In this table the number of latches required for a pipelined application are not provided since in the Conversion methods using Binary adders, the binary addition operation may have to be broken into several smaller ADD operations to match the latency of the slowest arithmetic operation. This in general may vary depending on the application.

The modulo operation using look-up tables is found to be efficient [9] for moduli values up to 6 bits. By using small modulus’ it is possible to realize a dynamic range of 64 bits; using moduli which are less than or equal to 6 bits, which may be adequate for a large number of applications. The Memory compression scheme reported in [13] may further reduce the memory elements in the look-up table implementing a modulo operation but requires random logic to implement it.

V. SUMMARY

A new technique for RNS to binary conversion using only look-up tables is proposed. The technique obtains the binary bits of the natural integer from the residues in a bit slice fashion by a sequence of base extensions to a modulus which is a power of 2. A significant reduction in latency and hardware count is possible by choosing an efficient base extension algorithm (11) in place of regular MRC. By selecting one of the “in range” moduli as a power of two further reduction in hardware and latency is possible.

References


Upper Bound on the Rate of Entropy Increase Accompanying Noise Power Flow Through Linear Systems

MADHU S. GUPTA

Abstract—An upper bound is established for the rate of entropy increase due to noise power flow in a non-isothermal linear network containing n independent noise sources. The bound depends on the net power flows to (or from) the noise sources collectively, the lowest noise temperature in the network, and the efficiency of a Carnot heat engine operating between the highest and the lowest noise temperature occurring in the system.

Consider a linear lossless time-invariant n-port network, terminated at each of its ports in a dissipative and noisy linear one-port. Such a network may represent, for example, an arbitrary linear time-invariant non-isothermal dissipative network with stationary noise sources, in which each dissipative and noisy element is represented as one port, and the remainder of the network constitutes the lossless n-port. The termination at the jth port is completely described, in steady-state and at one frequency, ω, by its driving point impedance, Zj(ω), and its effective noise temperature, Tj(ω), or equivalently, by the available noise power per unit bandwidth, Iρω(ω) = kTj(ω), where k is Boltzmann’s constant. There is some interest [1], [2] in the rate of increase of entropy in such a network due to power flow between the ports. The increase in the entropy of a heat reservoir, used for maintaining a resistive circuit element at a temperature Tj, can be calculated from Gibbs’ equation, ΔE = TΔS, in which ΔE is the thermal energy received by the heat reservoir, and ΔS is the resulting increase in the entropy of the reservoir [3]. The requirements of time-invariance and steady-state exclude cases where the rate of increase of entropy is time-varying, and may be related to the stability of the network [4].
Let $P_{in,j}(\omega)$ be the average noise power per unit bandwidth at frequency $\omega$, entering from the $j$th port and $P_{net}(\omega)$ be the net noise power per unit bandwidth. From the first law of thermodynamics (energy conservation in an isolated system), it follows that

$$\sum_{j=1}^{n} P_{in,j}(\omega) = 0.$$  \hspace{1cm} (1)

From the second law of thermodynamics (nonnegative rate of entropy increase in an isolated system), it is further known that

$$\sum_{j=1}^{n} \left| \frac{P_{in,j}(\omega)}{T_j(\omega)} \right| \geq 0.$$  \hspace{1cm} (2)

Suitable ideal narrow-band filters can be postulated for arriving at these frequency-dependent forms of the thermodynamic laws. The inequality in (2) has also been deduced [2] from the properties of linear lossless networks, without explicitly invoking the second law of thermodynamics, which is not surprising since electrical networks are themselves thermodynamic systems, and the axioms of network theory (Kirchhoff’s laws) are known to be consistent with the laws of thermodynamics [5]. It is, therefore, axiomatic that the rate of entropy increase is bounded from below.

