Ada Lovelace's Computer Program

Apple Time

Elsa Gonsiorowski

June 6, 2025

Apple Time

20 Min	Short Talk
15 Min	Discussion / Breakout
10 Min	Prizes!

- Links are in orange
- Full screen is recommended
- Slides available at gonsie.com/talks

Elsa Gonsiorowski

- HPC I/O Support Specialist in Livermore Computing since 2016
- LC Hotline technical consultant, focused on user engagement and communication
- Working remotely in RI
- Excited about emacs, org-mode, static websites, fish shell, cmake, documentation, crossfit, rowing, knitting

LC: Livermore Computing

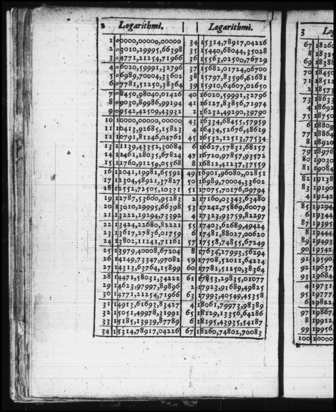
HPC Up Close poster session

Join us on June 17, 2pm at the Central Cafe

World's First Computer Program

- History of the first computer
- Brief bio for Ada Lovelace
- Overview of some math
- Hypothesis: *Ada Lovelace was the first computer programmer*

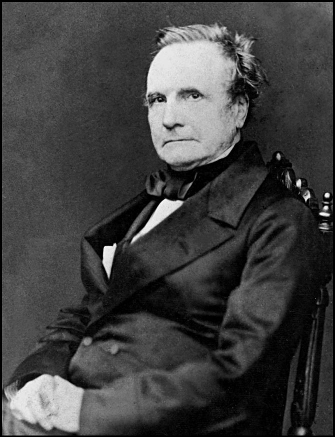
Mathematical Tables – 200 years ago



2	Logarithmi.			Logarithmi.	
1	0	0000,00000,00000	34	1	5314,78917,04226
2	0	3010,29995,66398	35	1	5440,68044,35028
3	0	4771,21254,71966	36	1	5563,02500,76729
4	0	6020,59991,32796	37	1	5682,01724,06700
5	0	6989,70004,33602	38	1	5797,83596,61681
6	0	7781,51250,38364	39	1	5910,64607,02650
7	0	8450,98040,01426	40	1	6020,59991,32796
8	0	9030,89986,99194	41	1	6127,83856,71974
9	0	9542,42509,43932	2	1	6232,49290,39790
10	1	0000,00000,00000	43	1	6334,68455,57959
11	1	0413,92685,15823	4	1	6434,52676,48619
12	1	0791,81246,04762	45	1	6532,12513,77534
13	1	1139,43352,30684	6	1	6627,57831,68157
14	1	1461,28035,67824	47	1	6720,97857,93572
15	1	1760,91259,05568	8	1	6812,41237,37559
16	1	2041,19982,65592	49	1	6901,96080,,02851
17	1	2304,48921,37827	50	1	6989,70004,33602
18	1	2552,72505,10331	51	1	7075,70176,09794
19	1	2787,53600,95283	2	1	7160,03343,63480
20	1	3010,29995,66398	53	1	7242,75869,60079
21	1	3222,19294,73392	4	1	7323,93759,82297
22	1	3424,22680,82221	55	1	7403,62689,49424
23	1	3617,27836,01759	6	1	7481,88027,00620
24	1	3802,11241,71161	57	1	7558,74855,67249
25	1	3979,40008,67204	8	1	7634,27993,56294
26	1	4149,73347,97082	59	1	7708,52011,64214
27	1	4313,63764,15899	60	1	7781,51250,38364
28	1	4471,58031,34222	61	1	7853,29835,01077
29	1	4623,97997,89896	2	1	7923,91689,49825
30	1	4771,21254,71966	63	1	7993,40549,45358
31	1	4913,61693,83427	4	1	8061,79973,98389
32	1	5051,49978,31991	65	1	8129,13356,64286
33	1	5185,13939,87789	6	1	8195,43935,54187
34	1	5314,78917,04226	67	1	8260,74802,70083

- Calculated values of logarithmic and trigonometric functions
- Built by hand by human "computers"
- Used to do rapid multiplication, division, and exponentiation

