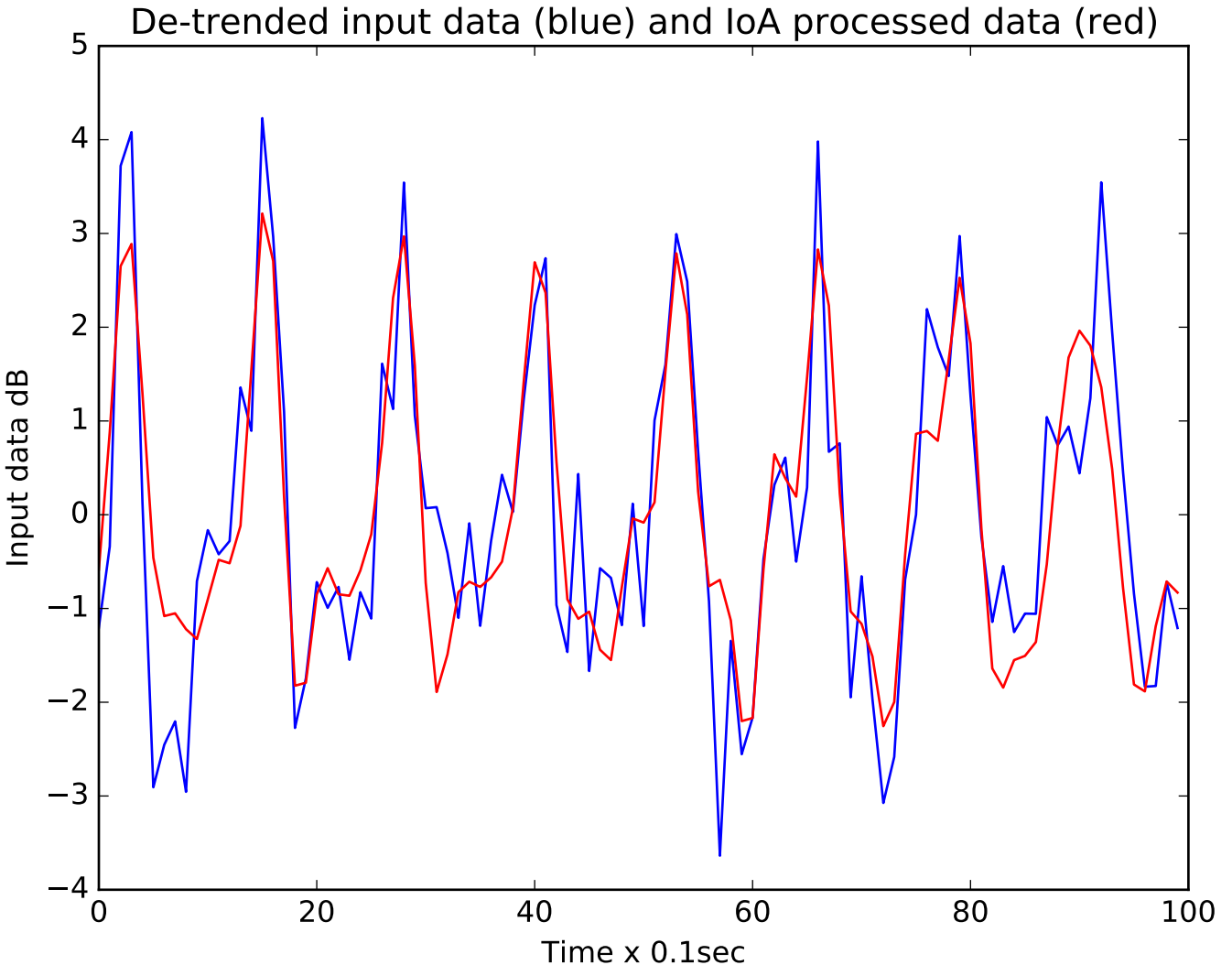
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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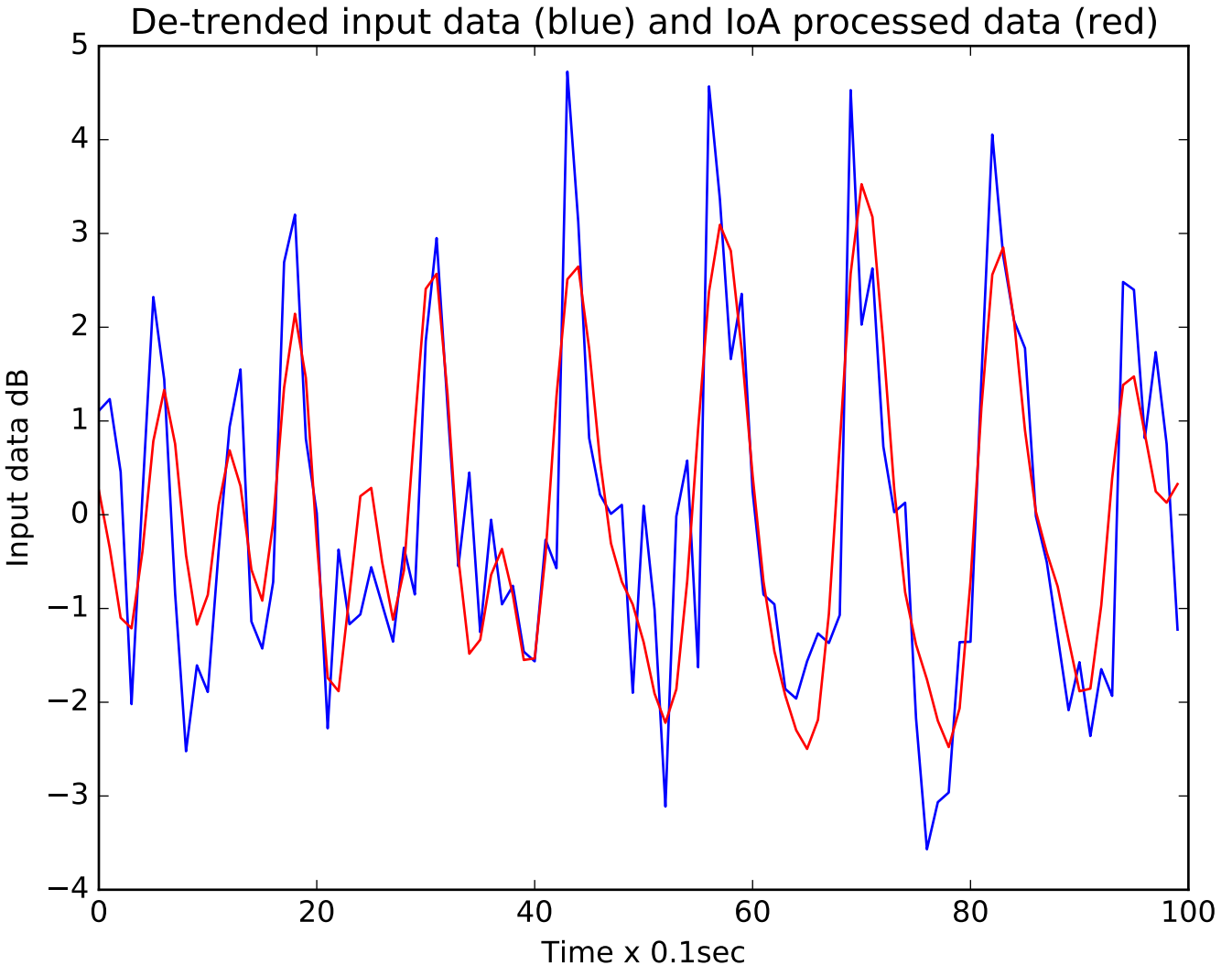
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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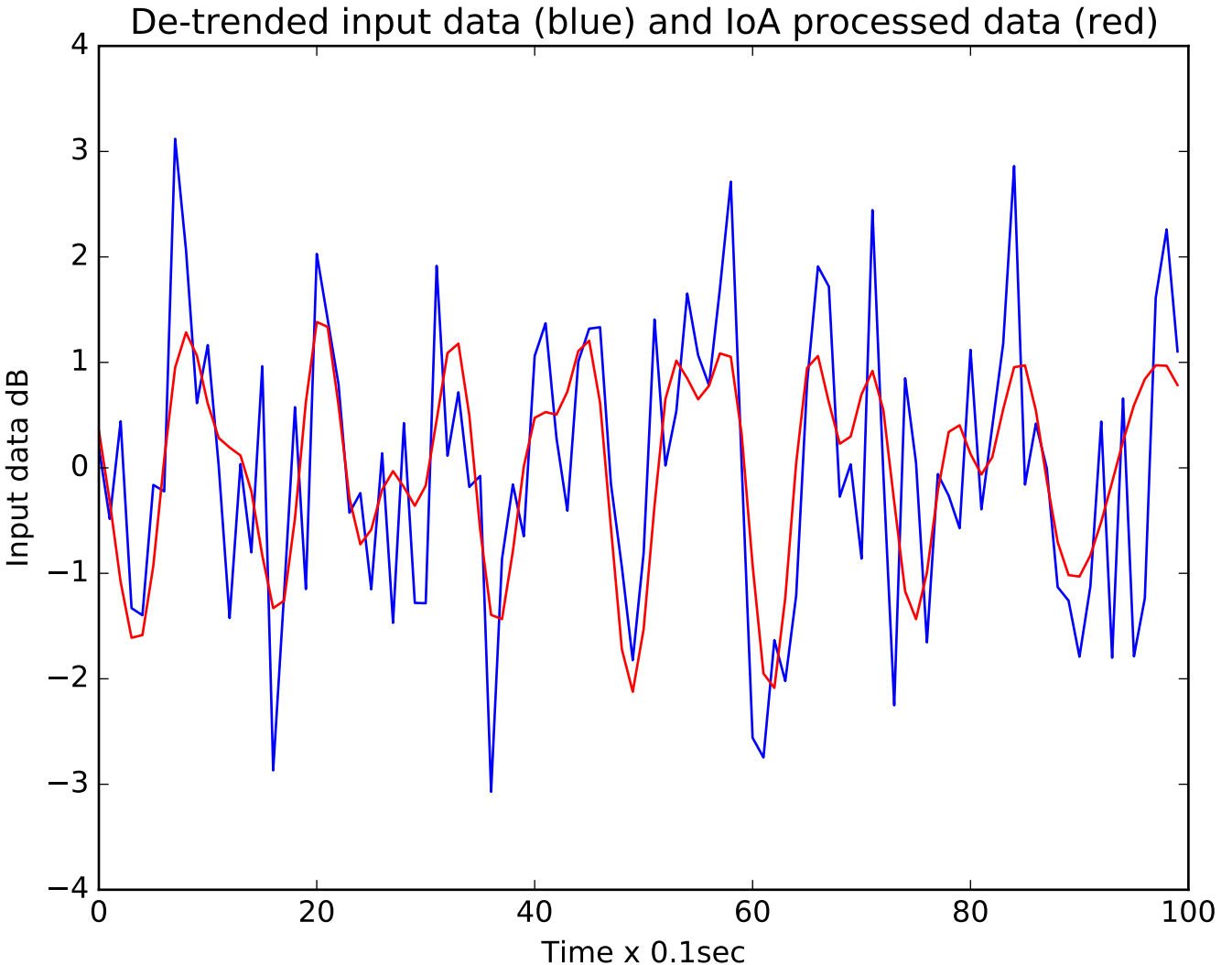
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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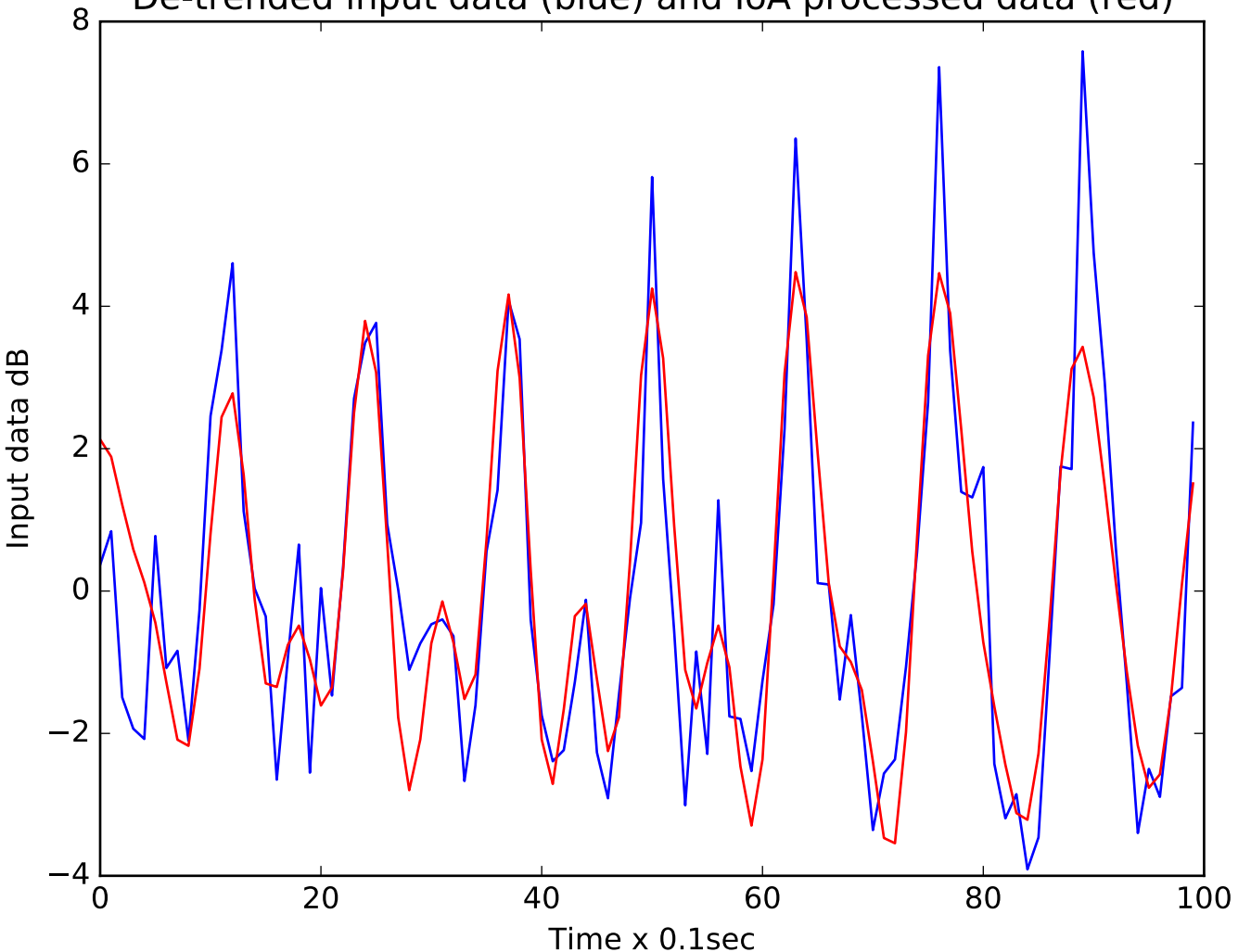
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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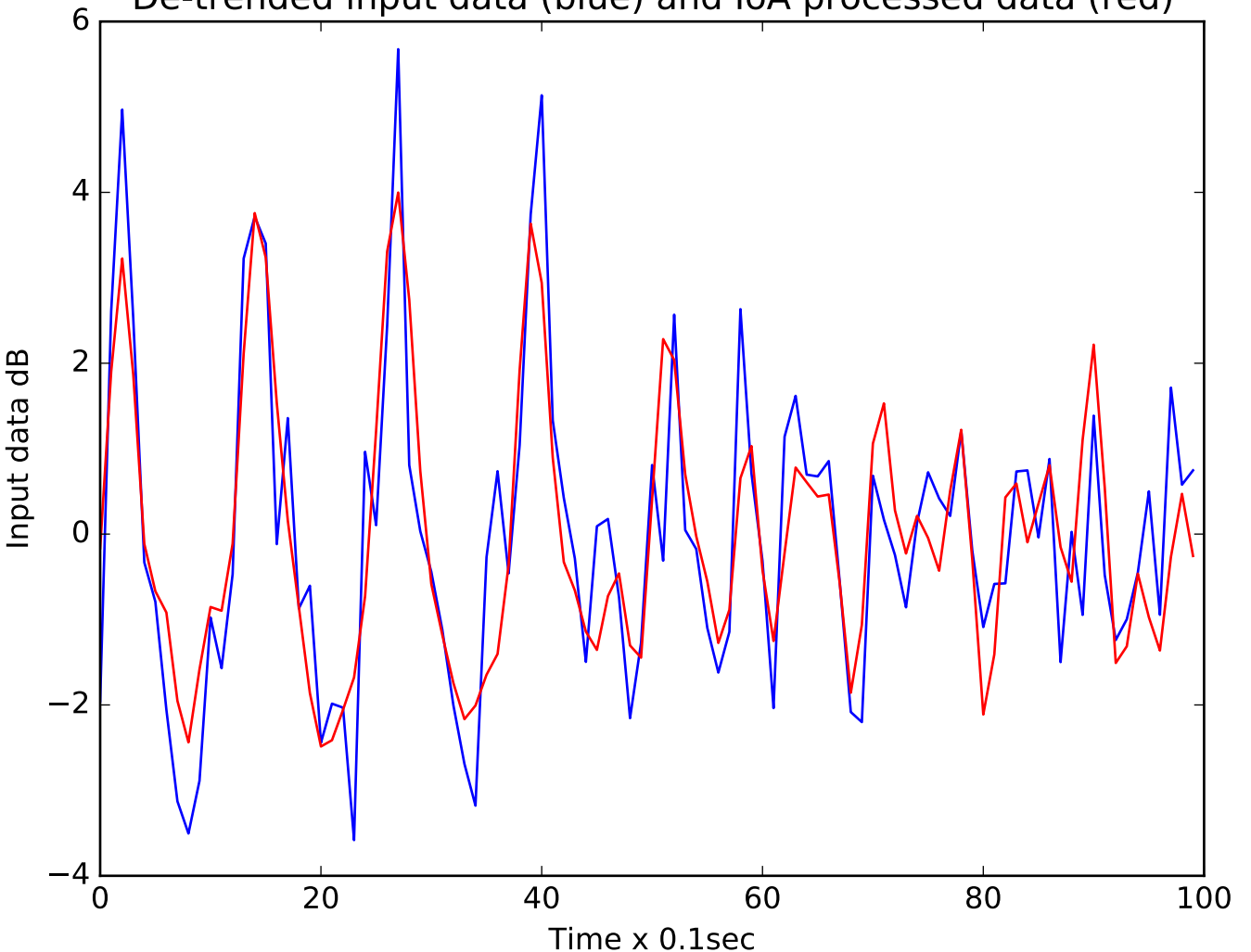
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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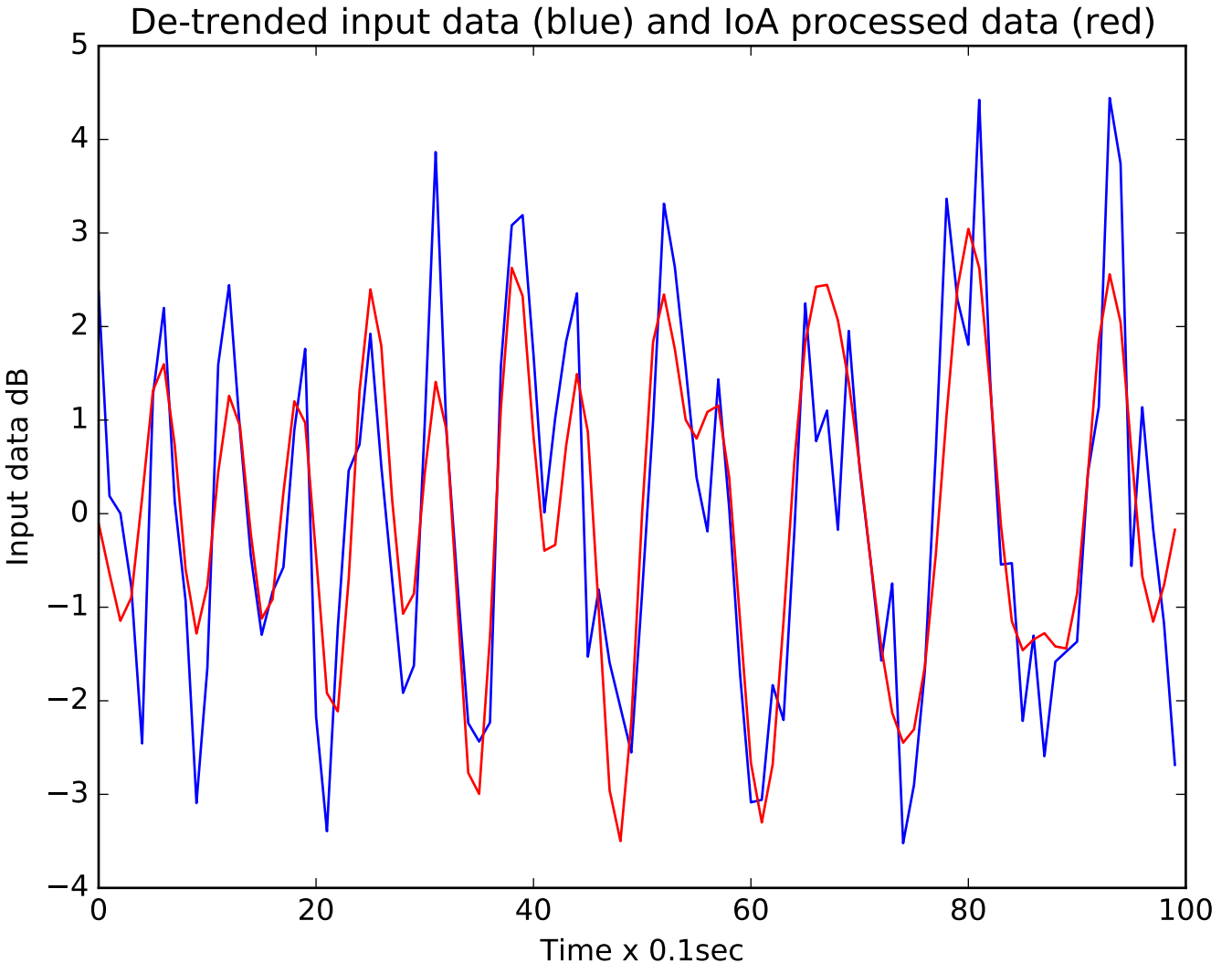
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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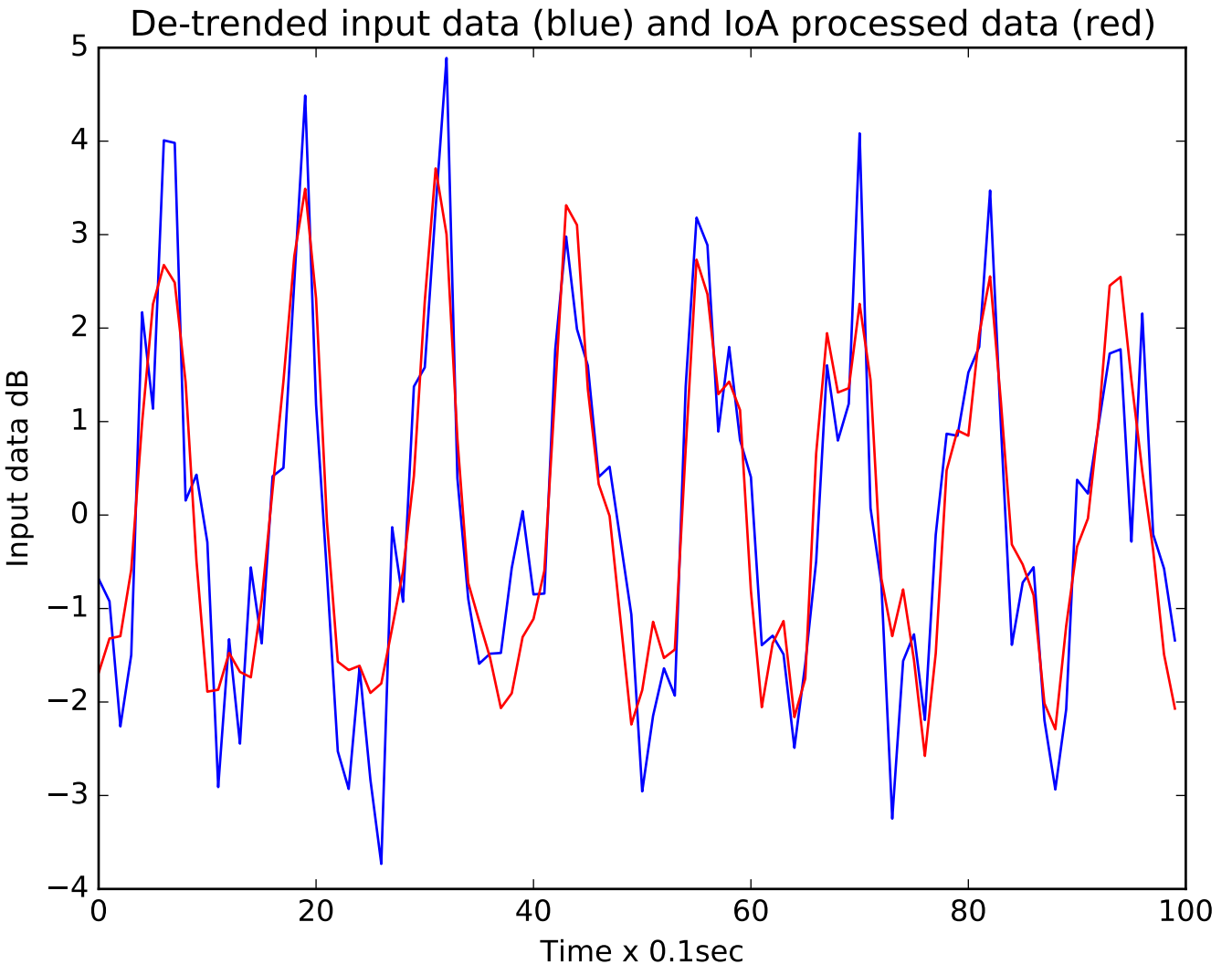