The purpose of this short paper is to establish an upper bound to the rate of entropy increase. This bound will be expressed in terms of the following variables. Let $T_{max}(\omega)$ and $T_{min}(\omega)$ be the highest and the lowest temperatures among the noise temperatures $T_j(\omega)$. Then the efficiency of a Carnot (i.e., reversible) heat engine, operating between two heat reservoirs at the maximum and minimum temperatures, is

$$\eta_c = \frac{T_{max} - T_{min}}{T_{max}}.$$  \hspace{1cm} (3)

One measure of the overall level of noise power flows taking place in the network is the net inflow (or outflow) noise power, which is half the sum of the power flow magnitudes at all ports by virtue of (1):

$$P_{net}(\omega) = \sum_j P_{in,j}(\omega) = \frac{1}{2} \sum_j \left| P_{in,j}(\omega) \right|.$$  \hspace{1cm} (4)

This quantity is a function of the lossless n-port network, as well as all $Z_j(\omega)$ and $T_j(\omega)$. The $\omega$ dependence of the various quantities will not be explicitly written in the following.

The rate of entropy increase can be written as

$$\frac{1}{2} \sum_{j=1}^{n} \left| \frac{P_{in,j}}{T_j} \right| \leq \frac{1}{2} \sum_{j=1}^{n} \left| \frac{1}{T_j} \right| \frac{1}{T_{min}} + \frac{1}{T_{max}} \right| \leq \frac{1}{2} \sum_{j=1}^{n} \left| \frac{1}{T_j} \right| \frac{1}{T_{min}} - \frac{1}{T_{max}} \right|.$$  \hspace{1cm} (5)

This is the desired upper bound, and the principal result of this paper. Note that the equality in (5) holds when all terminations receiving noise power are at the minimum temperature (i.e., $T_j = T_{min}$ for all $j$ such that $P_{in,j} < 0$), and all terminations delivering noise power are at the maximum temperature (i.e., $T_j = T_{max}$ for all $j$ such that $P_{in,j} > 0$).

To understand the physical interpretation of the result, consider the simplest possible case of a linear lossless two port, connecting two noisy linear one ports having two different effective noise temperatures $T_a$ and $T_b$ at ports 1 and 2, respectively, with $T_a > T_b$. Then a flow of heat will take place, in the form of noise power $P_n$, from the heat reservoir at temperature $T_a$ maintaining the noise temperature of the termination at port 1, to the heat reservoir at temperature $T_b$ maintaining the noise temperature of the termination at port 2. The rate of decrease of the entropy of the first reservoir is $P_n/T_a$, while the rate of increase of the entropy of the second reservoir is $P_n/T_b$. The net rate of increase of entropy of the entire system is, therefore,

$$\frac{P_n}{T_a} - \frac{P_n}{T_b} = \frac{P_n}{2T_c} \eta_c.$$  \hspace{1cm} (6)

where $\eta_c$ is the efficiency $(T_a - T_b)/T_a$ of a Carnot engine operating between the two heat reservoirs. The bound on the rate of entropy increase, appearing in (5), takes the form

$$\sum_{j=1}^{n} \left| \frac{P_{in,j}}{T_j} \right| \leq \frac{1}{2} \frac{P_{in,j}}{T_j} \frac{1}{T_{min}} + \frac{1}{T_{max}} \right| \leq \frac{1}{2} \sum_{j=1}^{n} \left| \frac{1}{T_j} \right| \frac{1}{T_{min}} - \frac{1}{T_{max}} \right|.$$  \hspace{1cm} (7)

which agrees with the result in (6).

In addition to illustrating the physical interpretation of the bound found in this short paper, this example also demonstrates that, for a two port, the upper bound is actually reached and, therefore, a tighter bound cannot be found in general. Based on this example, the bound in (5) can also be interpreted as the statement that the rate of entropy increase in the given n-port system cannot exceed that in a two port in which the terminations are at the maximum and minimum temperatures $T_{max}$ and $T_{min}$, and the power flow equals the net value $P_{net}$.

REFERENCES