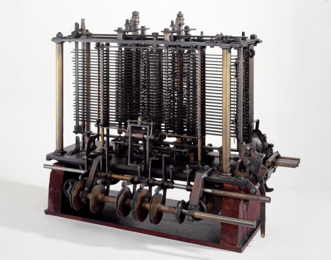
Charles Babbage and the Difference Engine



- 1791–1871
- Idea for a *Difference Engine* to mechanically do the work of human computers
    - Began development in 1822
    - would have composed 25,000 parts, weighed 15 tons, stood 8 feet tall

Analytical Engine

- Design began in 1833, described in 1837
- General purpose, i.e., Turing Complete
- Arithmetic logic unit, control flow (conditional branching and loops), memory, printer, and bell

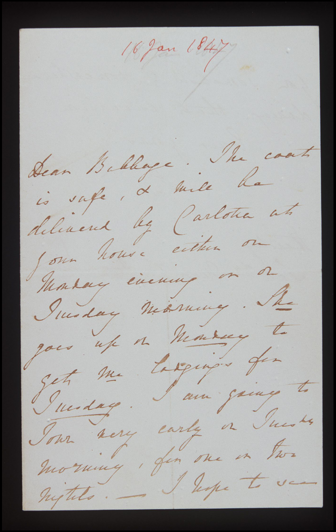


Augusta Ada King (née Byron), Countess of Lovelace

- Dec. 10, 1815–Nov. 27, 1852
- Child of poet Lord Byron and Lady Byron
- 1833: Met Charles Babbage at a party
- 1835: Married William King who became Earl of Lovelace

Babbage and Young Lady Byron

- 1833: Met at a party (Babbage age 41, Ada age 17)
- Ada had extensive mathematics eduction to "ward off wild, romatic sensibility" of her father
- They were in the same social circle and wrote each other frequently



16 Jan 1847

Dear Babbage. The coat is safe, & will be delivered by Carlotta at your house either on Monday evening or on Tuesday morning. She goes up on Monday to get me lodgings for Tuesday. I am going to Town very early on Tuesday morning, for one or two nights. — I hope to see

Sketch of the Analytical Engine

SCIENTIFIC MEMOIRS,

SELECTED FROM

THE TRANSACTIONS OF

FOREIGN ACADEMIES OF SCIENCE

AND LEARNED SOCIETIES,

AND FROM

FOREIGN JOURNALS.

EDITED BY

RICHARD TAYLOR, F.S.A.,

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UNDER SECRETARY OF THE LINNÆAN SOCIETY.

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1843.

ARTICLE XXIX.

Sketch of the Analytical Engine invented by Charles Babbage *Esq. By* L. F. MENABREA, *of Turin, Officer of the Military Engineers.*

[From the *Bibliothèque Universelle de Génève*, No. 82. October 1842.]

[BEFORE submitting to our readers the translation of M. Menabrea's memoir 'On the Mathematical Principles of the ANALYTICAL ENGINE' invented by Mr. Babbage, we shall present to them a list of the printed papers connected with the subject, and also of those relating to the Difference Engine by which it was preceded.

For information on Mr. Babbage's "*Difference* Engine," which is but slightly alluded to by M. Menabrea, we refer the reader to the following sources:—

1. Letter to Sir Humphry Davy, Bart., P.R.S., on the Application of Machinery to Calculate and Print Mathematical Tables. By Charles Babbage, Esq., F.R.S. London, July 1822. Reprinted, with a Report of the Council of the Royal Society, by order of the House of Commons, May 1823.

2. On the Application of Machinery to the Calculation of Astronomical and Mathematical Tables. By Charles Babbage, Esq.—Memoirs of the Astronomical Society, vol. i. part 2. London, 1822.

3. Address to the Astronomical Society by Henry Thomas Colebrooke, Esq., F.R.S., President, on presenting the first Gold Medal of the Society to Charles Babbage, Esq., for the invention of the Calculating Engine.—Memoirs of the Astronomical Society. London, 1822.

4. On the Determination of the General Term of a New Class of Infinite Series. By Charles Babbage, Esq.—Transactions of the Cambridge Philosophical Society.

5. On Mr. Babbage's New Machine for Calculating and Printing Mathematical Tables.—Letter from Francis Baily, Esq., F.R.S., to M. Schumacher. No. 46, Astronomische Nachrichten. Reprinted in the Philosophical Magazine, May 1824.