De-trended input data (blue) and IoA processed data (red)
Input data dB
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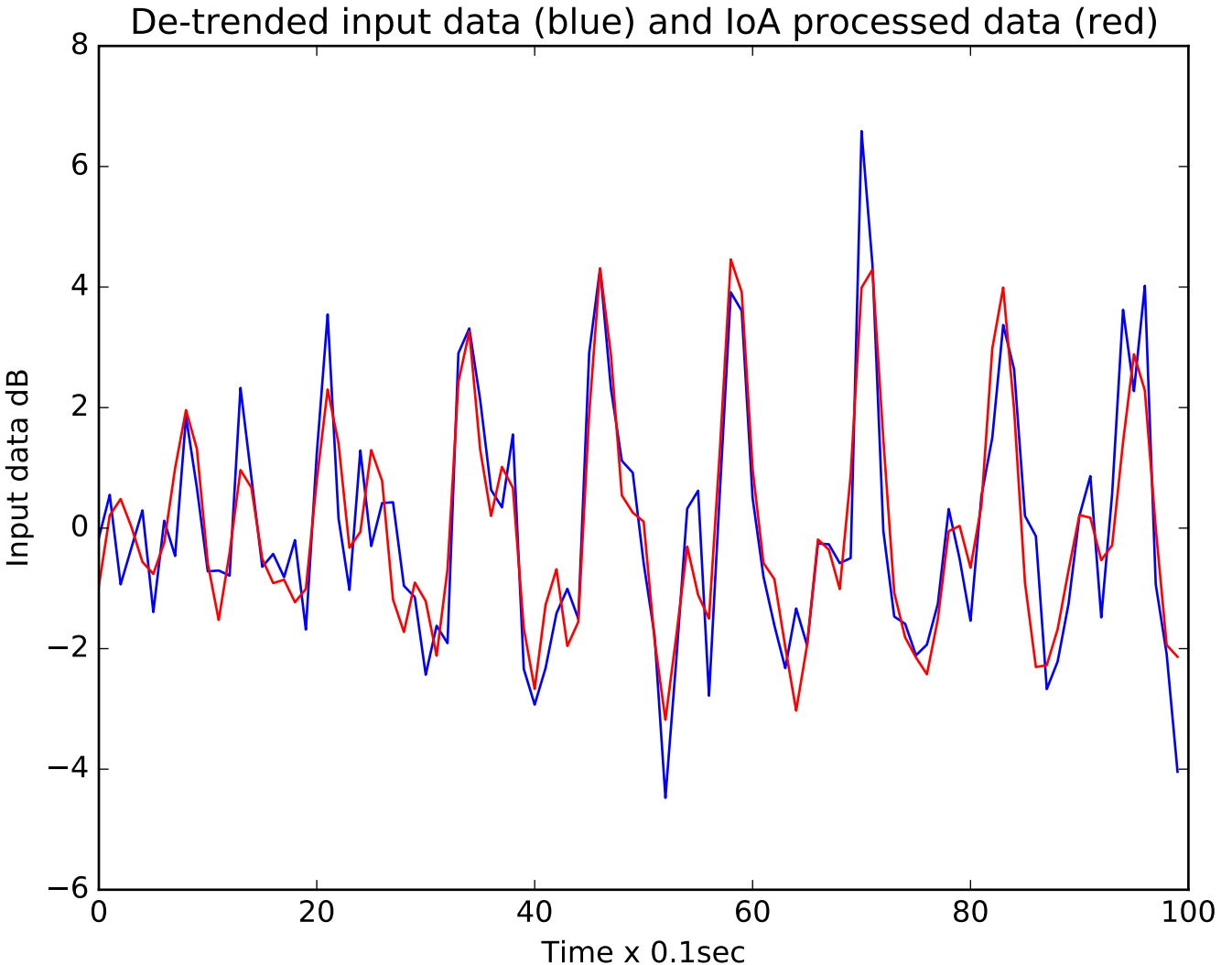
De-trended input data (blue) and IoA processed data (red)
Input data dB
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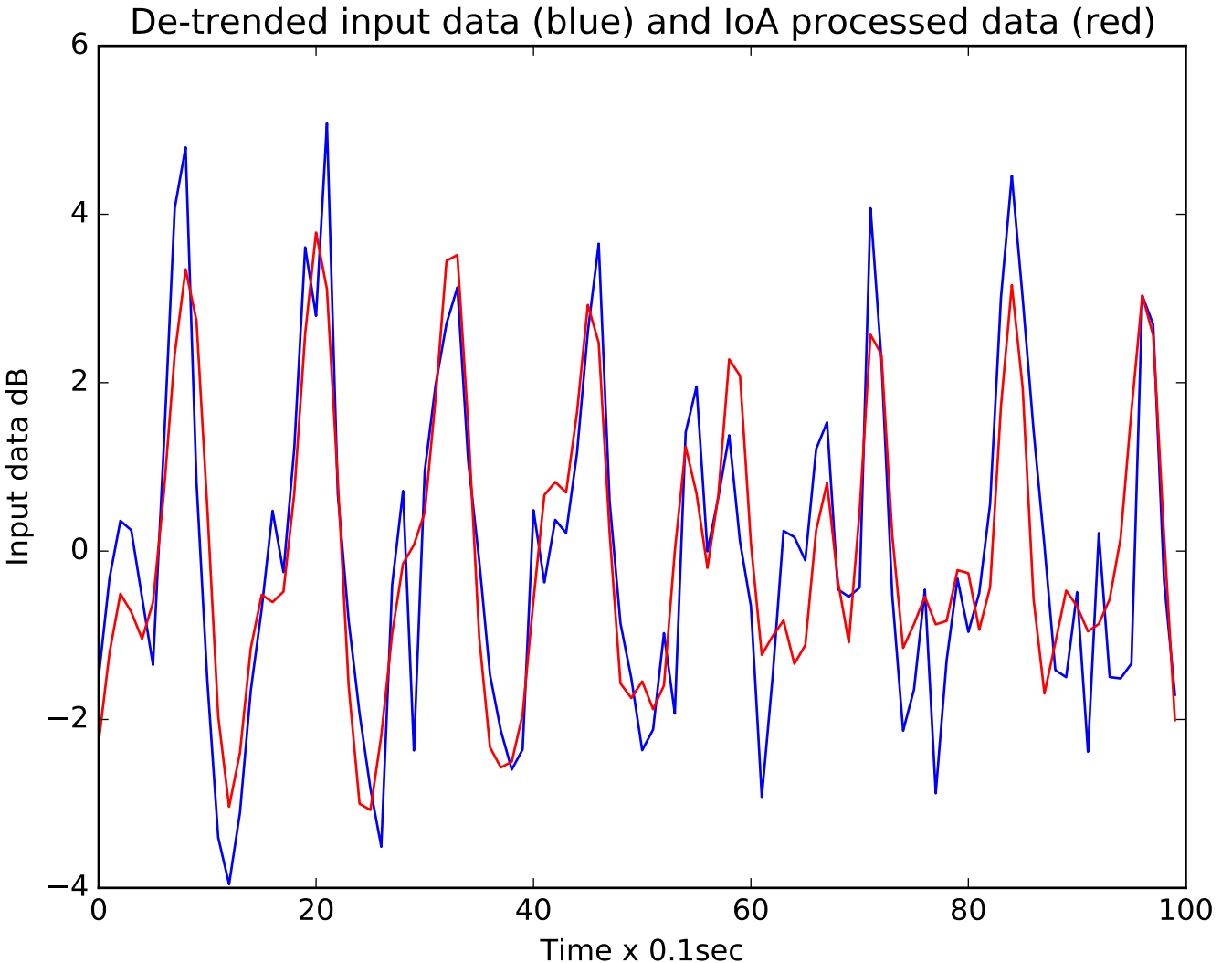
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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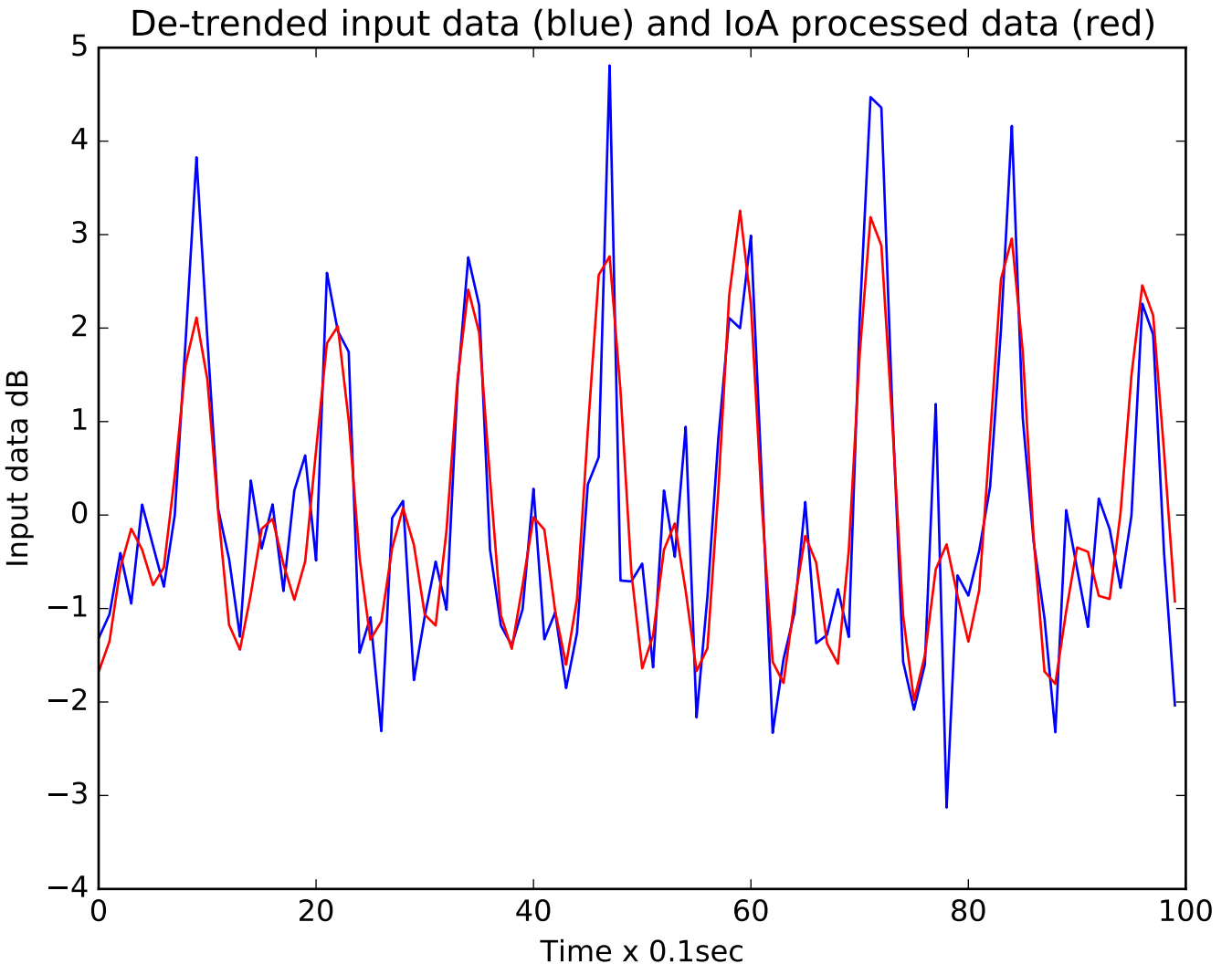
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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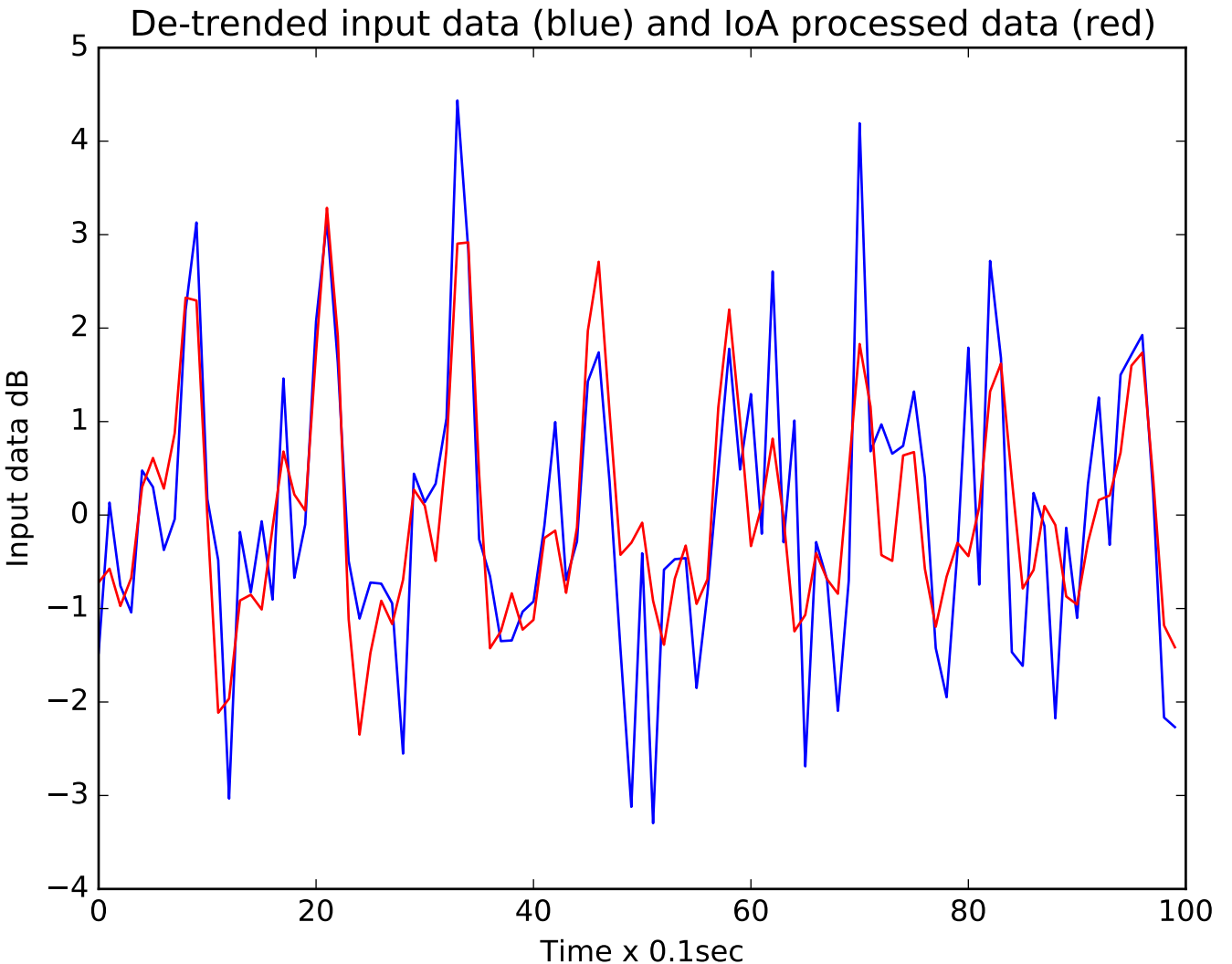
De-trended input data (blue) and IoA processed data (red)
Input data dB
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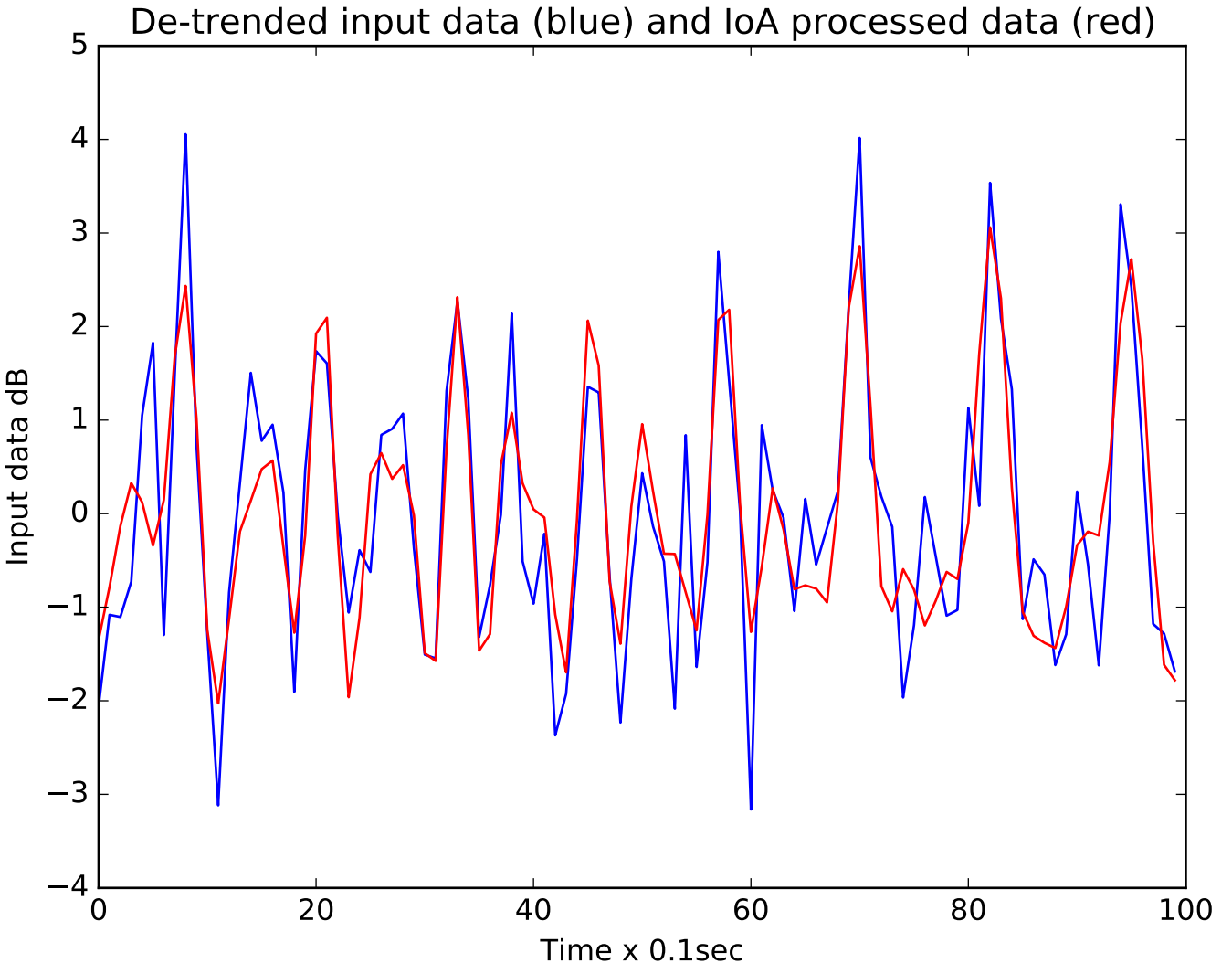
De-trended input data (blue) and IoA processed data (red)
Input data dB
