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Burst waveform undersampling circuit for ball surface acoustic wave sensor
球状弾性表面波センサのためのバースト波アンダーサンプリング回路

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1. Introduction

The ball surface acoustic wave (SAW) sensor, sensitively measuring the delay time and amplitude changes of SAW based on multiple-roundtrip prapagation[1], can realize precise temperature compensation by two-freqneucy measurement (TFM)[2]. Since the cost reduction of a measurement circuit is essential for practical use, we proposed a temperature compensation principle using undersampling (US) waveform, and verified it by a simulation using the decimation of oversampling waveform[3]. Here, narrow band-pass filter (BPF) was important for the prevention of a crosstalk of TFM. In this study, we develop burst waveform US (BUS) circuit based on the principle[3], where US was applied to the burst waveform after filtered by the narrow BPF and apply it to a trace moisture measurement.

2. BUS circuit

A schematic illustration of BUS circuit is shown in **Fig. 1**.

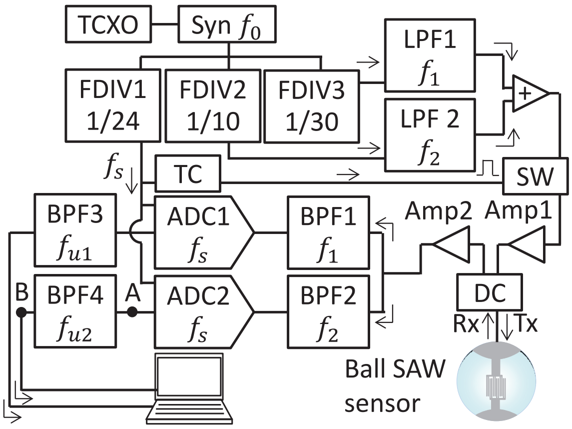

Fig. 1 Schematic illustration of BUS circuit. (TCXO: temperature-compensated crystal oscillator, Syn: synthesizer, FDIV: frequency divider, LPF: low-pass filter, TC: timing controller, SW: rf switch, Amp: amplifier, DC: directional coupler, BPF: band-pass filter, ADC: analog-digital converter)

Continuous signal at f_0=2.4 GHz of a synthesizer (Syn) is synchronously down-converted, using frequency dividers (FDIV1, 2, and 3), to f_1=80 MHz, f_2=240 MHz, and f_s=100MHz, respectively. The signals of f_1 and f_2 are added and the transmission burst waveform Tx is generated, using an rf switch (SW). The reflection waveform Rx is filtered by BPF1 and BPF2 with Q factors of 20 and 40, respectively. To select the US frequency components of f_{u1}=20 MHz and f_{u2}=40 MHz, we applied a wavelet transform using Gabor function (γ=50) as BPF3 and BPF4[3]. Prototype circuit is shown in **Fig. 2**.

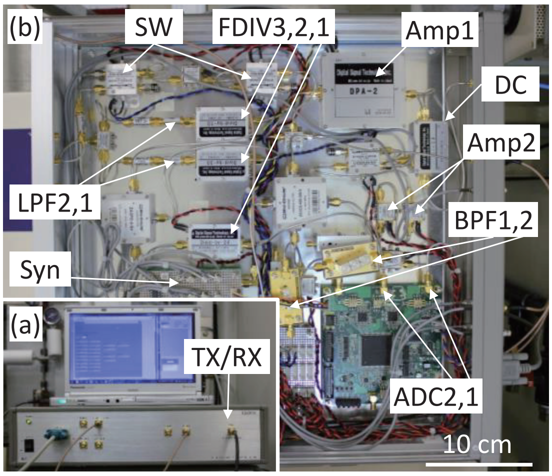

Fig. 2 Prototype of BUS circuit. (a) Front panel with control computer. (b) Inner structure.

3. Experiment

A quartz harmonic ball SAW sensor (3.3 mm diameter, 80 MHz fundamental frequency) was coated with sol-gel SiOx film, was set to ultra-high vacuum cell[4], and was applied to the measurement of N_2 flow (1 L/min) of trace moisture generator.

4. Results

4.1 US waveform

US waveform at position A in Fig. 1 is shown in **Fig. 3(a)**. The amplitude at f_{u2} was larger than that at f_{u1} by 33.8 dB [solid line in Fig. 3(b)].