6. On a Method of expressing by Signs the Action of Ma-

Bernoulli Numbers

$$\begin{aligned}\sum n &= \frac{1}{2}n^2 + \frac{1}{2}n \\ \sum n^2 &= \frac{1}{3}n^3 + \frac{1}{2}n^2 + \frac{1}{6}n \\ \sum n^3 &= \frac{1}{4}n^4 + \frac{1}{2}n^3 + \frac{1}{4}n^2\end{aligned}$$

$$\sum n^m = \frac{1}{m+1}\left(B_0 n^{m+1} \pm \binom{m+1}{1} B_1 n^m + \binom{m+1}{2} B_2 n^{m-1} + \ldots\right)$$

$B_7 = -1(A_0 + B_1\ A_1 + B_3\ A_3 + B_5\ A_5)$

$$
\begin{aligned}
A_0 &= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} \\
A_1 &= \frac{2n}{2} \\
A_3 &= \frac{2n(2n-1)(2n-2)}{2 \cdot 3 \cdot 4} \\
A_5 &= \frac{2n(2n-1)(2n-2)(2n-3)(2n-4)}{2 \cdot 3 \cdot 4 \cdot 5 \cdot 6}
\end{aligned}
$$

Notes from the Translator

Note A Promise of a machine that can perform arbirtary mathematical operations

Note G *Lady Lovelace's Objection* – despite it's power, the machine does not "think"

Note D "Diagram of development" for calculating $B_7 = -1(A_0 + B_1 A_1 + B_3 A_3 + B_5 A_5)$

Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data.			Working Variables.										Result Variables.			
						${}^1V_1$ ○ 0 0 0 1 $\boxed{1}$	${}^1V_2$ ○ 0 0 0 2 $\boxed{2}$	${}^1V_3$ ○ 0 0 0 4 $\boxed{n}$	${}^0V_4$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_5$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_6$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_7$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_8$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_9$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_{10}$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_{11}$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_{12}$ ○ 0 0 0 0 $\boxed{\ }$	${}^0V_{13}$ .... ○ 0 0 0 0 $\boxed{\ }$	${}^1V_{21}$ ○ 0 0 0 B_1 in a decimal fraction. $\boxed{B_1}$	${}^1V_{22}$ ○ 0 0 0 B_3 in a decimal fraction. $\boxed{B_3}$	${}^1V_{23}$ ○ 0 0 0 B_5 in a decimal fraction. $\boxed{B_5}$	${}^0V_{24}$... ○ 0 0 0 $\boxed{B_7}$
1	×	${}^1V_2 \times {}^1V_3$	${}^1V_4, {}^1V_5, {}^1V_6$	$\left\{\begin{matrix}{}^1V_2 = {}^1V_2 \\ {}^1V_3 = {}^1V_3\end{matrix}\right\}$	$= 2n$	...	2	n	$2n$	$2n$	$2n$											
2	−	${}^1V_4 - {}^1V_1$	${}^2V_4$	$\left\{\begin{matrix}{}^1V_4 = {}^2V_4 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 1$	1	...	...	$2n-1$													
3	+	${}^1V_5 + {}^1V_1$	${}^2V_5$	$\left\{\begin{matrix}{}^1V_5 = {}^2V_5 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n + 1$	1	...	...	...	$2n+1$												
4	÷	${}^2V_5 \div {}^2V_4$	${}^1V_{11}$	$\left\{\begin{matrix}{}^2V_5 = {}^0V_5 \\ {}^2V_4 = {}^0V_4\end{matrix}\right\}$	$= \frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	÷	${}^1V_{11} \div {}^1V_2$	${}^2V_{11}$	$\left\{\begin{matrix}{}^1V_{11} = {}^2V_{11} \\ {}^1V_2 = {}^1V_2\end{matrix}\right\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	${}^0V_{13} - {}^2V_{11}$	${}^1V_{13}$	$\left\{\begin{matrix}{}^2V_{11} = {}^0V_{11} \\ {}^0V_{13} = {}^1V_{13}\end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...	...	...	...	...	...	...	...	0	....	$-\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	${}^1V_3 - {}^1V_1$	${}^1V_{10}$	$\left\{\begin{matrix}{}^1V_3 = {}^1V_3 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 1\ (= 3)$	1	...	n	...	...	...	...	...	...	$n-1$							
8	+	${}^1V_2 + {}^0V_7$	${}^1V_7$	$\left\{\begin{matrix}{}^1V_2 = {}^1V_2 \\ {}^0V_7 = {}^1V_7\end{matrix}\right\}$	$= 2 + 0 = 2$	...	2	...	...	...	...	2										
9	÷	${}^1V_6 \div {}^1V_7$	${}^3V_{11}$	$\left\{\begin{matrix}{}^1V_6 = {}^1V_6 \\ {}^0V_{11} = {}^3V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} = A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2} = A_1$						
10	×	${}^1V_{21} \times {}^3V_{11}$	${}^1V_{12}$	$\left\{\begin{matrix}{}^1V_{21} = {}^1V_{21} \\ {}^3V_{11} = {}^3V_{11}\end{matrix}\right\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	....	B_1			
11	+	${}^1V_{12} + {}^1V_{13}$	${}^2V_{13}$	$\left\{\begin{matrix}{}^1V_{12} = {}^0V_{12} \\ {}^1V_{13} = {}^2V_{13}\end{matrix}\right\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$ ...	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	${}^1V_{10} - {}^1V_1$	${}^2V_{10}$	$\left\{\begin{matrix}{}^1V_{10} = {}^2V_{10} \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 2\ (= 2)$	1	...	...	...	...	...	...	...	...	$n-2$							
13	−	${}^1V_6 - {}^1V_1$	${}^2V_6$	$\left\{\begin{matrix}{}^1V_6 = {}^2V_6 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 1$	1	...	...	...	...	$2n-1$											
14	+	${}^1V_1 + {}^1V_7$	${}^2V_7$	$\left\{\begin{matrix}{}^1V_1 = {}^1V_1 \\ {}^1V_7 = {}^2V_7\end{matrix}\right\}$	$= 2 + 1 = 3$	1	...	...	...	...	...	3										
15	÷	${}^2V_6 \div {}^2V_7$	${}^1V_8$	$\left\{\begin{matrix}{}^2V_6 = {}^2V_6 \\ {}^2V_7 = {}^2V_7\end{matrix}\right\}$	$= \frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	${}^1V_8 \times {}^3V_{11}$	${}^4V_{11}$	$\left\{\begin{matrix}{}^1V_8 = {}^0V_8 \\ {}^3V_{11} = {}^4V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	${}^2V_6 - {}^1V_1$	${}^3V_6$	$\left\{\begin{matrix}{}^2V_6 = {}^3V_6 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 2n - 2$	1	...	...	...	...	$2n-2$											
18	+	${}^1V_1 + {}^2V_7$	${}^3V_7$	$\left\{\begin{matrix}{}^2V_7 = {}^3V_7 \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= 3 + 1 = 4$	1	...	...	...	...	...	4										
19	÷	${}^3V_6 \div {}^3V_7$	${}^1V_9$	$\left\{\begin{matrix}{}^3V_6 = {}^3V_6 \\ {}^3V_7 = {}^3V_7\end{matrix}\right\}$	$= \frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...	$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = A_3\right\}$						
20	×	${}^1V_9 \times {}^4V_{11}$	${}^5V_{11}$	$\left\{\begin{matrix}{}^1V_9 = {}^0V_9 \\ {}^4V_{11} = {}^5V_{11}\end{matrix}\right\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$	...	...	...	...	...	...	...	...	0								
21	×	${}^1V_{22} \times {}^5V_{11}$	${}^0V_{12}$	$\left\{\begin{matrix}{}^1V_{22} = {}^1V_{22} \\ {}^0V_{12} = {}^2V_{12}\end{matrix}\right\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = B_3 A_3$	...	...	...	...	...	...	...	...	...	...	0	$B_3 A_3$	....	......	B_3		
22	+	${}^2V_{12} + {}^2V_{13}$	${}^3V_{13}$	$\left\{\begin{matrix}{}^2V_{12} = {}^0V_{12} \\ {}^2V_{13} = {}^3V_{13}\end{matrix}\right\}$	$= A_0 + B_1 A_1 + B_3 A_3$	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{A_3 + B_1 A_1 + B_3 A_3\right\}$				
23	−	${}^2V_{10} - {}^1V_1$	${}^3V_{10}$	$\left\{\begin{matrix}{}^2V_{10} = {}^3V_{10} \\ {}^1V_1 = {}^1V_1\end{matrix}\right\}$	$= n - 3\ (= 1)$	1	...	...	...	...	...	...	...	...	$n-3$							
Here follows a repetition of Operations thirteen to twenty-three.																						
24	+	${}^4V_{13} + {}^0V_{24}$	${}^1V_{24}$	$\left\{\begin{matrix}{}^4V_{13} = {}^0V_{13} \\ {}^0V_{24} = {}^1V_{24}\end{matrix}\right\}$	$= B_7$	...	...	...	...	...	...	...	...	...	...	....	....	....	......	......	......	B_7
25	+	${}^1V_1 + {}^1V_3$	${}^1V_3$	$\left\{\begin{matrix}{}^1V_1 = {}^1V_1 \\ {}^1V_3 = {}^1V_3 \\ {}^5V_6 = {}^0V_6 \\ {}^5V_7 = {}^0V_7\end{matrix}\right\}$	$= n + 1 = 4 + 1 = 5$ .... by a Variable-card. by a Variable card.	1	...	$n+1$	...	...	0	0										