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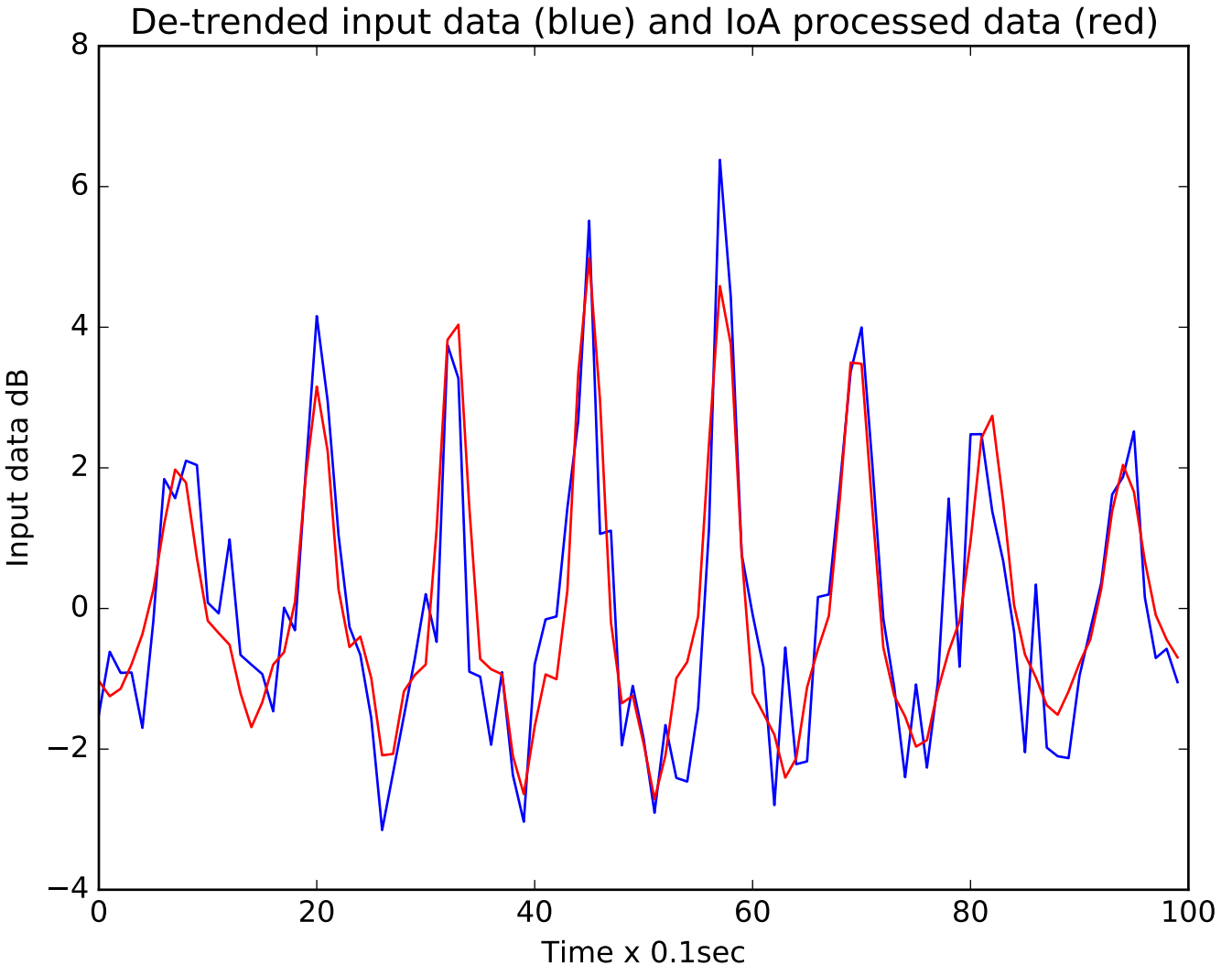
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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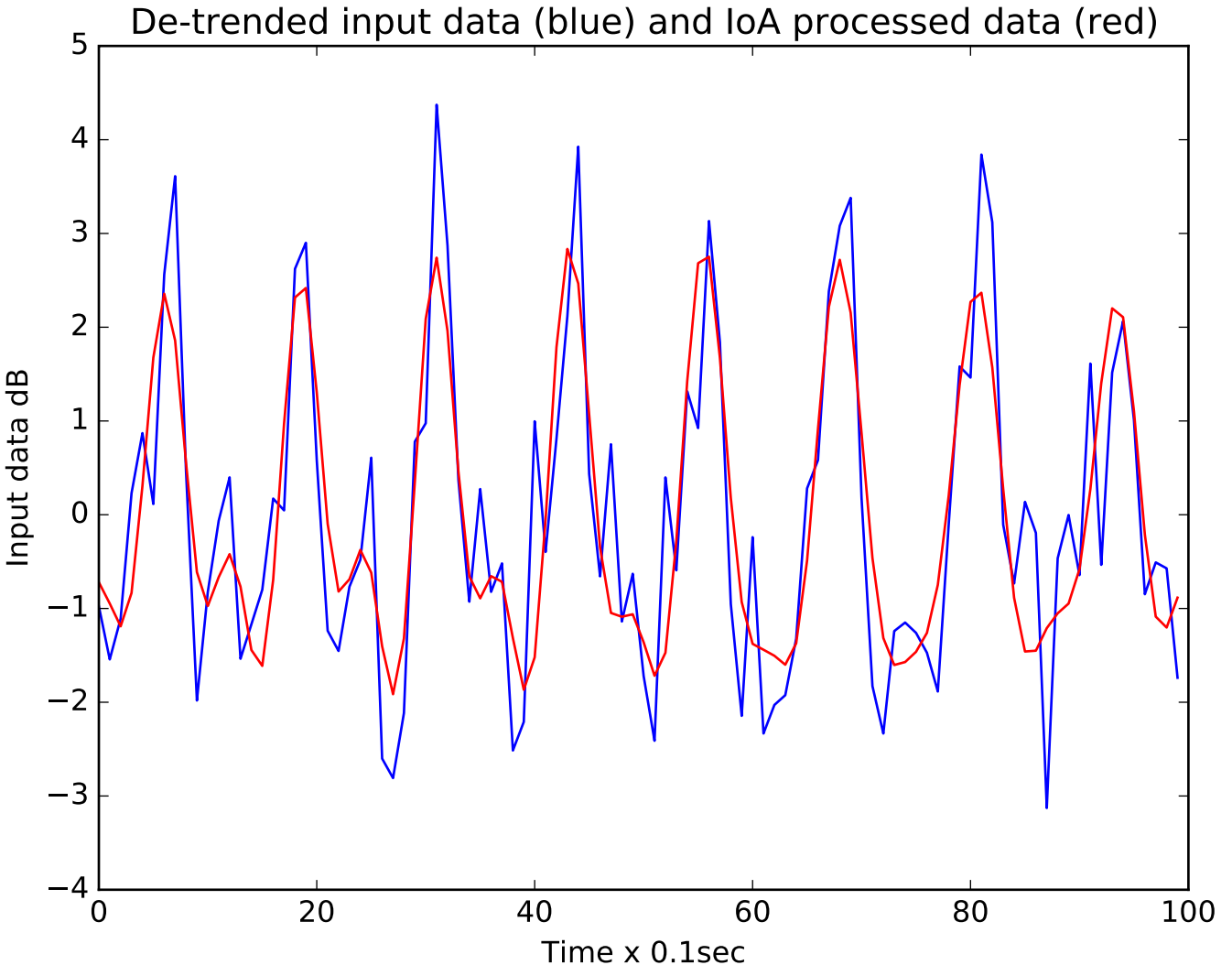
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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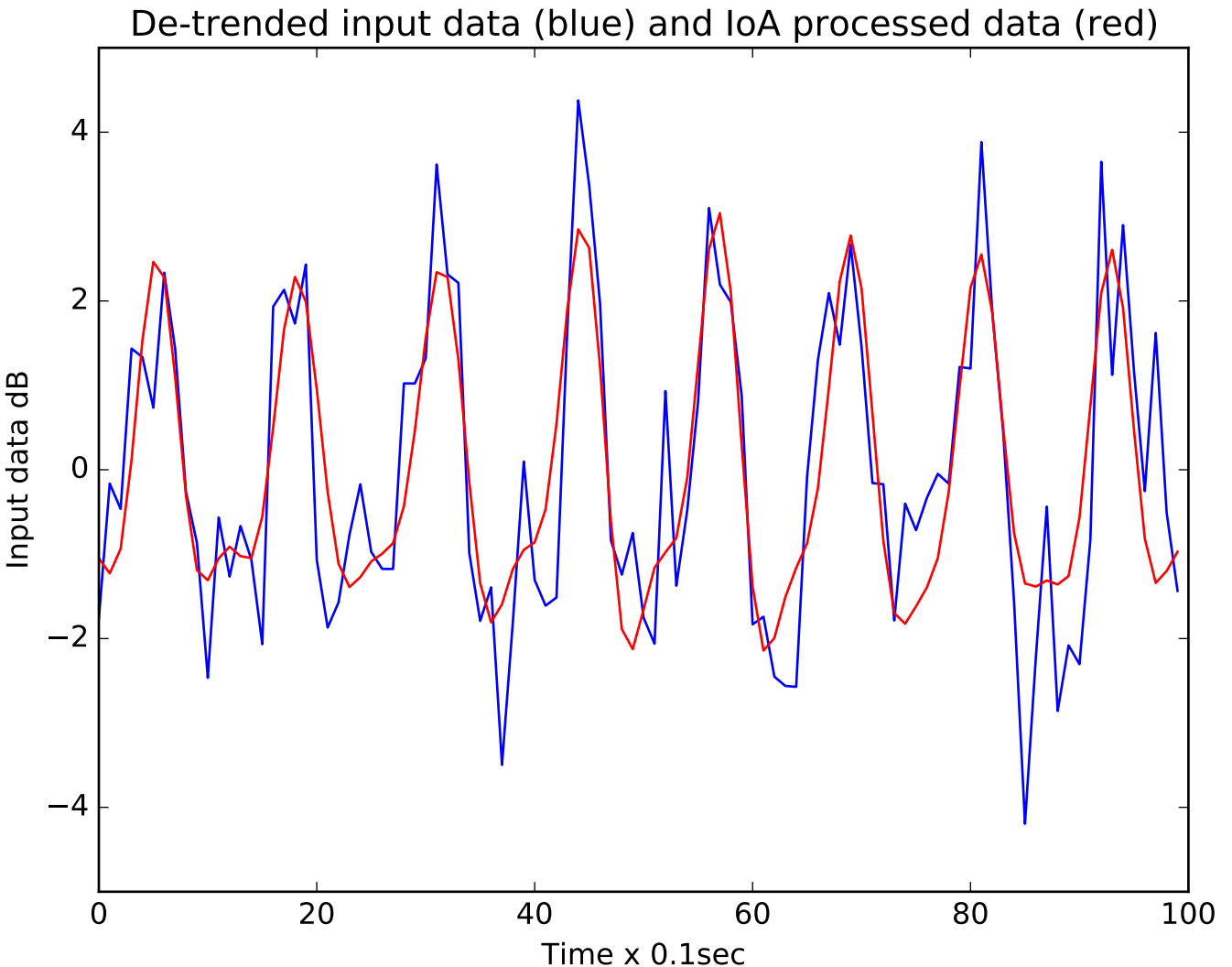
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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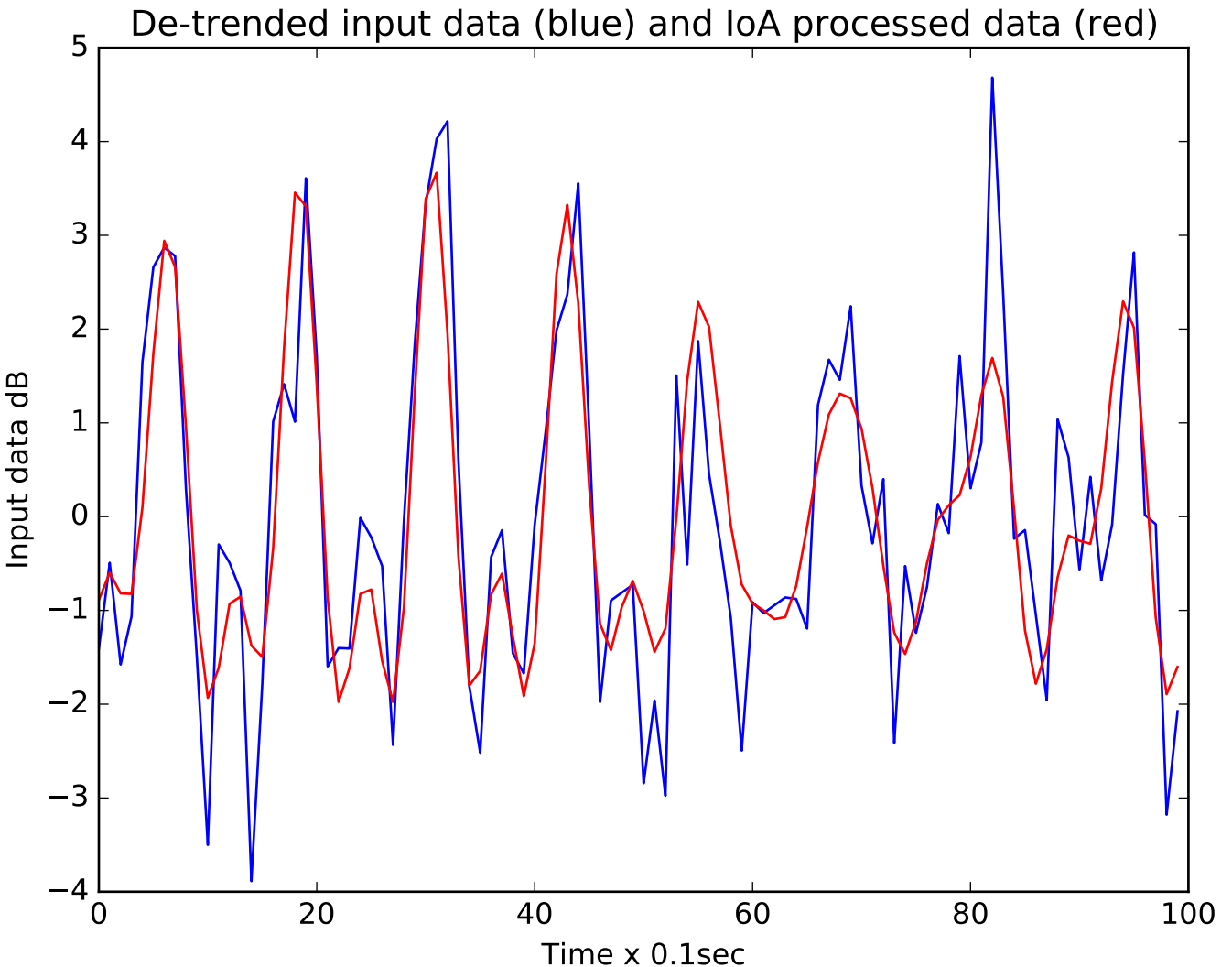
De-trended input data (blue) and IoA processed data (red)
Input data dB
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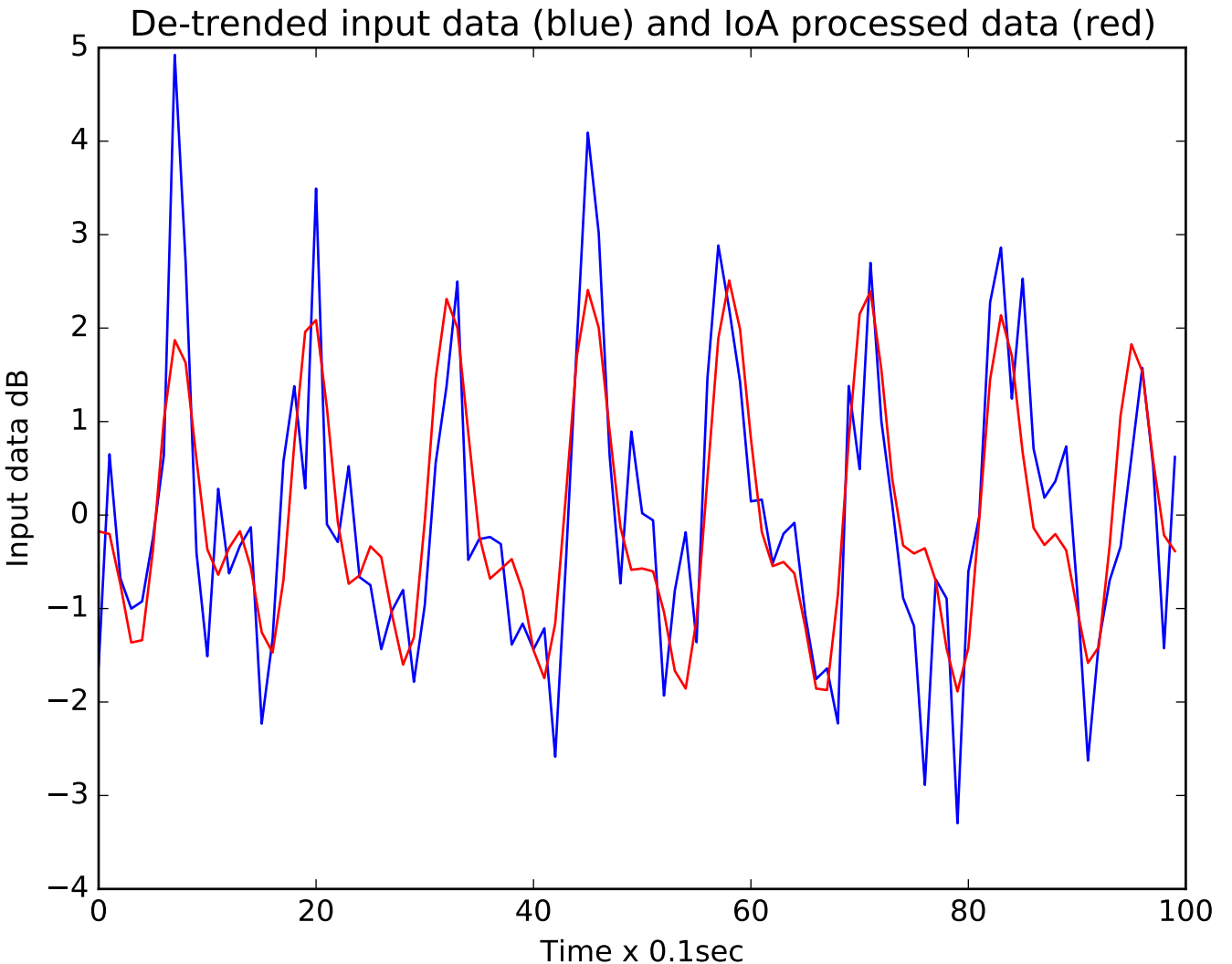
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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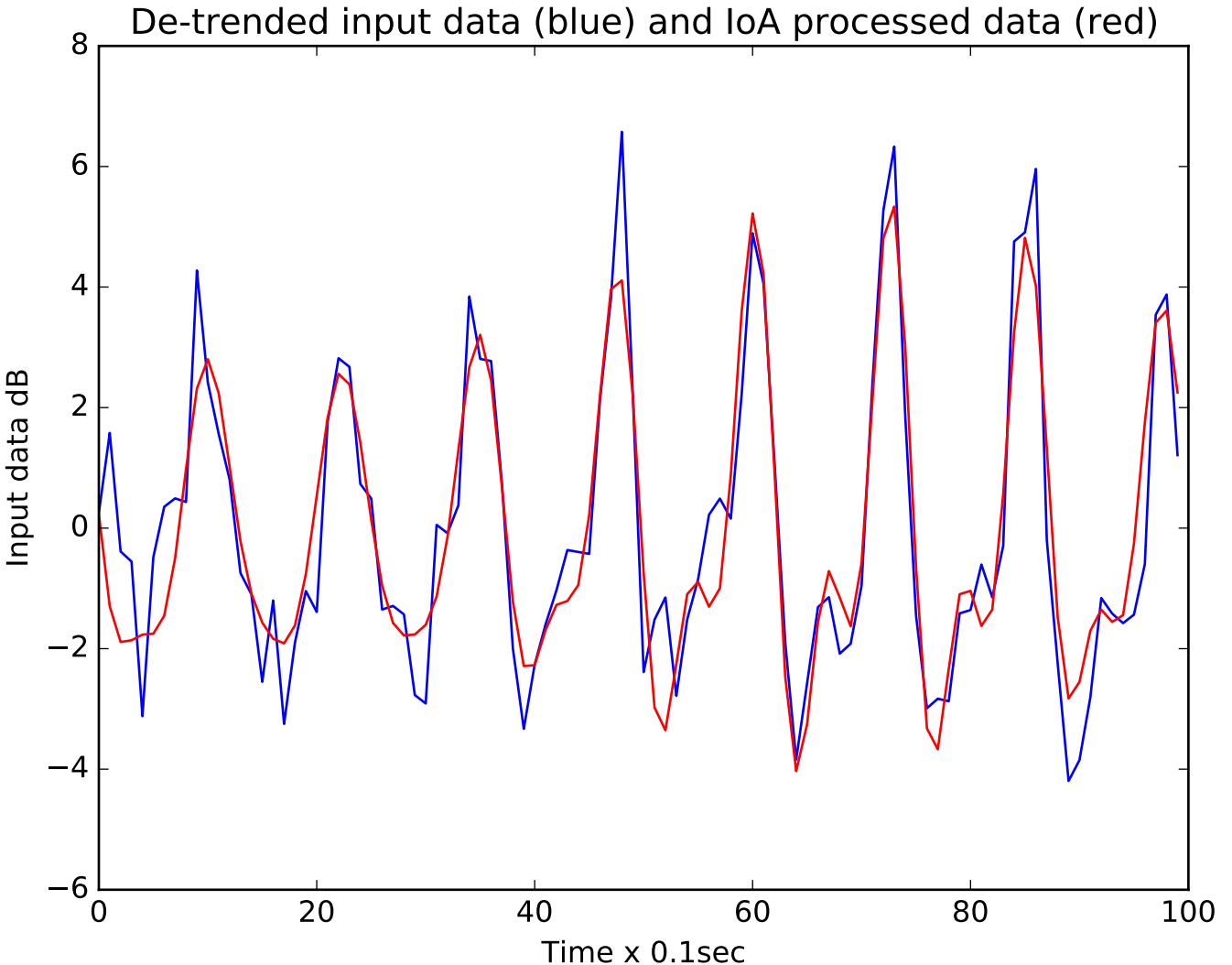
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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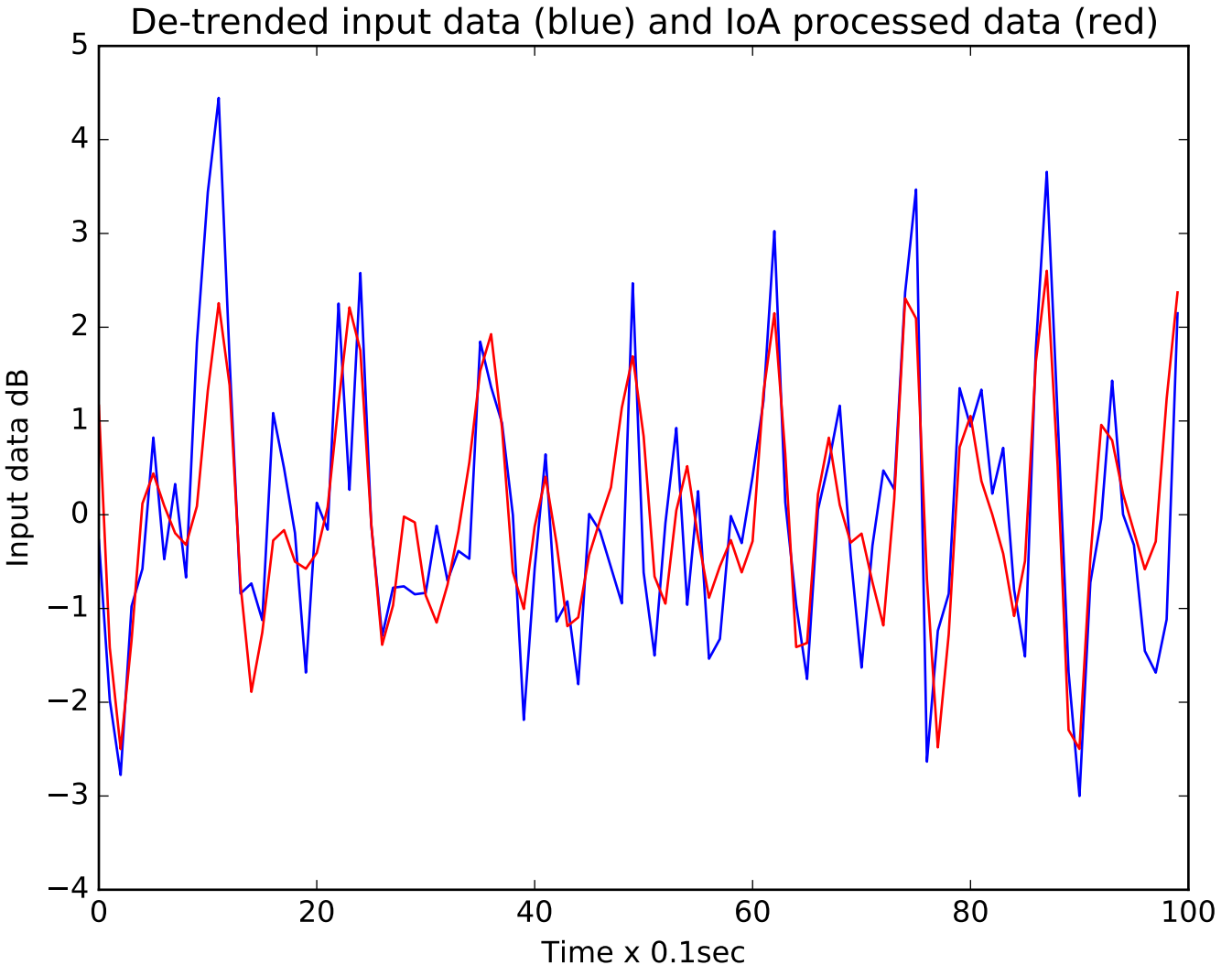