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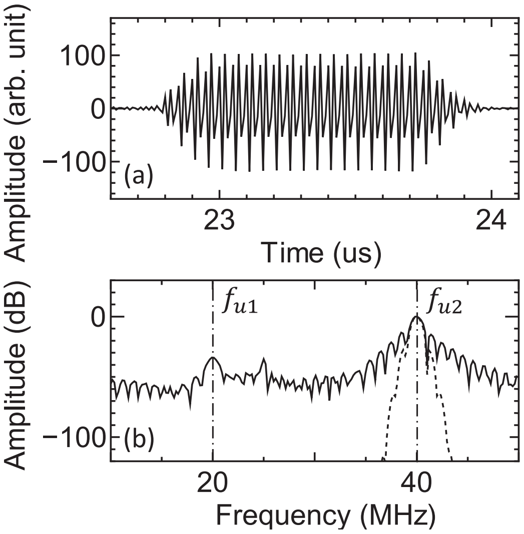

Fig. 3 US burst waveform at position A in Fig. 1.
(a) Waveform. (b) FFT spectra, where solid and broken lines represent original and wavelet-transform-filtered data, respectively.

A result of the wavelet transform is shown in **Fig. 4**. Figure 4(a) shows a part of Fig. 3(a). Figure 4(b) show a waveform interpolated by a factor of 100, where solid and broken lines show the real part and the magnitude, respectively. The zero cross time closest to the maximum magnitude shown by chained line was measured as the delay time.

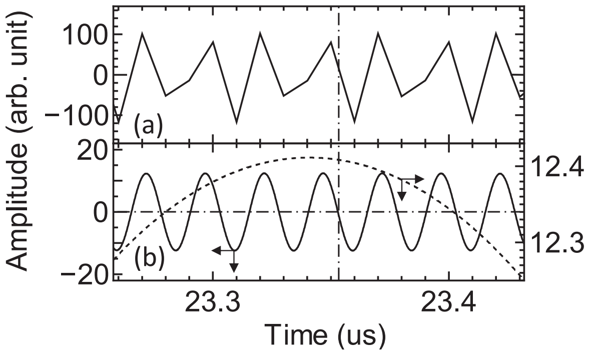

Fig. 4 Interpolation by wavelet transform.
(a) Original data at position A in Fig. 1.
(b) Wavelet-transformed data at position B in Fig. 1, where solid and broken lines represent real part and magnitude, respectively. Chained line represents zero cross time for delay time measurement.

4.2 Temperature compensation

The sensor outputs to trace moisture are shown in **Fig. 5**. Fractional delay time changes of Δt_{u1} at f_{u1} and Δt_{u2} at f_{u2} are plotted, divided by the magnification factors of -4 and 6, respectively[3][Figs. 5(a) and (b)]. The fluctuation of the output to constant concentration during 4-7 h was removed by the subtraction $\Delta t_{u2}/6 - \Delta t_{u1}/(-4)$ [Fig. 5(c)]. A signl-to-noise ratio to the concentration change of 2.4-18 nmol/mol was 92.1, where rms noise during 0-1 h was 0.00998 ppm.

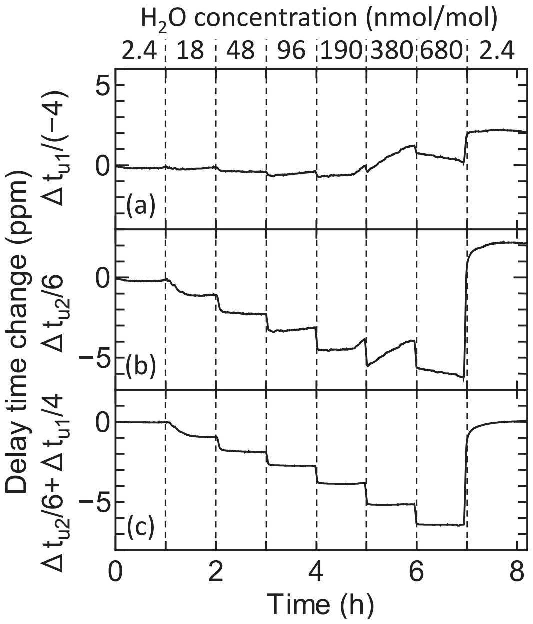

Fig. 5 Application to trace moisture measurement, where solid and broken lines show fractional delay time changes from the 3rd to the 7th turn and times of H_2O concentration changes, respectively.
(a), (b) and (c) are outputs at f_{u1}, f_{u2}, and temperature-compensated output.

5. Conclusions

We developed a BUS circuit based on the temperature compensation principle [3]. This circuit succeeded in precisely measuring the response of the ball SAW sensor. Since ADC at as low as 100MHz can be used for 240MHz SAW, this circuit will contribute to cost reduction of SAW sensors.

Acknowledgements

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