Diagram for the computation by the Engine of the Numbers of Bernoulli. See Note G. (page 722 *et seq.*)

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data.			Working Variables.										Result Variables.			
						$^{1}V_{1}$ 0 0 0 1 $\boxed{1}$	$^{1}V_{2}$ 0 0 0 2 $\boxed{2}$	$^{1}V_{3}$ 0 0 0 4 $\boxed{n}$	$^{0}V_{4}$ 0 0 0 0	$^{0}V_{5}$ 0 0 0 0	$^{0}V_{6}$ 0 0 0 0	$^{0}V_{7}$ 0 0 0 0	$^{0}V_{8}$ 0 0 0 0	$^{0}V_{9}$ 0 0 0 0	$^{0}V_{10}$ 0 0 0 0	$^{0}V_{11}$ 0 0 0 0	$^{0}V_{12}$ 0 0 0 0	$^{0}V_{13}$ 0 0 0 0	$^{1}V_{21}$ B_1 in a decimal fraction. $\boxed{B_1}$	$^{1}V_{22}$ B_3 in a decimal fraction. $\boxed{B_3}$	$^{1}V_{23}$ B_5 in a decimal fraction. $\boxed{B_5}$	$^{0}V_{24}$... 0 0 0 0 $\boxed{B_7}$
1	$\times$	$^{1}V_{2}\times{}^{1}V_{3}$	$^{1}V_{4}, {}^{1}V_{5}, {}^{1}V_{6}$	$\left\{\begin{matrix}^{1}V_{2}={}^{1}V_{2}\\ ^{1}V_{3}={}^{1}V_{3}\end{matrix}\right\}$	$=2n$	...	2	n	$2n$	$2n$	$2n$											
2	$-$	$^{1}V_{4}-{}^{1}V_{1}$	$^{2}V_{4}$	$\left\{\begin{matrix}^{1}V_{4}={}^{2}V_{4}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=2n-1$	1	...	...	$2n-1$													
3	$+$	$^{1}V_{5}+{}^{1}V_{1}$	$^{2}V_{5}$	$\left\{\begin{matrix}^{1}V_{5}={}^{2}V_{5}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=2n+1$	1	...	...	...	$2n+1$												
4	$\div$	$^{2}V_{5}\div{}^{2}V_{4}$	$^{1}V_{11}$	$\left\{\begin{matrix}^{2}V_{5}={}^{0}V_{5}\\ ^{2}V_{4}={}^{0}V_{4}\end{matrix}\right\}$	$=\frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	$\div$	$^{1}V_{11}\div{}^{1}V_{2}$	$^{2}V_{11}$	$\left\{\begin{matrix}^{1}V_{11}={}^{2}V_{11}\\ ^{1}V_{2}={}^{1}V_{2}\end{matrix}\right\}$	$=\frac{1}{2}\cdot\frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2}\cdot\frac{2n-1}{2n+1}$						
6	$-$	$^{0}V_{13}-{}^{2}V_{11}$	$^{1}V_{13}$	$\left\{\begin{matrix}^{2}V_{11}={}^{0}V_{11}\\ ^{0}V_{13}={}^{1}V_{13}\end{matrix}\right\}$	$=-\frac{1}{2}\cdot\frac{2n-1}{2n+1}=A_0$	...	...	...	...	...	...	...	...	...	...	0	....	$-\frac{1}{2}\cdot\frac{2n-1}{2n+1}=A_0$				
7	$-$	$^{1}V_{3}-{}^{1}V_{1}$	$^{1}V_{10}$	$\left\{\begin{matrix}^{1}V_{3}={}^{1}V_{3}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=n-1\ (=3)$	1	...	n	...	...	...	...	...	...	$n-1$							
8	$+$	$^{1}V_{2}+{}^{0}V_{7}$	$^{1}V_{7}$	$\left\{\begin{matrix}^{1}V_{2}={}^{1}V_{2}\\ ^{0}V_{7}={}^{1}V_{7}\end{matrix}\right\}$	$=2+0=2$	...	2	...	...	...	...	2										
9	$\div$	$^{1}V_{6}\div{}^{1}V_{7}$	$^{3}V_{11}$	$\left\{\begin{matrix}^{1}V_{6}={}^{1}V_{6}\\ ^{0}V_{11}={}^{3}V_{11}\end{matrix}\right\}$	$=\frac{2n}{2}=A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2}=A_1$						
10	$\times$	$^{1}V_{21}\times{}^{3}V_{11}$	$^{1}V_{12}$	$\left\{\begin{matrix}^{1}V_{21}={}^{1}V_{21}\\ ^{3}V_{11}={}^{3}V_{11}\end{matrix}\right\}$	$=B_1\cdot\frac{2n}{2}=B_1A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2}=A_1$	$B_1\cdot\frac{2n}{2}=B_1A_1$	....	B_1			
11	$+$	$^{1}V_{12}+{}^{1}V_{13}$	$^{2}V_{13}$	$\left\{\begin{matrix}^{1}V_{12}={}^{0}V_{12}\\ ^{1}V_{13}={}^{2}V_{13}\end{matrix}\right\}$	$=-\frac{1}{2}\cdot\frac{2n-1}{2n+1}+B_1\cdot\frac{2n}{2}$ ...	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{-\frac{1}{2}\cdot\frac{2n-1}{2n+1}+B_1\cdot\frac{2n}{2}\right\}$				