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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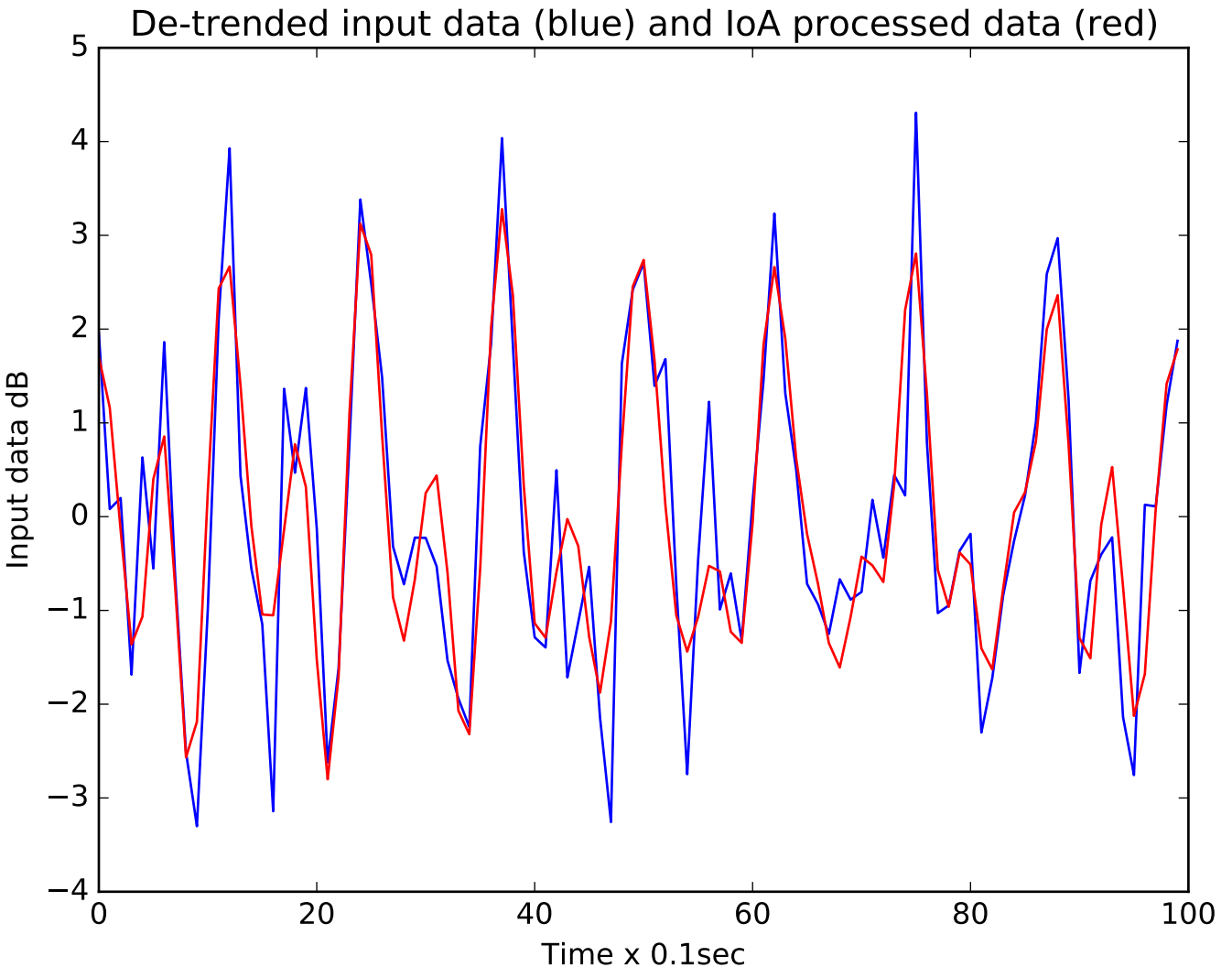
De-trended input data (blue) and IoA processed data (red)
Input data dB
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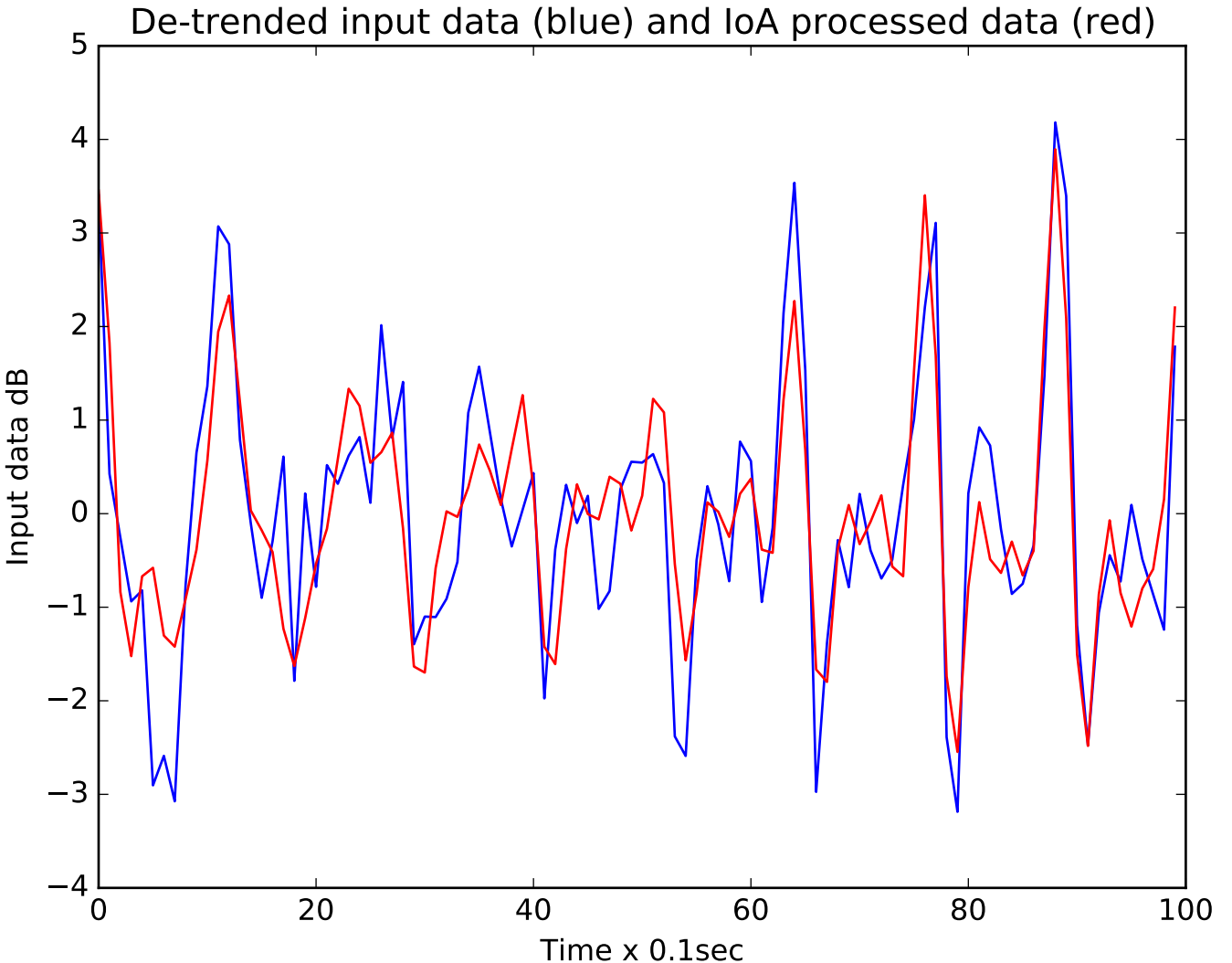
De-trended input data (blue) and IoA processed data (red)
Input data dB
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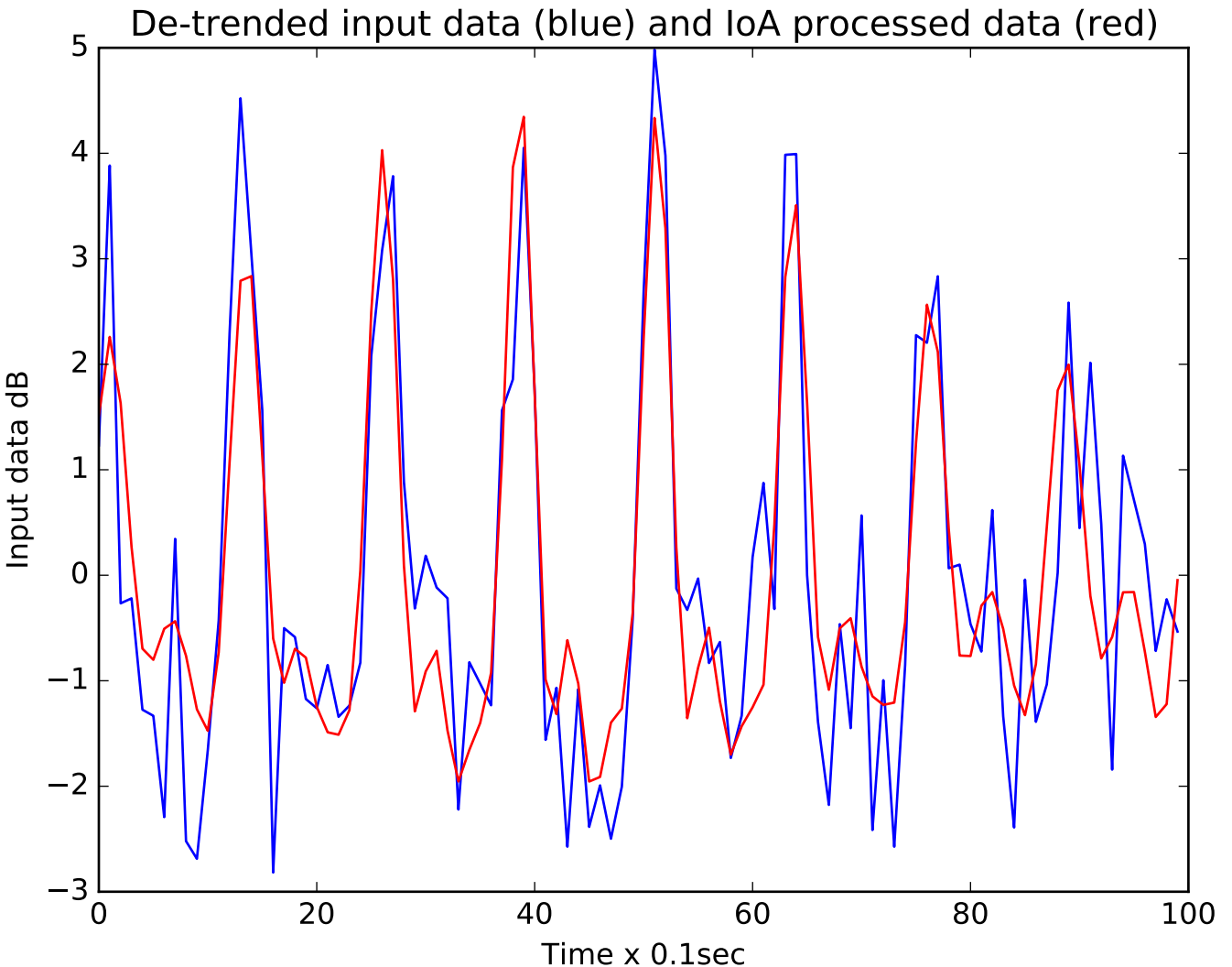
De-trended input data (blue) and IoA processed data (red)
Input data dB
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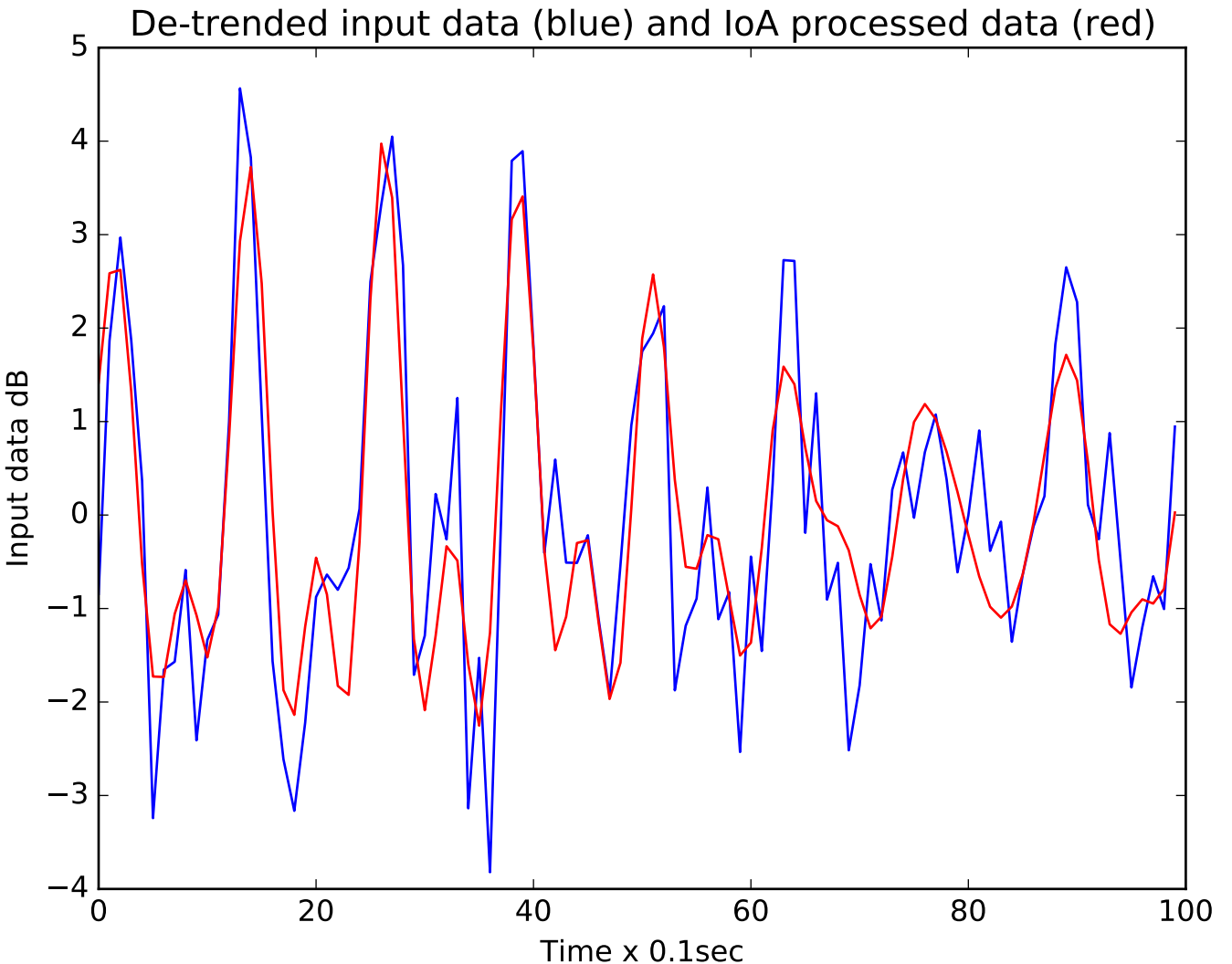
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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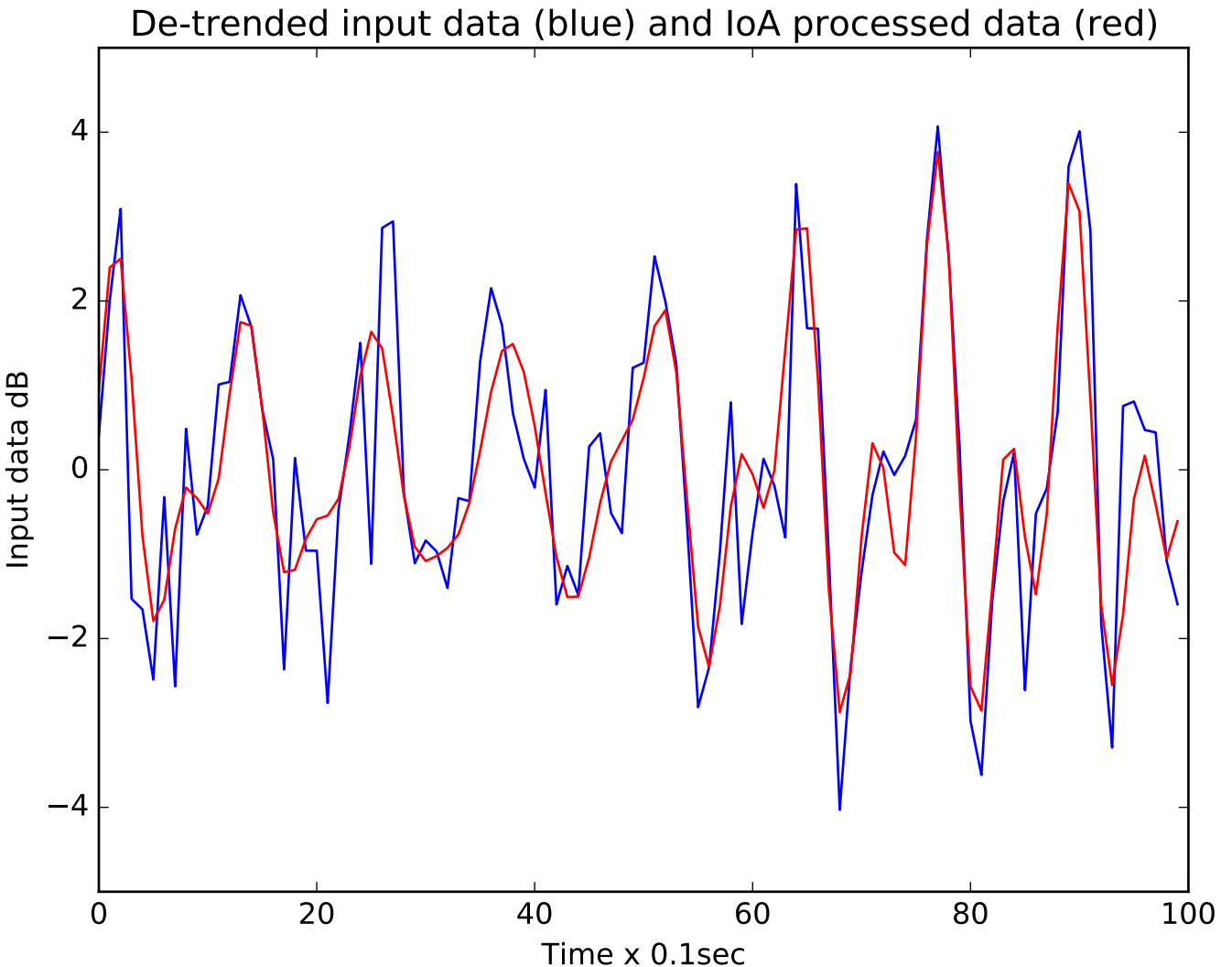
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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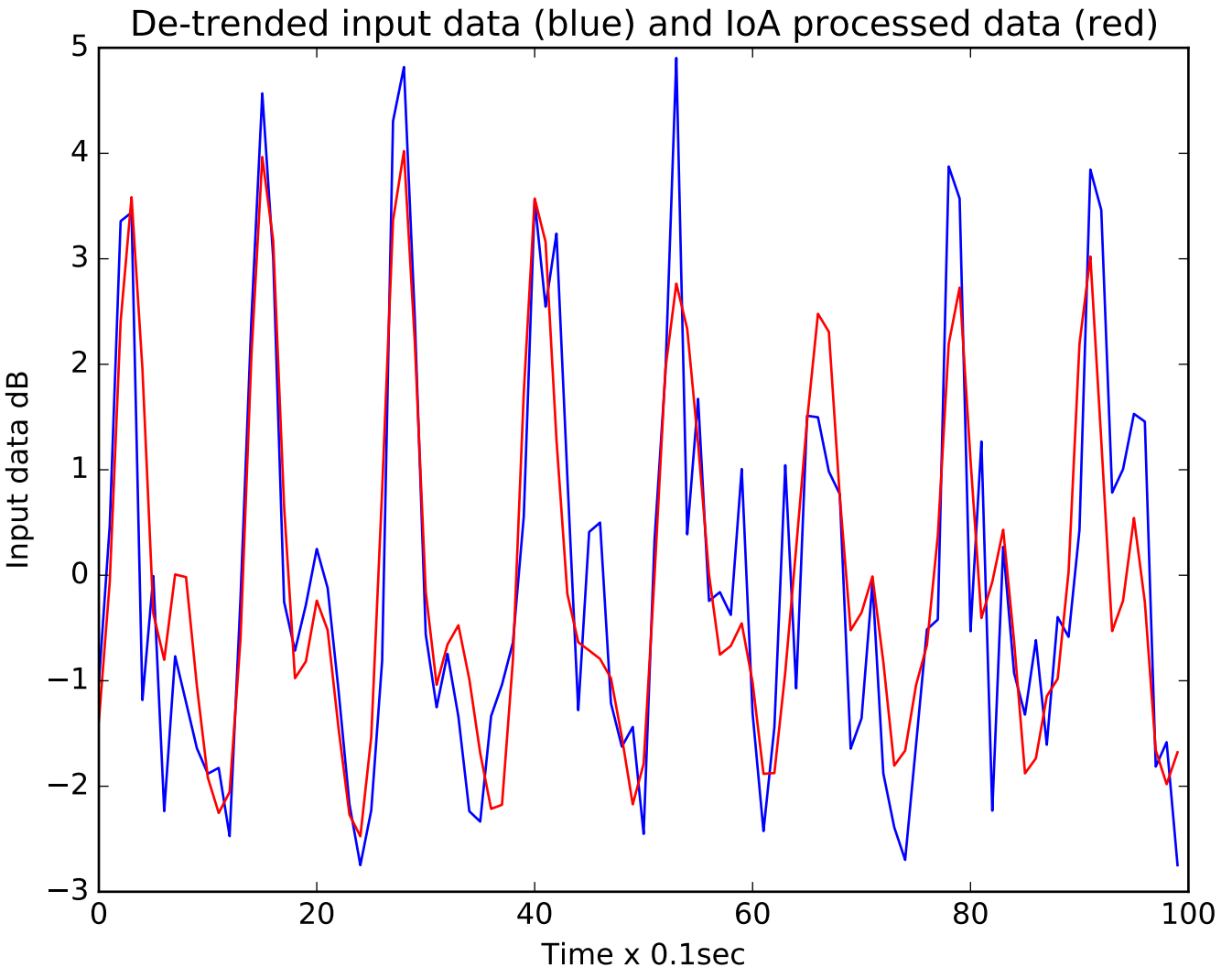
De-trended input data (blue) and IoA processed data (red)
Input data dB
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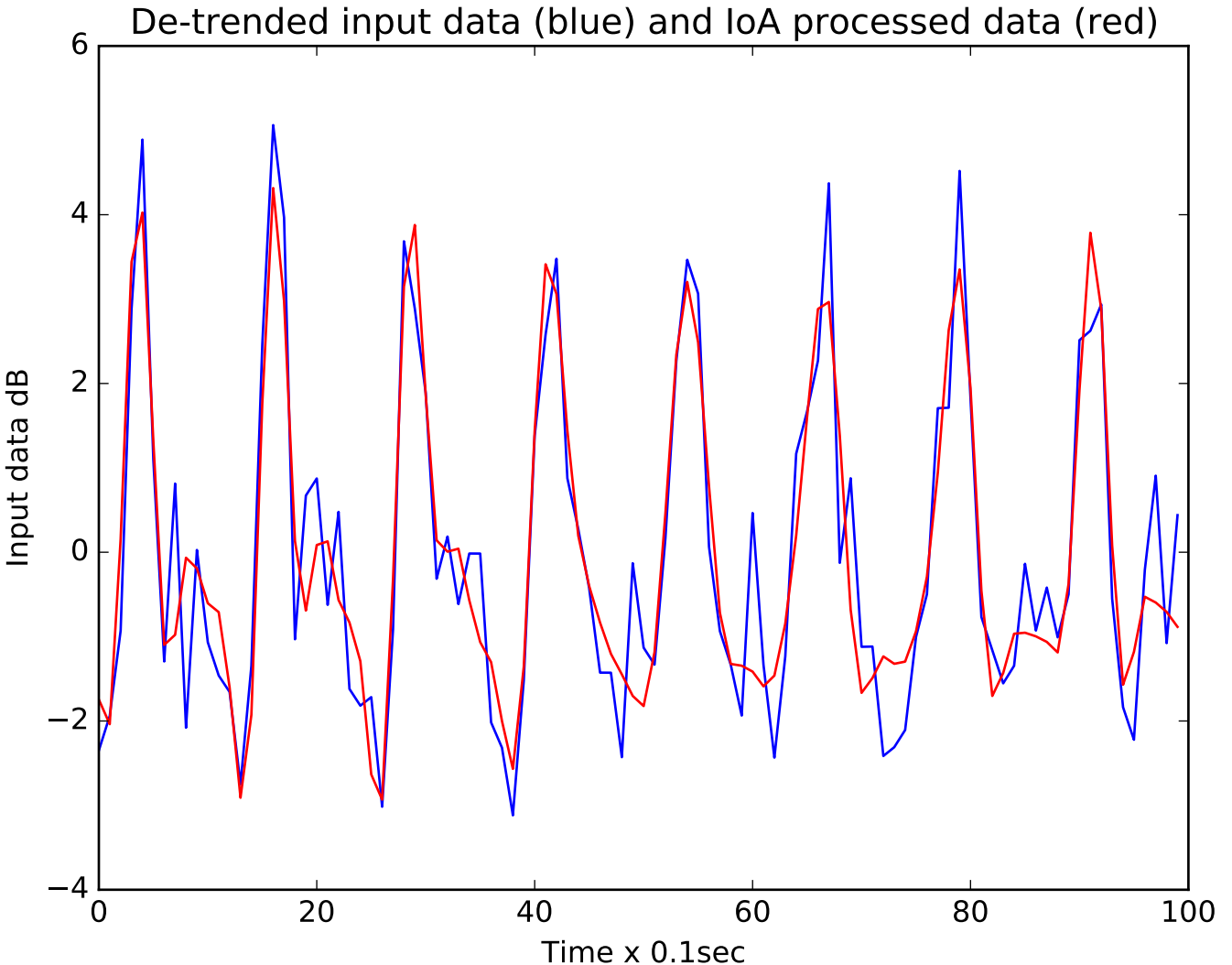
De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
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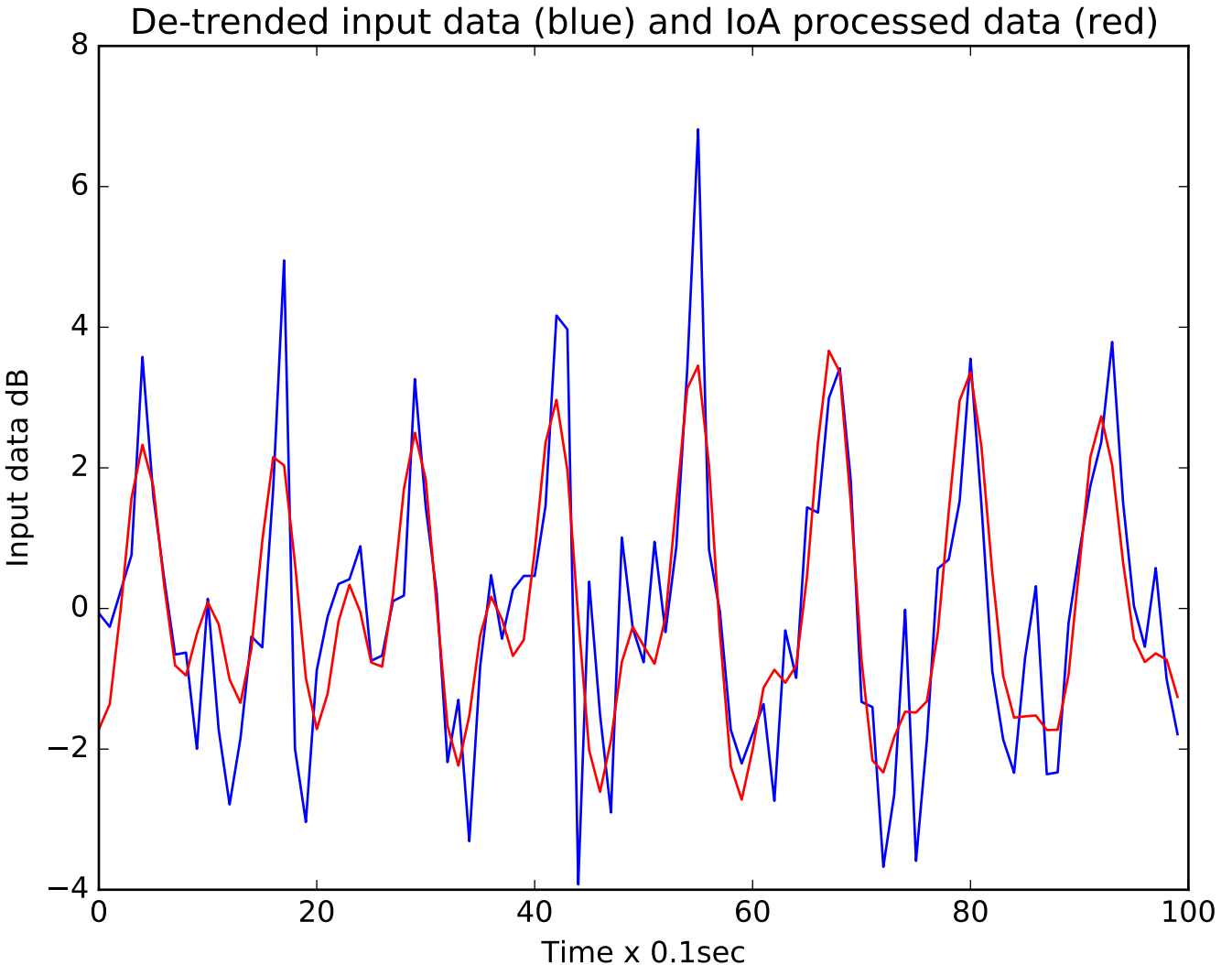
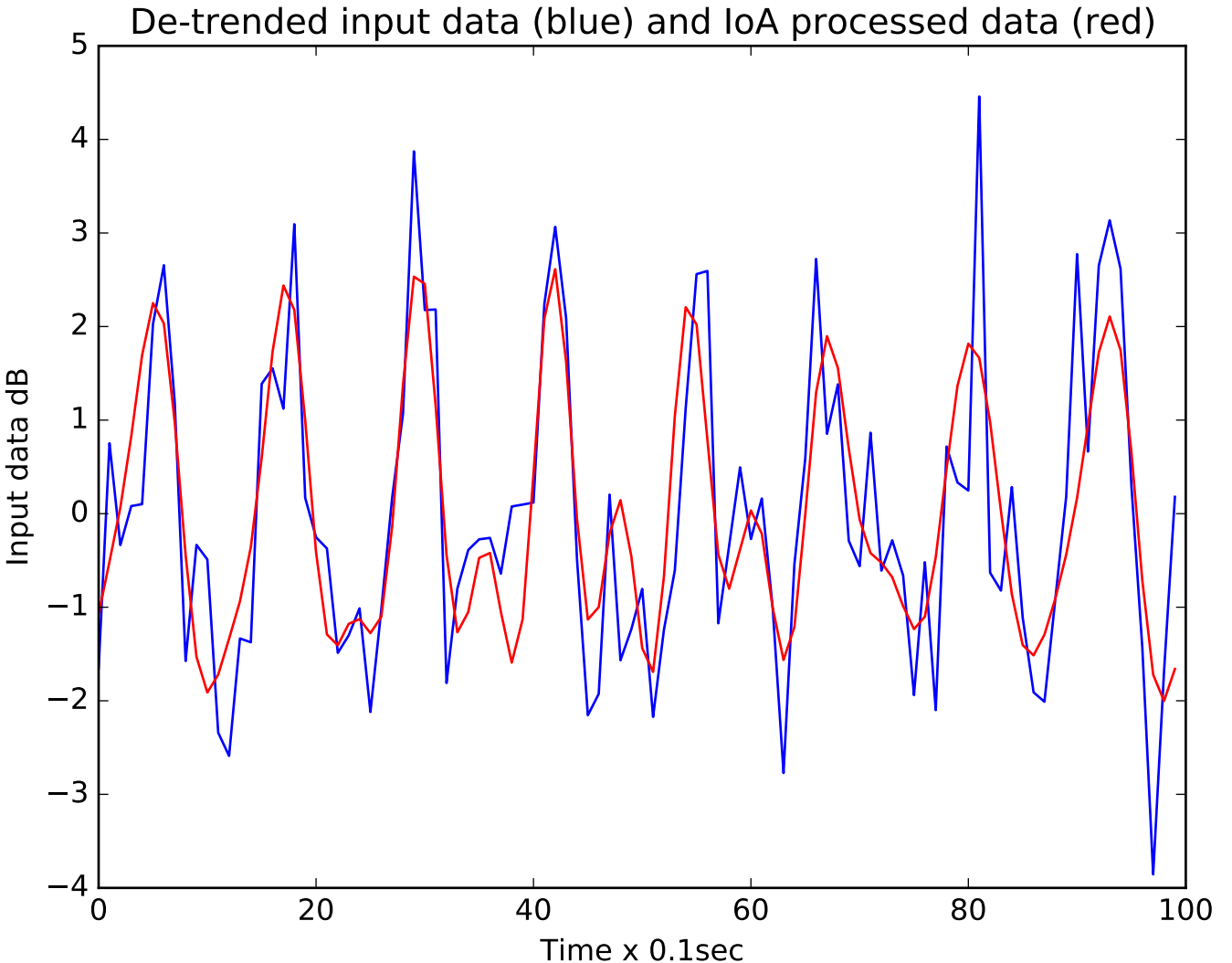
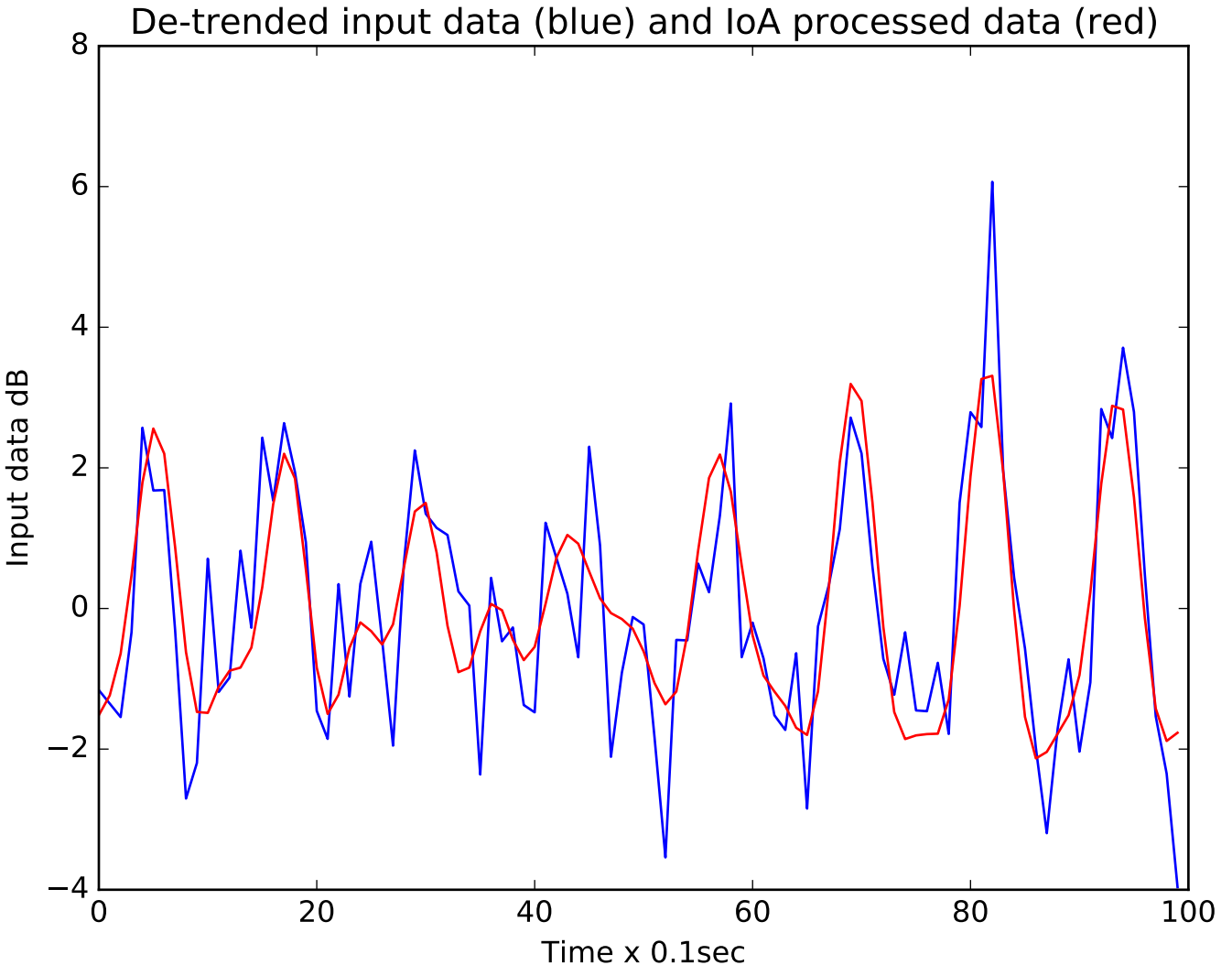
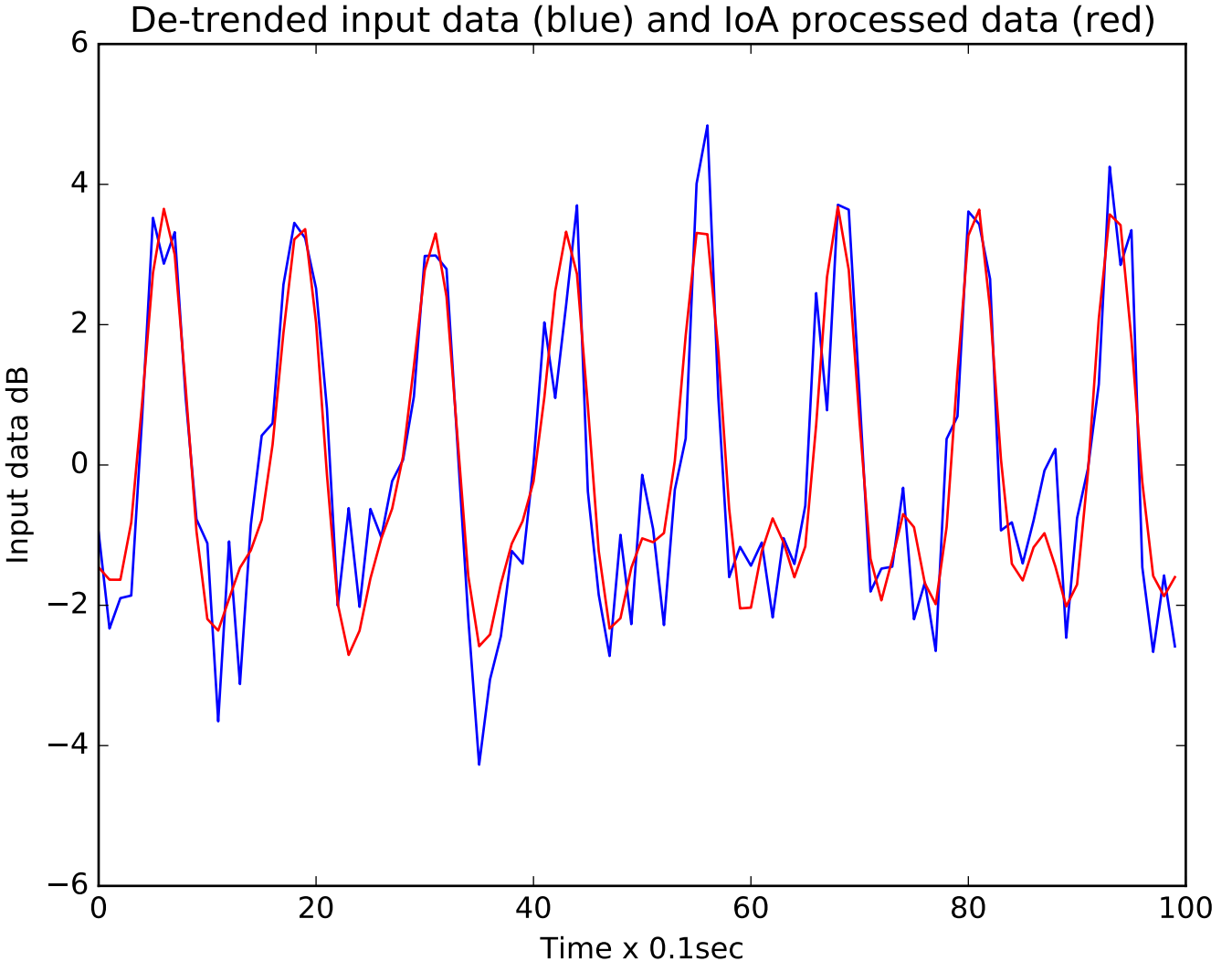
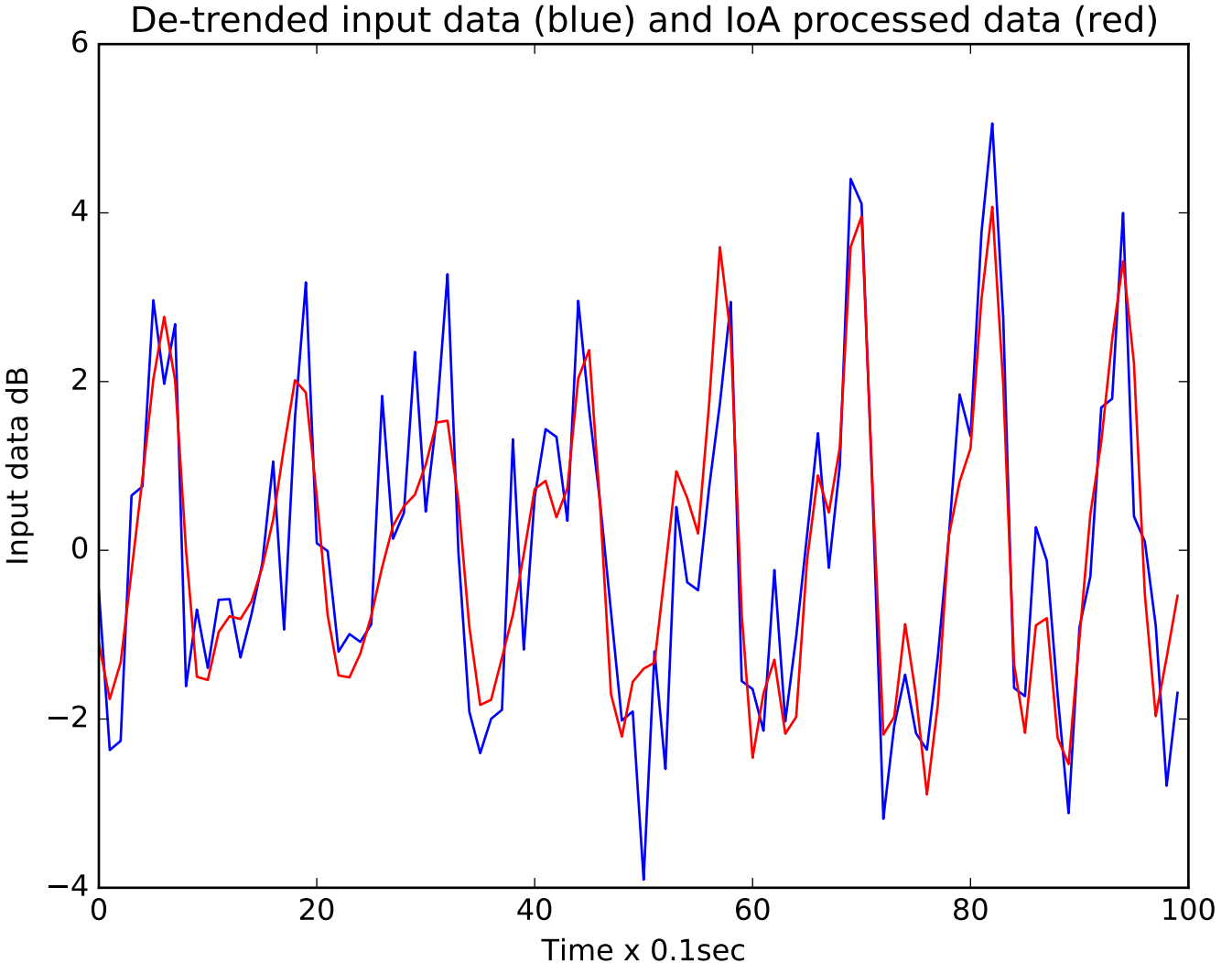
80
100

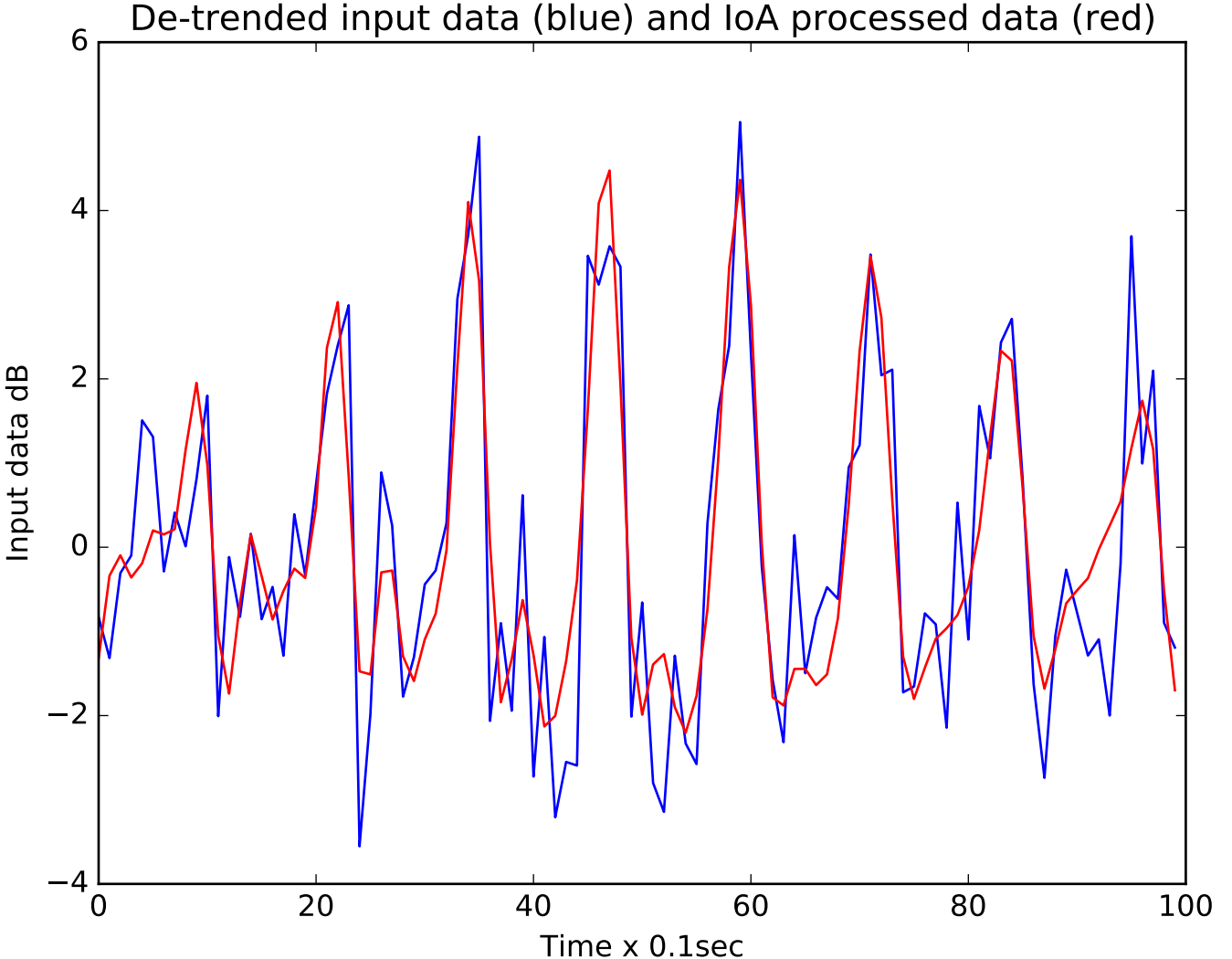

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
8
6
4
2
0
−2
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
5
4
3
2
1
0
−1
−2
−3
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
8
6
4
2
0
−2
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
−6
0
20
40
60
80
100