12	$-$	$^{1}V_{10}-{}^{1}V_{1}$	$^{2}V_{10}$	$\left\{\begin{matrix}^{1}V_{10}={}^{2}V_{10}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=n-2\ (=2)$	1	...	...	...	...	...	...	...	...	$n-2$							
13	$-$	$^{1}V_{6}-{}^{1}V_{1}$	$^{2}V_{6}$	$\left\{\begin{matrix}^{1}V_{6}={}^{2}V_{6}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=2n-1$	1	...	...	...	...	$2n-1$											
14	$+$	$^{1}V_{1}+{}^{1}V_{7}$	$^{2}V_{7}$	$\left\{\begin{matrix}^{1}V_{1}={}^{1}V_{1}\\ ^{1}V_{7}={}^{2}V_{7}\end{matrix}\right\}$	$=2+1=3$	1	...	...	...	...	...	3										
15	$\div$	$^{2}V_{6}\div{}^{2}V_{7}$	$^{1}V_{8}$	$\left\{\begin{matrix}^{2}V_{6}={}^{2}V_{6}\\ ^{2}V_{7}={}^{2}V_{7}\end{matrix}\right\}$	$=\frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	$\times$	$^{1}V_{8}\times{}^{3}V_{11}$	$^{4}V_{11}$	$\left\{\begin{matrix}^{1}V_{8}={}^{0}V_{8}\\ ^{3}V_{11}={}^{4}V_{11}\end{matrix}\right\}$	$=\frac{2n}{2}\cdot\frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2}\cdot\frac{2n-1}{3}$						
17	$-$	$^{2}V_{6}-{}^{1}V_{1}$	$^{3}V_{6}$	$\left\{\begin{matrix}^{2}V_{6}={}^{3}V_{6}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=2n-2$	1	...	...	...	...	$2n-2$											
18	$+$	$^{1}V_{1}+{}^{2}V_{7}$	$^{3}V_{7}$	$\left\{\begin{matrix}^{2}V_{7}={}^{3}V_{7}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=3+1=4$	1	...	...	...	...	...	4										
19	$\div$	$^{3}V_{6}\div{}^{3}V_{7}$	$^{1}V_{9}$	$\left\{\begin{matrix}^{3}V_{6}={}^{3}V_{6}\\ ^{3}V_{7}={}^{3}V_{7}\end{matrix}\right\}$	$=\frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...	$\left\{\frac{2n}{2}\cdot\frac{2n-1}{3}\cdot\frac{2n-2}{3}=A_3\right\}$						
20	$\times$	$^{1}V_{9}\times{}^{4}V_{11}$	$^{5}V_{11}$	$\left\{\begin{matrix}^{1}V_{9}={}^{0}V_{9}\\ ^{4}V_{11}={}^{5}V_{11}\end{matrix}\right\}$	$=\frac{2n}{2}\cdot\frac{2n-1}{3}\cdot\frac{2n-2}{4}=A_3$	...	...	...	...	...	...	...	...	0								
21	$\times$	$^{1}V_{22}\times{}^{5}V_{11}$	$^{0}V_{12}$	$\left\{\begin{matrix}^{1}V_{22}={}^{1}V_{22}\\ ^{0}V_{12}={}^{2}V_{12}\end{matrix}\right\}$	$=B_3\cdot\frac{2n}{2}\cdot\frac{2n-1}{3}\cdot\frac{2n-2}{3}=B_3A_3$	...	...	...	...	...	...	...	...	...	...	0	B_3A_3	....	......	B_3		
22	$+$	$^{2}V_{12}+{}^{2}V_{13}$	$^{3}V_{13}$	$\left\{\begin{matrix}^{2}V_{12}={}^{0}V_{12}\\ ^{2}V_{13}={}^{3}V_{13}\end{matrix}\right\}$	$=A_0+B_1A_1+B_3A_3$	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{A_3+B_1A_1+B_3A_3\right\}$				
23	$-$	$^{2}V_{10}-{}^{1}V_{1}$	$^{3}V_{10}$	$\left\{\begin{matrix}^{2}V_{10}={}^{3}V_{10}\\ ^{1}V_{1}={}^{1}V_{1}\end{matrix}\right\}$	$=n-3\ (=1)$	1	...	...	...	...	...	...	...	...	$n-3$							
					Here follows a repetition of Operations thirteen to twenty-three.																	
24	$+$	$^{4}V_{13}+{}^{0}V_{24}$	$^{1}V_{24}$	$\left\{\begin{matrix}^{4}V_{13}={}^{0}V_{13}\\ ^{0}V_{24}={}^{1}V_{24}\end{matrix}\right\}$	$=B_7$	...	...	...	...	...	...	...	...	...	...	....	....	....	......	......	......	B_7
25	$+$	$^{1}V_{1}+{}^{1}V_{3}$	$^{1}V_{3}$	$\left\{\begin{matrix}^{1}V_{1}={}^{1}V_{1}\\ ^{1}V_{3}={}^{1}V_{3}\\ ^{5}V_{6}={}^{0}V_{6}\\ ^{5}V_{7}={}^{0}V_{7}\end{matrix}\right\}$	$=n+1=4+1=5$ .... by a Variable-card. by a Variable card.	1	...	$n+1$	...	...	0	0										