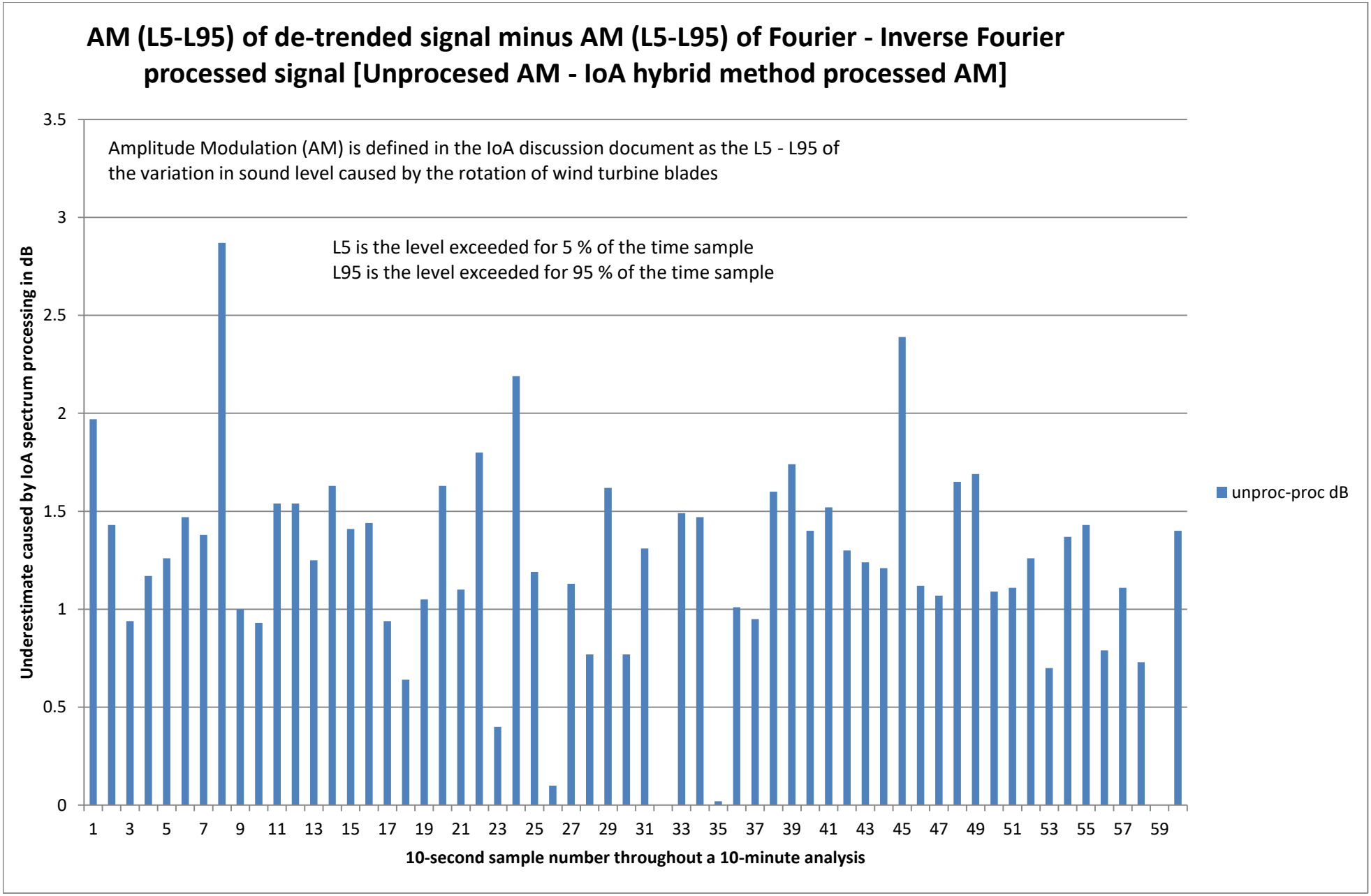

De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100


De-trended input data (blue) and IoA processed data (red)
Input data dB
Time x 0.1sec
6
4
2
0
−2
−4
0
20
40
60
80
100

Input File name: LHAM6-100to400.txt
Frequency range for modulation frequency: 0.4 to 0.9 Hz
10 minute results
10 min Block No. 10 min AM Rating (dB)
10s results

10 sec Block No.	Prominence	Fundamental Mod Freq (Hz)	10 sec AM rating (dB)	10 sec unprocessed AM (dB)	unproc-proc dB
0	31.72	0.9	4.26	6.23	1.97
1	37.17	0.8	3.59	5.02	1.43
2	81.83	0.8	4.78	5.72	0.94
3	13.87	0.8	3.35	4.52	1.17
4	73.84	0.8	4.66	5.92	1.26
5	157.1	0.8	4.04	5.51	1.47
6	29.8	0.8	4.13	5.51	1.38
7	10.08	0.9	1.85	4.72	2.87
8	23.52	0.8	3.91	4.91	1
9	95.68	0.8	5.57	6.5	0.93
10	22.54	0.8	4.3	5.84	1.54
11	8.17	0.8	3.18	4.72	1.54
12	91.66	0.8	6.48	7.73	1.25
13	251.99	0.8	4.79	6.42	1.63
14	26.24	0.8	4	5.41	1.41
15	74.7	0.8	5.36	6.8	1.44
16	17.75	0.8	3.19	4.13	0.94
17	67.64	0.8	5.3	5.94	0.64
18	23.98	0.8	4.38	5.43	1.05
19	168.13	0.8	4.28	5.91	1.63
20	16.95	0.8	5.91	7.01	1.1
21	12.68	0.7	3.8	5.6	1.8
22	23.49	0.8	4.81	5.21	0.4
23	10.41	0.8	3.12	5.31	2.19
24	8.26	0.8	3.83	5.02	1.19
25	36.01	0.8	8.85	8.95	0.1
26	43.02	0.8	4.59	5.72	1.13

27	26.04	0.8	4.84	5.61	0.77
28	15.83	0.8	2.7	4.32	1.62
29	24.64	0.8	6.67	7.44	0.77
30	19	0.8	5.29	6.6	1.31
31	3.86				0
32	23.15	0.8	5.11	6.6	1.49
33	97.54	0.8	4.85	6.32	1.47
34	59.37	0.8	6.2	6.22	0.02
35	14.69	0.8	5.51	6.52	1.01
36	64.73	0.8	4.25	5.2	0.95
37	13.58	0.8	3.71	5.31	1.6
38	30.71	0.8	3.88	5.62	1.74
39	56.65	0.8	5.6	7	1.4
40	129.22	0.8	4.08	5.6	1.52
41	57.02	0.8	4.42	5.72	1.3
42	73.37	0.8	4.77	6.01	1.24
43	36.04	0.8	3.81	5.02	1.21
44	180.9	0.8	7.11	9.5	2.39
45	27.03	0.8	3.59	4.71	1.12
46	64.72	0.8	4.74	5.81	1.07
47	34.27	0.8	3.87	5.52	1.65
48	30.3	0.8	4.82	6.51	1.69
49	26.61	0.8	4.82	5.91	1.09
50	31.12	0.8	5.01	6.12	1.11
51	76.14	0.8	5.35	6.61	1.26
52	87.84	0.8	5.42	6.12	0.7
53	131.12	0.8	5.14	6.51	1.37
54	47.99	0.8	3.87	5.3	1.43
55	29.32	0.8	4.63	5.42	0.79
56	297.13	0.8	5.7	6.81	1.11
57	63.94	0.8	5.18	5.91	0.73
58	3.55				0
59	103.81	0.8	5.22	6.62	1.4


AM (L5-L95) of de-trended signal minus AM (L5-L95) of Fourier - Inverse Fourier processed signal [Unprocesed AM - IoA hybrid method processed AM]
Amplitude Modulation (AM) is defined in the IoA discussion document as the L5 - L95 of the variation in sound level caused by the rotation of wind turbine blades
L5 is the level exceeded for 5 % of the time sample
L95 is the level exceeded for 95 % of the time sample
Underestimate caused by IoA spectrum processing in dB
3.5
3
2.5
2
1.5
1
0.5
0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
10-second sample number throughout a 10-minute analysis
unproc-proc dB