Program Snippet (GitHub Gist)

```
// -------- A0 --------
/* 01 */ v4 = v5 = v6 = v2 * v3;      // 2n
/* 02 */ v4 = v4 - v1;                // 2n - 1
/* 03 */ v5 = v5 + v1;                // 2n + 1

// In Lovelace's diagram, the below appears as v5 / v4, wh
/* 04 */ v11 = v4 / v5;               // (2n - 1) / (2n +

/* 05 */ v11 = v11 / v2;              // (1 / 2) * ((2n -
/* 06 */ v13 = v13 - v11;             // -(1 / 2) * ((2n -
/* 07 */ v10 = v3 - v1;               // (n - 1), set coun

// On the first loop this calculates B3A3 and adds it on t
// On the second loop this calculates B5A5 and adds it on
while (v10 > 0)
{
    // -------- B3A3, B5A5 --------
```

Resources

- *What Did Ada Lovelace's Program Actually Do?* TwoBitHistory.org
- Sketch of the Analytical Engine
- Translation of Note D to C. (gist)
- Wikipedia

Breakout Discussions

- Introduce yourself to your group; what are you working on this summer?
- What is the most difficult bug you've encountered?
- What is the best thing you've attended so far this summer? And/or what are you most looking forward to?

Prizes!
A prize will be awarded to anyone who shares their bug story at the end of the hour

Tools

Created with Emacs, Org Mode, and LaTeX/Beamer.
View the source.